final report

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Operator controlled beef shackling system

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1 Scope

The projects aim was to develop and trial an operator controlled beef shackling tool, and automatically reload the tool with shackles from an existing abattoir setup. The peripheral devices associated with implementing the system into an abattoir were also designed and tested both in house and at the abattoir.

Beef cattle hoof shackling is carried out shortly after the animal is stunned. Immediately following stunning, cattle often experience nervous reactions which cause them to move their legs violently. This violent leg movement can often cause injury to operators tasked with applying shackles to the hooves of the animal.

The Operator controlled beef shackling system allows the operator to be situated outside of the danger area when shackling the animal, reducing the chance of injury and related OH&S costs.

2 Project overview

The Operator controlled beef shackling system will be a robust and reliable system that can place a shackle around the hooves of a wide range of beef cattle. The operator will be at a safe distance from the animal, while operating the shackling tool, reducing the chance of injury from the kicking leg. The tool will be able to restrain the animal's leg and apply the shackle. The shackle is then loaded onto a bleed roller for the animal to be conveyed off for processing.

The shackling tool, after each operation, is automatically loaded with a new shackle. The shackle will be removed, by the automated system, from the returning bleed rollers and loaded into the tool.

The shackling tool and loading system have been designed to work with the current bleed roller track at the E. C. Throsby plant in Whittingham, NSW. The system is designed to be easily adaptable for the varying setups of different plants.

The Operator Controlled Beef Shackling System consists of two main components:

1. ***Shackling tool*** – The operator controlled tool used to place the shackle on the animal then onto the bleed roller.

2. ***Automatic shackle loading system*** – The system used to remove the shackles from the returning bleed rollers and load the shackles onto the shackling tool.

3 System Hardware

3.1 Beef Shackling Tool

3.1.1 Overview

A prototype Beef Shackling Tool was designed, constructed and trialed in accordance with project A.TEC.0061. The Beef Shackling Tool was designed with the intent to improve operating conditions in abattoirs by reducing human contact with potentially aggressive livestock. The tool replaces the manual shackling procedure currently used in abattoirs, which can have many drawbacks; slow cycle times due to the operator waiting for the leg to stop kicking, OH&S issues arising from operators working within the kicking range of the beast. The Beef Shackling Tool

improved upon this method of manual shackling by removing the operator from the danger zone and increasing the consistency and reliability of the shackle application.

The Beef Shackling Tool was designed to be easily adapted for use as an operator controlled tool or fitted to a robotic arm for a completely automated shackling system. The Beef Shackling Tool project was deemed a success as it was reliably able to apply a shackle to the leg of a kicking animal.

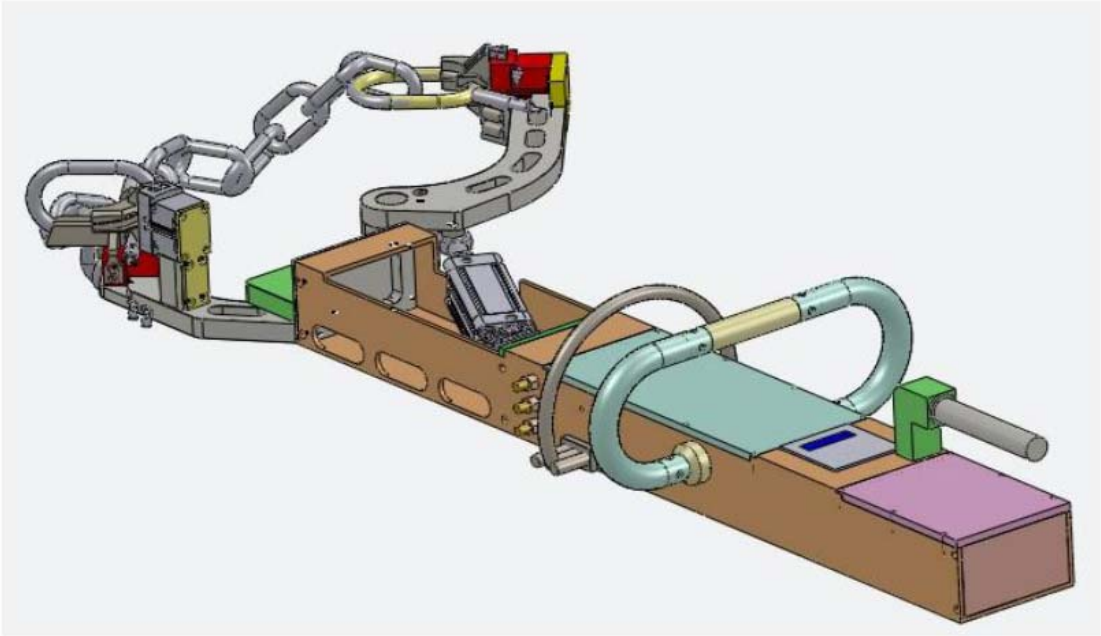

Figure 1: Solid model of the Beef Shackling Tool

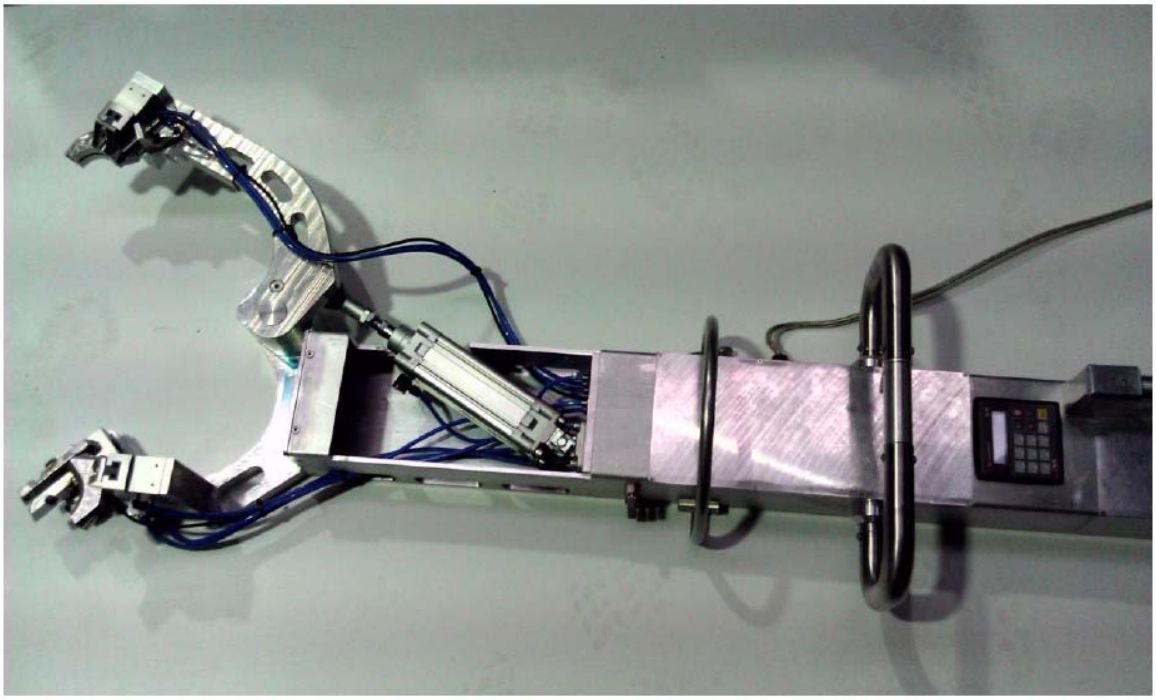

Figure 2: Beef Shackling Tool

3.1.2 Beef Shackling Tool Design

Enclosure

The Beef Shackling Tools control and electrical systems are housed in a sealed aluminium body with the operation of the tool controlled by two finger triggers. The tool is protected from the ingress of dust and moisture so that it can be operated in a wet and aggressive environment. The tool is also of a design so it is easily washed down after use.

The shell of the enclosure is fabricated from an aluminium rectangular hollow section. The body has been balanced to allow easy manoeuvrability during operation. The body also has top and side mounted handle bars to effortlessly steer the tool in the desired direction.

Moving arm

The purpose of the moving arm is to lasso the chain around the cattle hock in order to perform the shackling operation. When the moving arm is actuated it wraps the shackle around the beef hock and feeds the bottom link through the top link. The moving arm is driven by a 50-bore pneumatic cylinder using a proportional control valve.

A pneumatically actuated parallel link gripper is mounted on the end of the moving arm. This is used to grasp the bottom link of the shackle. An inductive sensor is mounted parallel to the gripper to ensure the link is correctly in place before closing

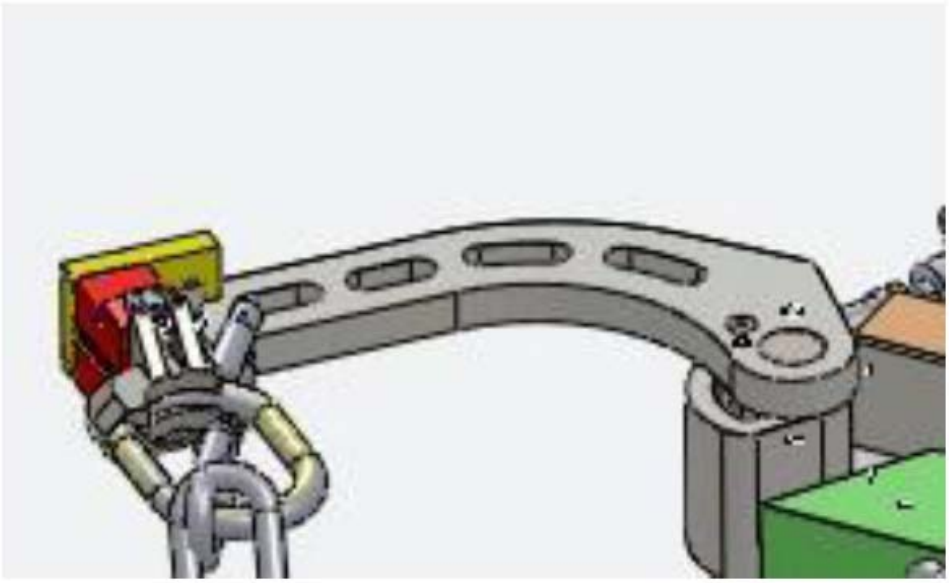

Figure 3: Moving arm

Stationary arm

The stationary arm consists of two parallel grippers, the Top Link Gripper and the Bleed Roller Gripper. The Top Link Gripper is vertically mounted and used to receive the top link of the shackle from the ASLS. This gripper is coupled with an inductive sensor which detects the presence of a shackle and actuates the gripper accordingly. The Bleed Roller Gripper is horizontally mounted and used to receive the bottom link of the shackle from the moving arm of the BST. Once the bottom link is loaded into the Bleed Roller Gripper the shackle may be easily transferred to the bleed roller.

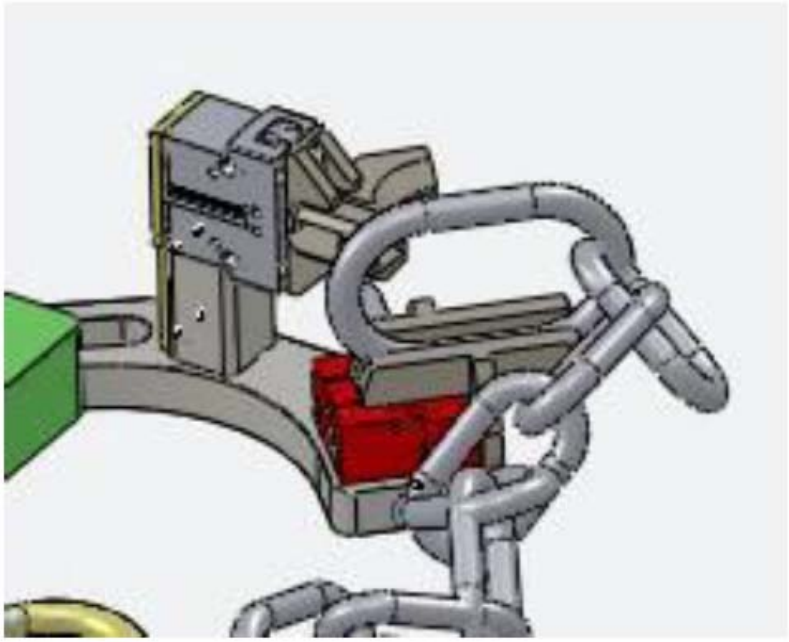

Figure 4: Stationary arm

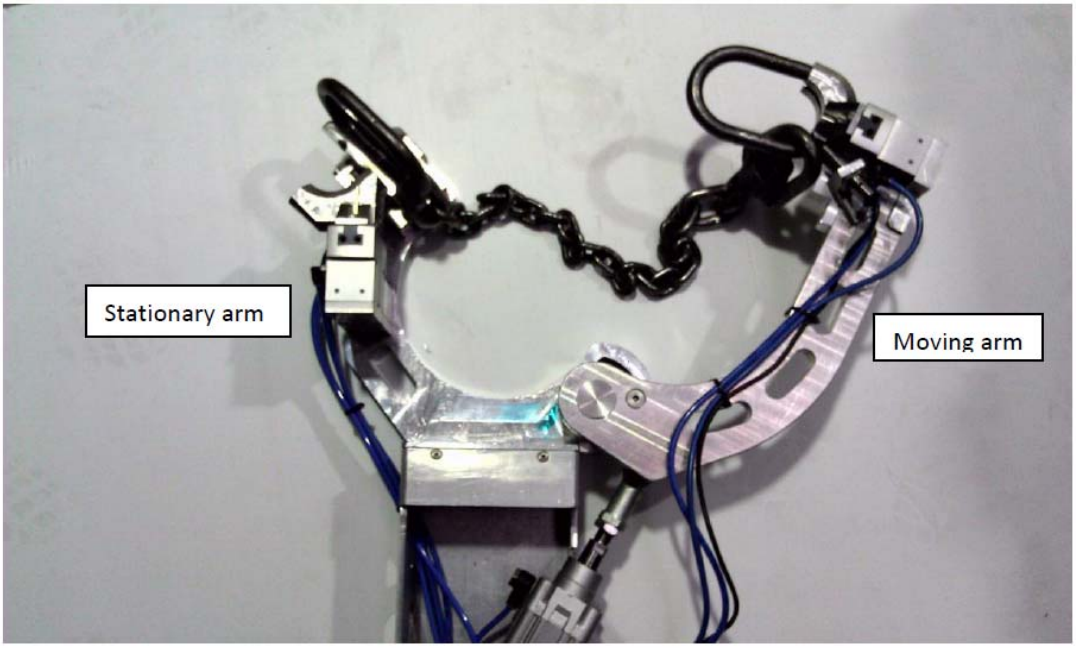

Figure 5: Tool arms with loaded shackle

3.1.3 Beef Shackling Tool Operation

The beef shackling tool is controlled by two trigger switches located in the handles of the tool. The tool is activated only when the operator has both triggers engaged, this prevents the chance of the moving arm accidently being activated. The positioning of the trigger switches also allows the tool to be easily operated when the tool is being positioned to shackle the animal.

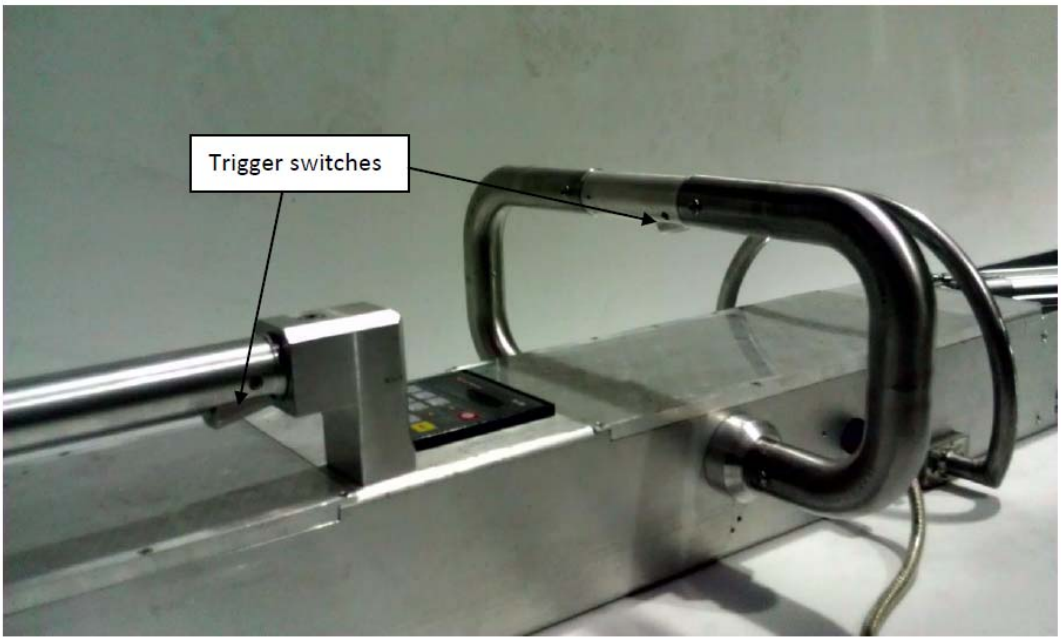

Figure 6: Operator Controls

The Beef shackling tool is supported using a spring balancer fitted to a swinging arm; this allows the tool to be easily maneuvered for the shacking of the kicking animal. The shackling tool is designed so that the spring balancer supports the weight through a fixing in the center balance position; this allows the tool to be moved up down, side to side, and forwards and back with ease. The tool is maneuvered using the two grips towards the end of the tool allowing the shackling position to be easily and quickly adapted. The swinging arm that supports the spring balancer is a double bearing system, allowing the shackling tool to have a working radius of 3 meters. The swinging arm used for the trial was designed to integrate into the existing frame work at E.C. Throsby and was designed and manufactured such that it can be flexibly integrated into a range of plants.

Figure 7: Spring Balancer

3.2 Automated Shackle Loading System

3.2.1 Overview

The Automated Shackle Loading System removes the shackle from the returning bleed roller, and then loads the shackle links into the Beef Shackling Tool in preparation for the shackling procedure. The system integrates with existing abattoir bleed roller return systems. The returning bleed rollers are controlled and queued prior to the bleed roller and shackle being loaded into the Automated Shackling System. The next bleed roller with shackle is allowed to enter the system once the Beef Shackling Tool has been correctly docked into its docking station, and a bleed roller with shackle is available from the bleed roller feeding system.

Figure 8: Automatic Shackle Loading System

3.3 ASLS Design

Framework

The Automated Shackle Loading System utilizes the robust lightweight framework of the 80/20's modular automation framework. 80/20 components allow the design of complex support structures with the use of standard off-the-shelf components. This framework significantly reduces the mass of the structure without compromising the integrity. It is envisaged that the framework for the final commercialized version would be a custom designed fabricated steel frame.

Bleed Roller Feeding System

To cater for accumulation of shackles, and to process each shackle individually, the system must separate the shackle/bleed roller assemblies on the return rails. To approach this issue we used a simple proximity sensor to detect the presence of bleed rollers, and a pneumatic stopper to stop shackles travelling along the bleed rail. The stopper holds back bleed rollers until the system

requests a shackle. As the Shackles are let through, the proximity sensor would see this, indicating to the stopper to hold the next shackle back.

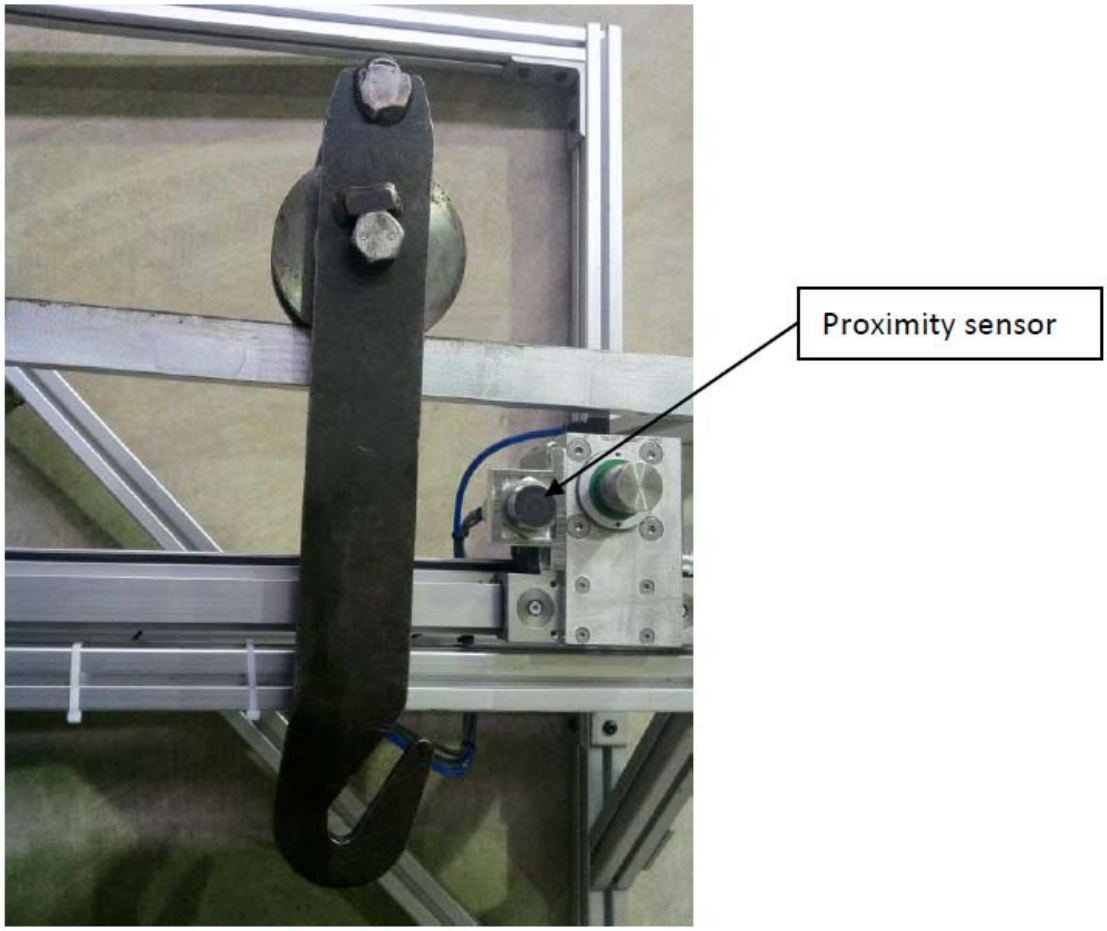

Figure 9: Bleed roller stopper

Docking Station

The docking station base consists of a long stainless steel flat bed used to support the mass of the BST while loading. There is an inductive sensor mounted flush with the flat bed to ensure the BST is in the loading position before commencing operation. The docking station is free from obstruction to allow the BST to be easily guided into position by a human operator.

The BST must be restrained on the docking station prior to loading to ensure the shackles are properly transferred to the grippers. Translation or rotation during loading may cause the loading procedure to fail. Therefore a locating profile is used to fasten the BST to the docking table and restrict translation in all axes. When in position, two pneumatic cylinders drive dowel pins into the BST. These pins lock the BST in position and inhibit rotation while the links are loaded into the grippers.

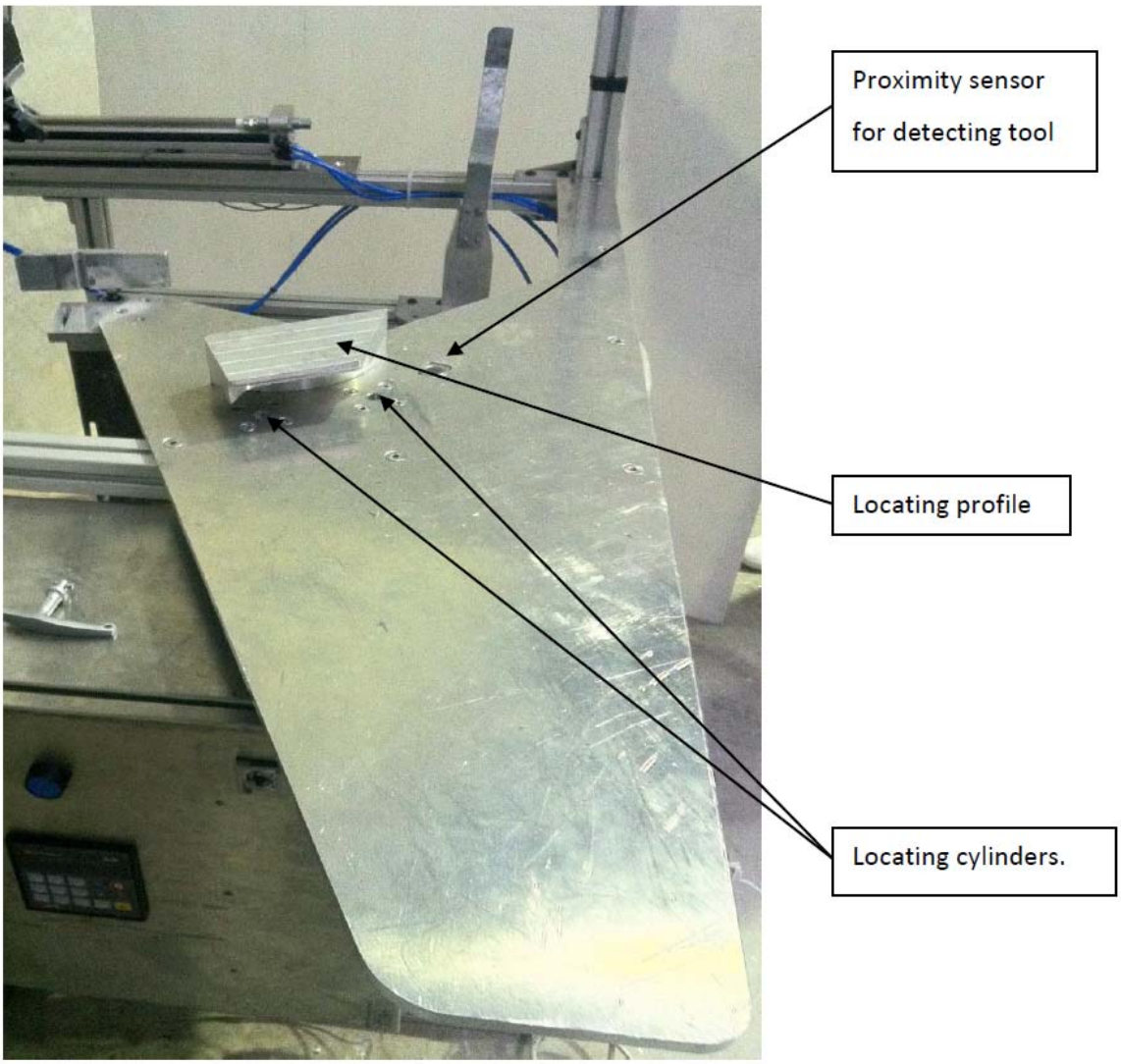

Figure 10: Tool docking station

Top Link Manipulation

The process of removing the top link from the bleed roller and transferring it to the BST is performed in three phases:

- Securing the top link

This phase occurs after the bleed roller has travelled from the inclined rail and is resting in position by the Rodless Cylinder/Stopper Cylinder assembly. A 180° finger gripper mounted on an extension arm on a rotary drive is used to grasp the top link of the shackle, securing it in position.

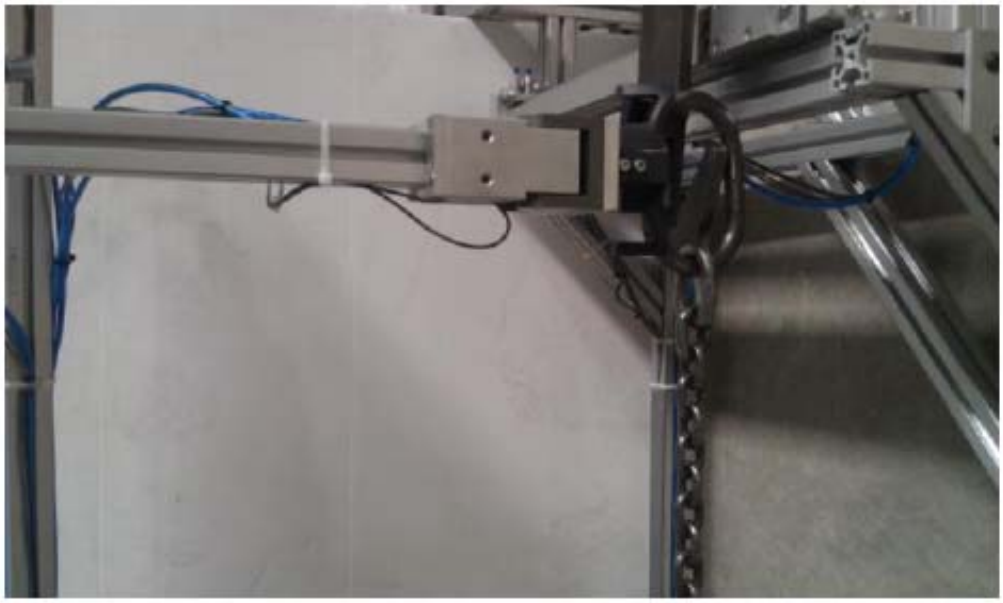

Figure 11: Shackle top link removal

- Removing the shackle from the bleed roller

Firmly secured, the Rodless Cylinder and Top Link Cylinder are simultaneously actuated. This raises the shackle whilst pushing the bleed roller backwards, allowing the shackle to slip off the bleed roller.

Figure 12: Shackle removal from bleed roller

- Feeding the top link into the stationary arm gripper

When the link is in the appropriate position, the rotary drive is actuated, lowering the extension arm and transferring the top link into the stationary arm of the BST below.

Figure 13: Top link to stationary gripper

Bottom Link Manipulation

The process of loading the bottom link into the moving arm of the BST is performed in two phases:

- Securing the bottom link

A 180° gripper is used to grasp the bottom link as it is suspended from the Top Link Finger Gripper. As the chain is susceptible to swaying as the shackle is fed through the system an inductive sensor is used to determine if the link has been successfully grasped. If the link is not present when the gripper is fully closed it is reactivated and subsequent attempts are made until the link is detected.

Figure 15: Bottom link manipulator open

Figure 14: Bottom link manipulator closed

- Rotary drive mounted on rodless cylinder used to feed link into moving arm parallel gripper on BST

Once the link is held firmly by the gripper the rotary drive and rodless cylinder are actuated, propelling the bottom link forwards into the awaiting parallel gripper on the moving arm of the BST.

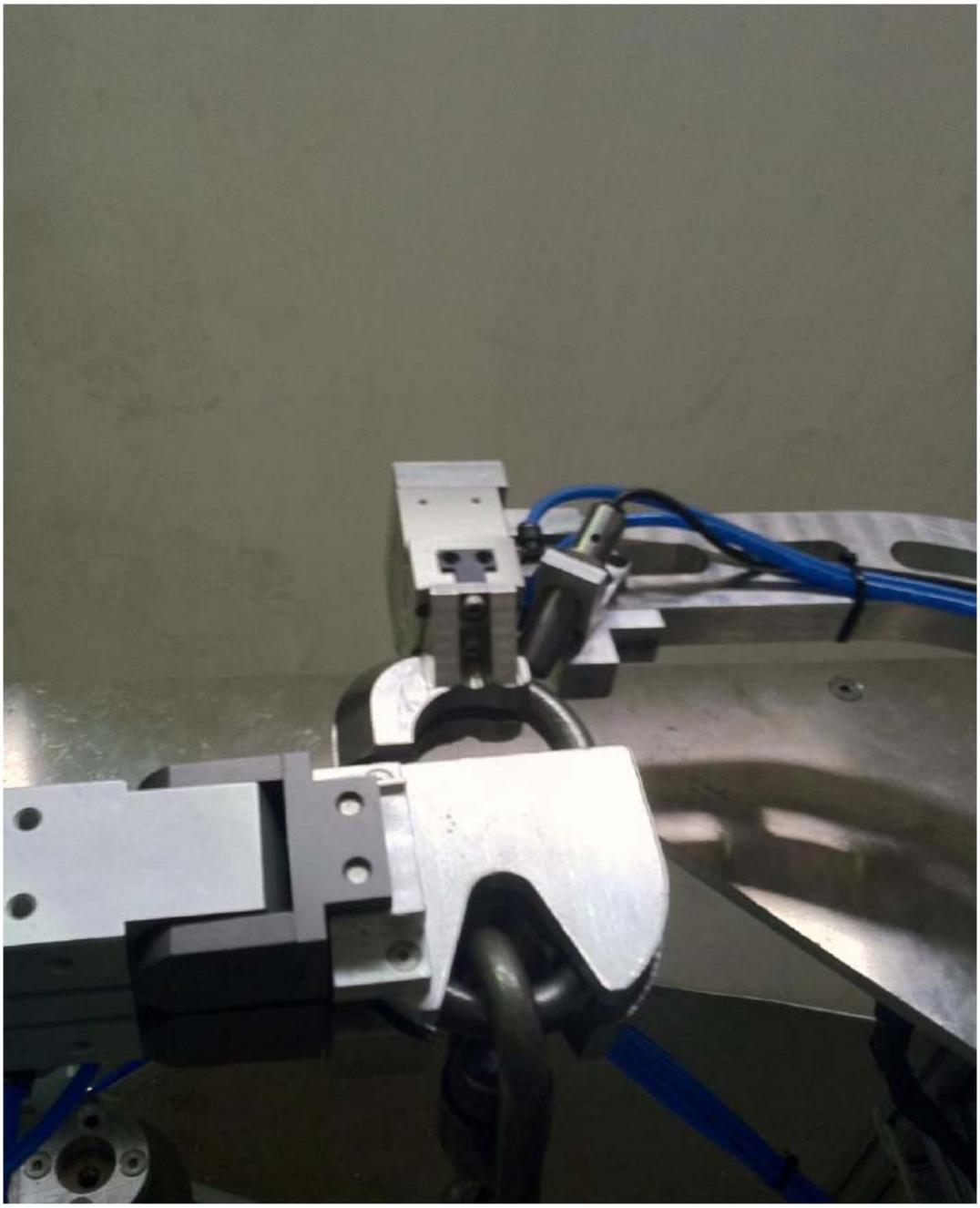

Figure 16: Bottom link to moving gripper

Chain Manipulation

After the shackle is loaded into the BST, the chain is often in a position which may impede shackling. To solve this inconvenience a rotary motor and compact cylinder with attached tooling are used to push the chain links at either end into the correct position.

Figure 17: Chain before manipulation

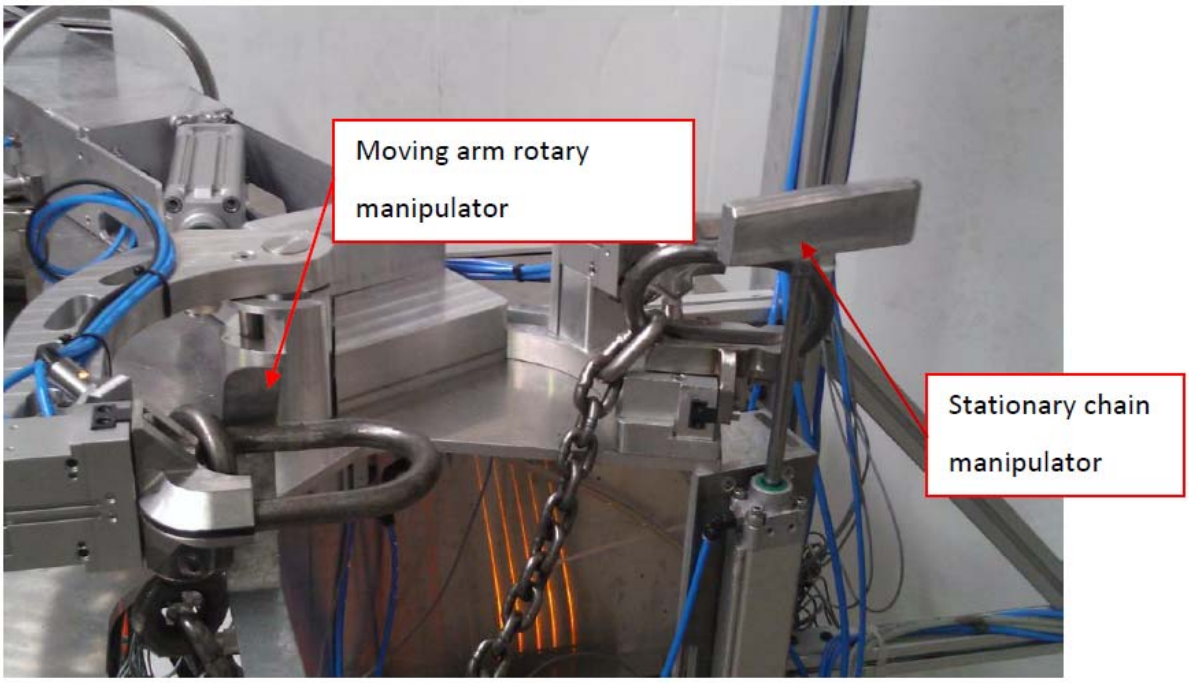

Figure 18: Chain after manipulation

4 Control System

The Operator Controlled Beef Shackling System contains two Programmable Logic Controllers (PLCs) to perform logic operations in both individual systems. PLCs are minimalist digital computers commonly used in industrial applications to manage arrays of analog and/or digital inputs and outputs.

M91-2-UA2 Unitronics PLCs were selected as the primary control apparatus in this application. Unitronics PLCs are compact, all-in-one modules which include an intelligent controller and embedded text-based display. The displays may be used to produce powerful Human-Machine Interfaces to illustrate information including monitoring parameters, system states, error messages and so forth. The ASLS also required an IO-DI16A3-RO16 expansion module to cater for additional inputs/outputs.

Figure 19: Unitronics PLC system

4.1 Beef Shackling Tool

Operation

The operation of the BST is limited to two procedures. The First is the loading procedure which utilizes the ASLS to automatically load the shackle into the parallel grippers. The second is the shackling procedure which lassos the loaded shackle around the hock of stunned cattle. Figure 26 and Figure 27 below detail the actions behind the respective processes.

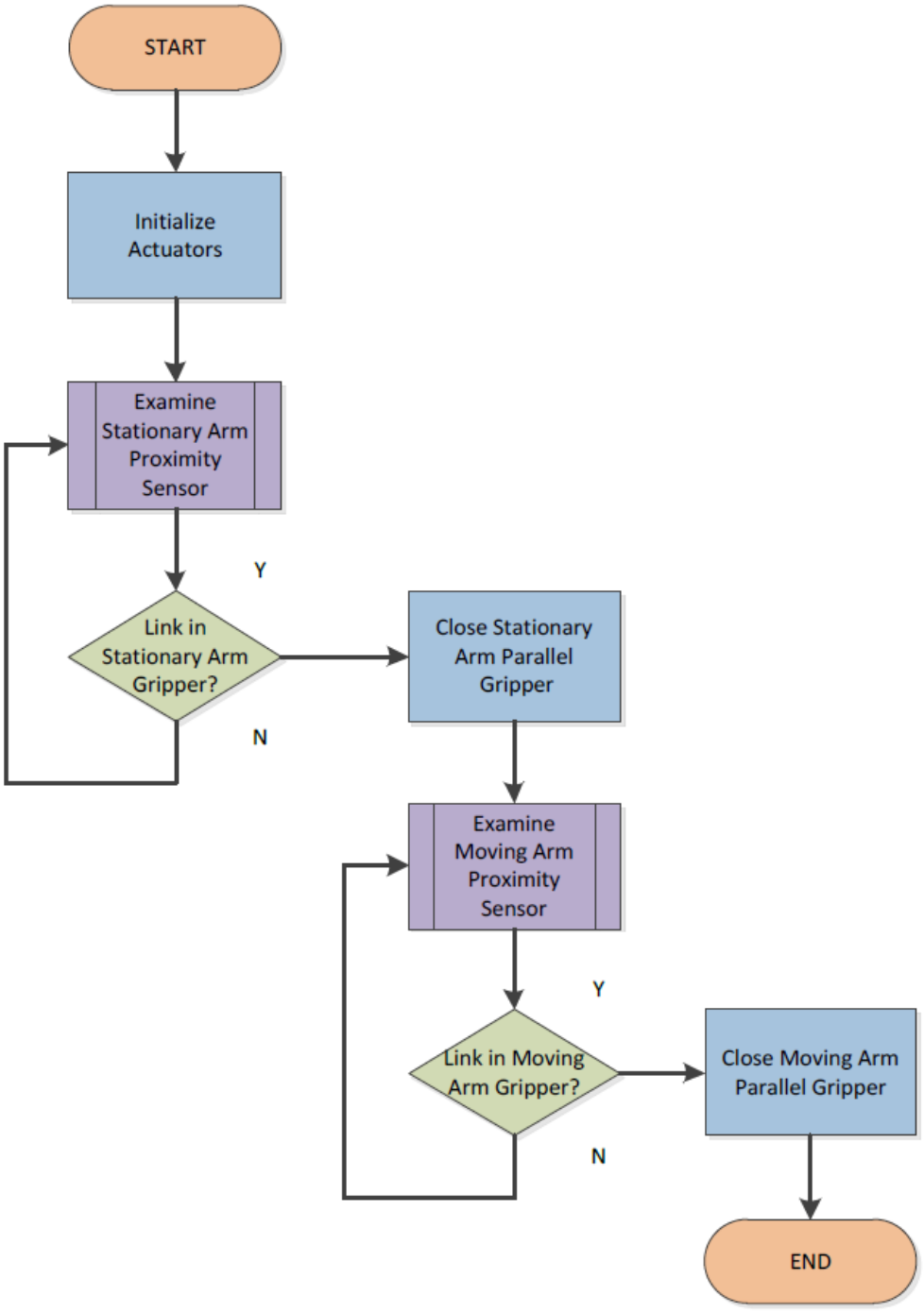

Figure 20: BST Shackle Loading Flow Chart

4.2 Automated Shackle Loading System

Electrical components on the ASLS are confined to an IP65 rated electrical cabinet. Power is supplied to the electrical cabinet via a 240V AC plug. A 24V DC transformer is used to supply power to all electronic devices. Standard socket connectors are used to interface the electrical cabinet with external peripherals.

Figure 22: Shackle Loading System Electrical Cabinet

Operation

1. A Stopper 1m away from loader holds rollers in queue
2. Bleed roller released & rolls down to loader and is stopped
3. Correct positioning of the Beef Shackling Tool in the tool dock is detected
4. The top shackle links is grabbed by pneumatically actuated grippers
5. The top shackle link is raised while bleed roller is reversed, to unhook shackle from bleed roller
6. Top shackle link is lowered back down
7. Bottom shackle is gripped
8. Top & Bottom link are transferred to Beef Shackling Tool grips
9. Reposition chain along links outside shackling envelope
10. Reset actuators to initial positions

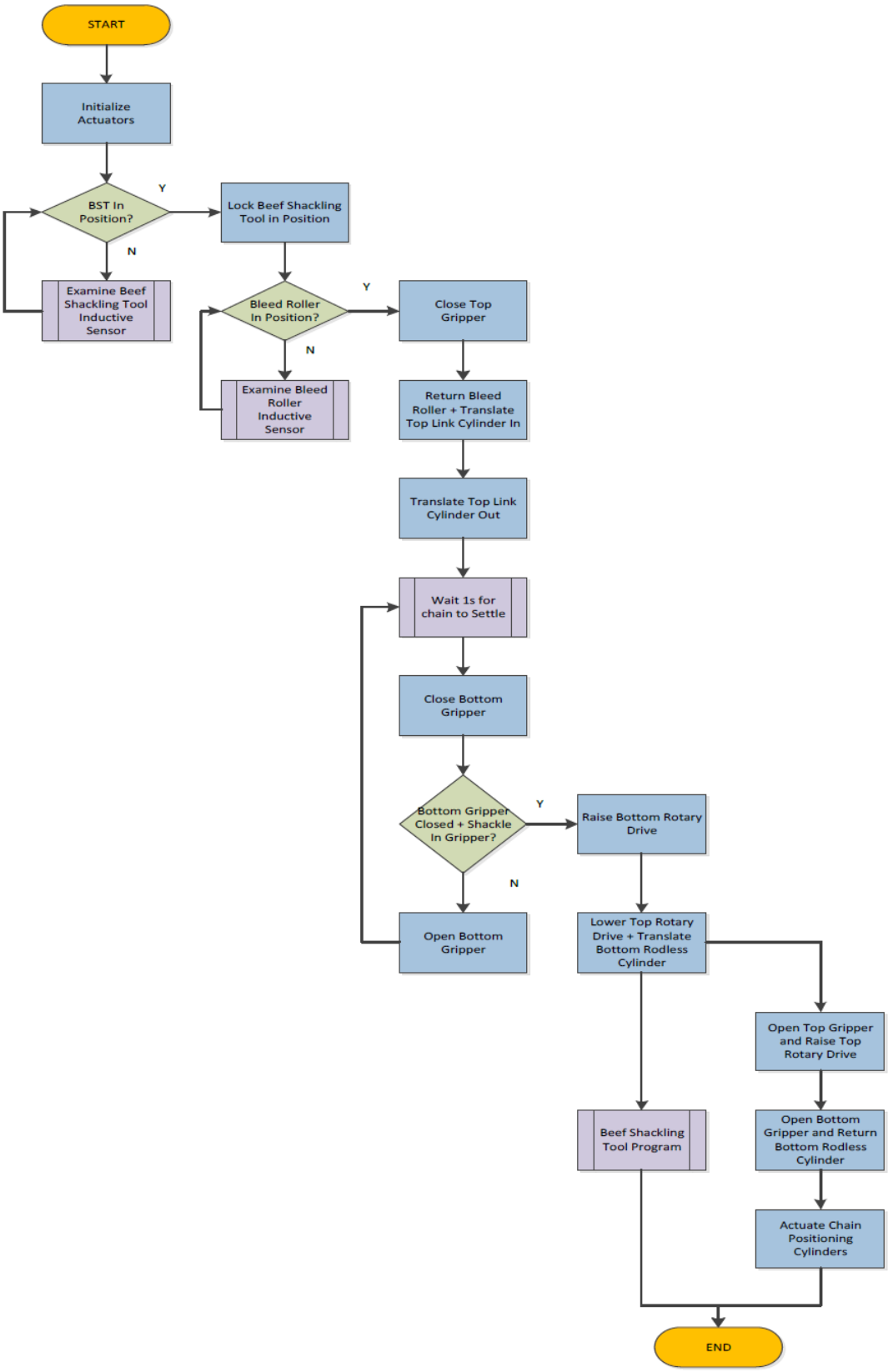

Figure 23: ASLS Shackle Loading Flow Chart

5 Testing

The BST and ASLS were thoroughly tested and refined while undertaking their respective projects. Both projects were subsequently integrated and further development was undertaken in order to produce a commercially viable Operator Controlled Beef Shackling System. Testing of the integrated system was then undertaken to ensure the developed system adhered to strict functionality and stability guidelines.

The OCBSS test assembly was evaluated in two phases. The initial phase involved trialing the BST over two days on the slaughter floor of E.C. Throsby in Wittingham, NSW and the second phase involved a comprehensive functionality and operability assessment at Strategic Engineering's Kirrawee facility.

The first day of plant trials provided key information relating to the viability and practicability of the BST. Feedback from this trial indicated that the BST was difficult to maneuver, requiring the operator to get very close to the beast to shackle. This resulted in little clearance between the operator and a violently kicking cattle hock. The BST also had difficulty shackling larger beasts, unable to wholly rotate the moving arm to the closed position.

The BST was subsequently redesigned in compliance to the feedback gained from the first day of trials. To cater for larger cattle the area of the BST in its closed state was doubled. The length of the tool was also increased to approximately 1.5m to distance the operator from the hazardous area. To ease maneuverability and accommodate the extended length, the tool was balanced.

The second day of plant trials was used to evaluate the aforementioned modifications and provided positive results. The new, longer design was substantially easier to wield and operate, allowing operators to safely and reliably perform the shackling task. The only criticism from the trial was that the handle bars felt slightly unnatural to operate. This flaw has since been addressed by replacing the front handle bar with a rounded handle instead.

Figure 24: BST Trial at E.C. Throsby

The second evaluation phase involved a more comprehensive procedure and was undertaken at Strategic Engineering's facilities. These trials were conducted using the closest possible environmental conditions present within an E.C. Thorsby abattoir. Polyurethane rods were used to substitute the rear hocks of a recently stunned bovine specimen.

The PLC software was strenuously tested and validated to ensure reliable system operation. Software validation testing was performed by inducing potential faults in the system and ensuring the system produced a suitable reaction. It was important to observe the system reaction was operator friendly and the presence of the fault was acknowledged and illustrated on the HMI of the PLC.

Ease of operation is another important facet of the system. To guarantee reproducible results testing was undertaken using multiple operators following simple operational guidelines. It was observed that after reading simple operating procedures and a visual demonstration, all operators were able to safely operate the OCBSS.

To ensure the system operates in a predictable manner, inductive sensors were used to monitor the state of all moving components. In the event of equipment failure (i.e. a link is improperly grasped or a cylinder fails to actuate after a given time constant) the software will either reattempt the previous operation or performs an escape condition which alerts the operator.

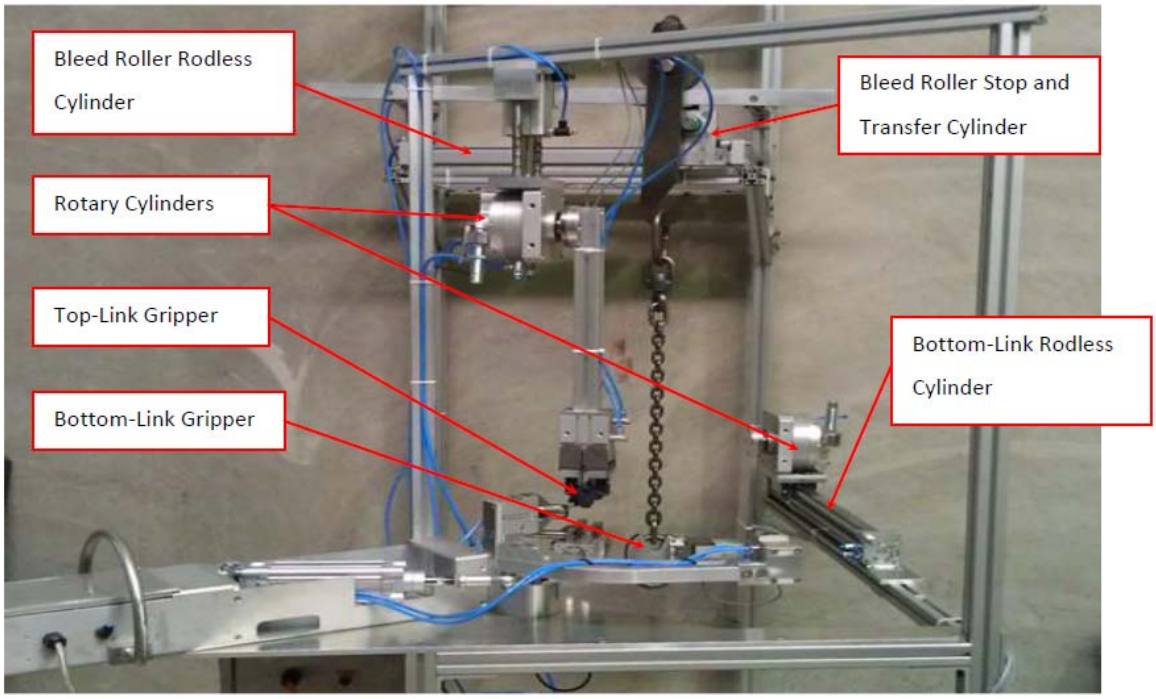

Figure 25: Test Assembly

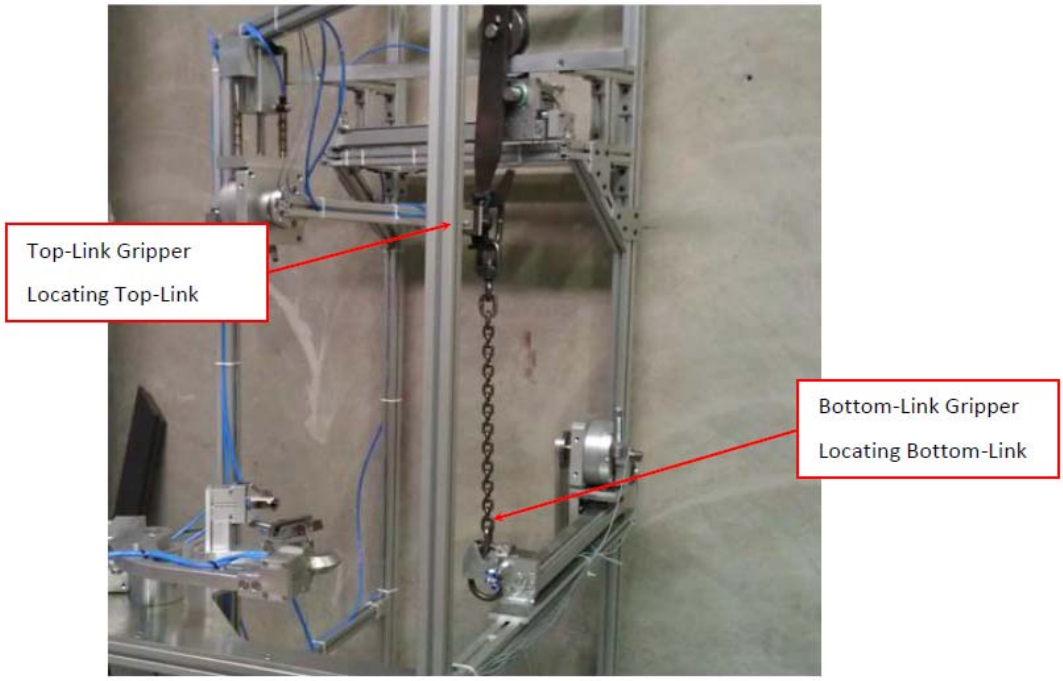

Figure 26: Shackle Removal from Bleed Roller

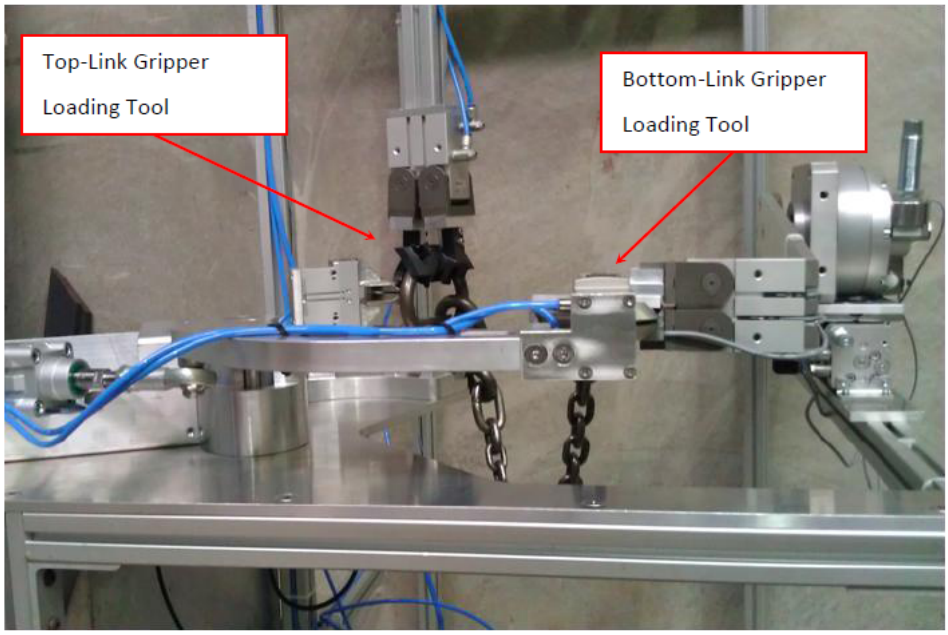

Figure 27: Loading the Shackle into the Tool

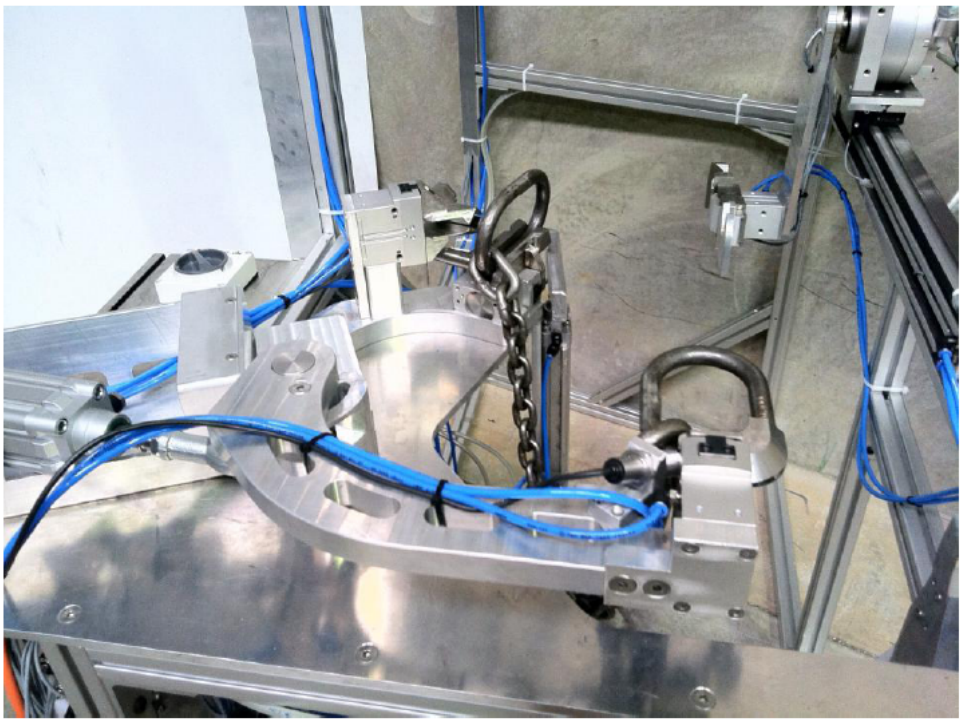

Figure 28: Tool Loaded with Shackle

Overall, testing of the system was successful. The system substantially minimizes risk of harm to the operator over conventional beef shacking procedures. The system is inherently safe in design and operation. It utilizes failure conditions and error messages to alert an operator in the event of equipment failure.

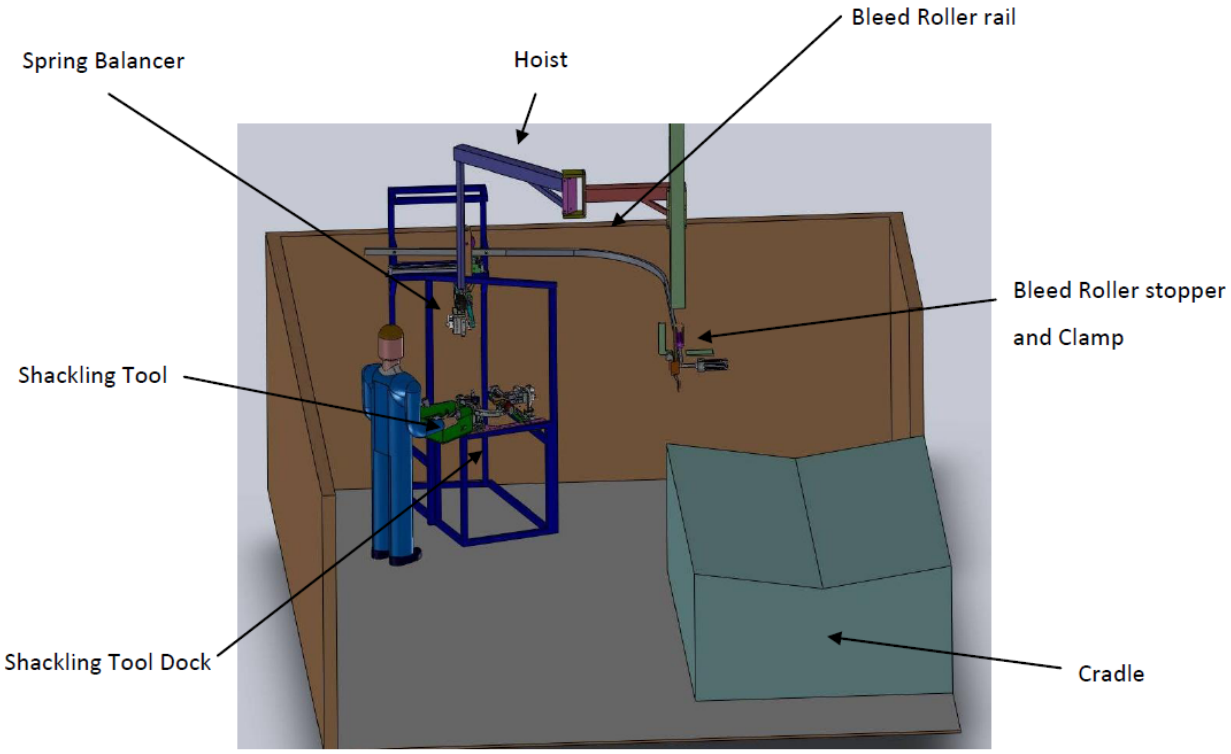

Figure 29: System overview

6 Conclusion

This report sees the completion of the Operator Controlled Beef Shackling System project. A commercially viable Beef Shackling Tool and Automated Shackle Loading System was designed and constructed, and a trial of the system was successfully undertaken on the production floor of E.C. Throsby.

The system is very adaptable and with simple modifications it can be set up for the use in different abattoir configurations. The loading system framework and controls would be modified to integrate into the differing bleed roller systems used in the beef cattle processing industry.

On commercialization the system would be fully guarded and the docking system would be contained so that the operators could not be injured by the moving actuators. The tool would also be lightened using different materials and construction methods.

The system successfully removes the operator from the danger area of the kicking animal and allows the animal to be controlled, and easily shackled. The Operator Controlled Beef Shackling System can be quickly installed and easily maintained, it has demonstrated the reliable and repeatable application of the shackle to the beast.