

# **Can a live production asset be transferred inter-company without affecting customer relations?**



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**A thesis submitted for the degree of**

**BSc (Hons) Mechanical Engineering**

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# Non-Disclosure Agreement

Date: March 2020

Parties:

Robert Thomas – Gestamp Llanelli Ltd

John Williams – University of Trinity Wales St. David

Chris Davies – University of Trinity Wales St. David

For Parties:

John Williams of University Trinity of Wales St. David

AND

Chris Davies of University Trinity of Wales St. David

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**Signed by John Williams of University Trinity of Wales St. David**

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Name

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Position

**Signed by Chris Davies of University Trinity of Wales St. David**

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Position

## 1 Acknowledgments

Firstly, I would like to thank the key individuals of the project team who were all crucial in the deployment of the dissertation matter, Mr K Morris of Gestamp Llanelli, Mr H Davies of Gestamp Llanelli. Without their professionalism and competency this project would not have been a success. Mr P Morris of Gestamp Llanelli for allowing myself the dedicated time on the project.

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Finally, I would also like to thank Mr J Williams of University of Trinity Wales St. David as the second reader of this dissertation, and I am grateful for his valuable comments on this thesis.

Thank you.

Robert Thomas

## 2 Summary

This thesis shows the deployment of a cross functional team to install, commission and deliver a product to a customer on time with a restricted time period.

By following a strict timing plan which itemises each action required to be completed and allocated a duration period, the commissioning of the asset is delivered on time and without delay to the customer.

Key information had to initially be identified to the project team for them to be most prepared for the project at hand. The process then required further investigation and research to be carried out to identify the most efficient solutions for the asset to be situated at the Llanelli site.

From the installation stage, the commissioning stage begins which includes the operation of the asset and also all quality requirements and documentation to be carried out.

Finally the asset is commissioned inter-company and the first shipment of production components is delivered to the customer within the period set by the initial timing plan.

Proof that the customer relationship was not effected in the process is shown by the signed part submission warrant found in Appendix 20.

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## 5 List of Abbreviations and Acronyms

|                    |                                                                        |
|--------------------|------------------------------------------------------------------------|
| <b>OEM</b>         | Original Equipment Manufacturer                                        |
| <b>NED</b>         | North Europe Division                                                  |
| <b>R&amp;D</b>     | Research and Development                                               |
| <b>BIW</b>         | Body in White                                                          |
| <b>GWM</b>         | Gestamp West Midlands                                                  |
| <b>SOP</b>         | Start of production                                                    |
| <b>RFQ</b>         | Request for quotation                                                  |
| <b>SOR</b>         | Statement of requirement                                               |
| <b>BOP</b>         | Bought out Part                                                        |
| <b>CHILD PARTS</b> | Child parts are components that are required to make a final assemble. |
| <b>RMW</b>         | Robot MAG Weld                                                         |
| <b>O.E.E</b>       | Overall Equipment Effectiveness                                        |
| <b>CMM</b>         | Co-ordinate Measuring Machine                                          |
| <b>PIST</b>        | Percentage of Inspection Points Satisfying Tolerances.                 |
| <b>PFMEA</b>       | Process failure modes and effects analysis                             |
| <b>RPN</b>         | Risk Priority Number                                                   |
| <b>PPAP</b>        | Production part approval process                                       |
| <b>PSW</b>         | Part Submission Warrant                                                |
| <b>PPM</b>         | Parts Per Million                                                      |

## 6 Introduction

Gestamp Talent Ltd is a multi-national automotive components supplier, founded in 1997 in Madrid, Spain. The relatively new manufacturing company has grown steadily and amassed 96 plants across 5 continents and 13 R&D centres with 41,000 employees. (Gestamp, 2019). Gestamp is now a market leader in the tier 1 sector of the automotive market due to their cutting edge technology and precision quality.



*Figure 1 - Gestamp IZB Exhibition 2018*

Gestamp's Llanelli plant is the basis for this thesis. Gestamp Llanelli is predominately a BiW pressing plant. In 2009 the plant was owned by Thyssen Krupp until Gestamp bought the plant in 2011 due to the site being on the brink of closure under the predecessor's management according to Wales online. (Kelsey, 2014)

Since the Spanish company have bought the plant there has been a steady growth and the work force has grown from 224 in 2014 to 550 in 2020.

The company has heavily invested in hot stamping and laser technologies and vastly grown its assembly department where the site is on the verge of becoming a predominately assembly plant. The site has the potential to gain a larger revenue stream from assembled products rather single pressed components. The company has also recently expanded its customer base and welcomed Aston Martin Lagonda. From March 2020 Gestamp Llanelli will supply a full aluminium car cross beam into the St Athens site, a complex assembly which is a prime example of Gestamp's expansion and market leading edge.

This thesis is based on the expansion of Gestamp as they have opened a new pressing facility in the West Midlands, England.

Due to the opening of GWM, Gestamp will be closing its sister plant in Cannock. Therefore, all production assets that are currently still in production will either cease production prior to the site closing or will have to be transferred from the site to another Gestamp site or lose the potential business to a competitor if they can no longer produce the components.

The component shown below is a rear bumper assembly for the Land Rover Discovery Sport 2020 model. The assembly is the basis of this dissertation as the component is one of the products produced at the Cannock plant which will be in serial production for another 4 years post the closure of the Cannock site.

Gestamp Cannock has produced this component since 2016. Gestamp also still has a legal contractual agreement to supply aftermarket quantities of this product as well as produce the 2020 model variant.



*Figure 2 - L550 20MY Rear Bumper*

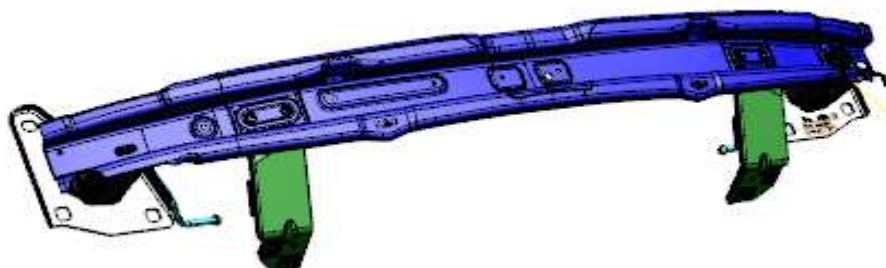


*Figure 3 - L550 16MY Rear Bumper*

## **7 Project Selection, proposal and agreement.**

Gestamp Ltd has 6 tier 1 automotive plants Llanelli (South Wales), Cannock (Midlands) Aycliffe (North England), Washington (North England), Fareham (Birmingham) and Gestamp West Midlands (GWM). For this project, a specific asset that's based in Gestamp Cannock plant will be selected to be transferred inter-company.

When new business is won by a tier 1 supplier from an OEM the minimum quantity of components required to be produced is identified and also the duration of the product life. Normally for an automotive supplier it is the life of the car before a new model variant is released which can be anywhere from 4 to 10 years. Once mass production of the product is completed the company will also have a responsibility to still supply smaller quantities of the product for spares and repairs, known as aftermarket production. Therefore, the nominated supplier could potentially be producing a product for a supplier for 5-10 years in mass production and then must produce aftermarket components for additional years also.

This project looks at a Rear Bumper assembly for the Land Rover Discovery Sport. The component is currently being produced at Gestamp Cannock site. The asset will have to be transferred from Cannock due to the plant closure. The issue becomes that the product must continue to be supplied by Gestamp Ltd to Land Rover even though the plant is facing closure due to the initial agreement signed by Gestamp on being nominated for the project i.e. Gestamp will be financially liable for any stoppages of Land Rovers production lines if the supply of product is stopped. Fines can be issued to Gestamp in the regions of £7,000 per hour of production line stoppages

Further complications are that currently Gestamp Cannock produce the product under the project name L550 16 MY (model year) which is the Land Rover Discovery Sport Range. From 2020, Land Rover will be selling a "facelift" model of the Discovery Sport, which will affect the design of the rear bumper. The "facelift" model will affect a number of components built into the assembly. From 2020, The Rear Bumper will be produced under a new project name of L550 20MY Rear Bumper.

To outline what is required for this project, the assembly assets and ancillary equipment required to produce the 16MY component will need to be transferred to an alternative Gestamp site. The assets will then need to be modified to be able to produce the 20MY variant, and then commissioned to serial production standards.

The 20MY product will be mass produced and 16MY will be required for aftermarket supply to customer circa 5200 per annum to be produced.

The assembly assets required to be transferred from Cannock includes:

- X2 ABB Flex Arc assembly cells. One cell is used to produce all sub assembly components and the other used for the finished assembly.
- X3 fully articulated welding robots and all associated equipment. X2 are required for sub assembly builds and x1 required for finished assembly.
- L550 16MY Rear Bumper assembly tooling.
- L550 16MY Rear Bumper press tooling.
- X1 existing pedestal welder. For 16MY only one pedestal welder is required for resistance welding two M6 nuts to the bumper beam.
- X2 New pedestal welders. Due to the engineering changes required for 20MY, two M8 x 35mm annular projection studs are now required and an additional M8 nut.
- The finished component is also painted so the new facility will need to have painting facilities.

All items listed above will be shown in greater detail later in this thesis under section 8.

The author is employed by Gestamp Llanelli, therefore the project selection was tasked to the author by senior management. The proposed solution is that the product is to be transferred to Gestamp's Llanelli site. Due to capacity issues within the organisation, Gestamp's only viable option for producing the component will be the Llanelli plant. Once Gestamp Cannock is closed, the Llanelli plant will be the only one of five Gestamp plants that has a paint plant and as the assembly is painted the most cost effective solution would be to produce at Gestamp Llanelli.

In addition to this, Gestamp already produce the Hot Stamped bumper used in the assembly. See heading 8.2.5 for the advantages of this.

Other than the project coming to the Llanelli site, the only other possible option would be to sell the project to a competitor, which would ruin customer relations between Gestamp and Land Rover. As a competing business the company would be aware that Gestamp would have no other option and would only agree to produce the component for less than what Gestamp sell the product to Land Rover for. This would leave the remaining cost for Gestamp to incur.

From the two proposals identified, senior executives at Gestamp decided that the most viable option is to transfer the asset to Gestamp Llanelli.

This was agreed by Gestamp Corporate NED (Madrid), Gestamp Llanelli Plant Director Mr B Davies, Engineering Manager Mr P Morris, Senior Engineer Mr K Morris and also Gestamp Cannock Plant Director Mr C Oakley.

## **8 Project Specification**

The initial requirements to commissioning an assembly asset firstly need to be clarified. Items such as tooling, the production process, floor space, utilities, labour, performance of the asset and agreed sales of the product must be known so that the project team can plan as a cross functional team to deliver the project on time.

### **8.1 Project Members**

- Cannock Site Project Manager – John Parker
- Llanelli Engineering Lead – Robert Thomas
- Senior Engineer – Karl Morris
- Quality lead – Huw Davies
- Cannock Engineering Lead – Stuart Dunne
- Logistics lead – Robert Owens
- Health and Safety – Leighton Lewis
- Finance lead – Amy Charles
- Purchasing lead – David McNulty

From the initial project meeting all key factors listed above were identified and all requirements were identified and proposals approved. See the following sections for clarification on project deployment.



Figure 4 - MY20 Land Rover Discovery Sport - [www.Landrover.com](http://www.Landrover.com)

## 8.2 Production Components Required

For a new product or design, the customer will release a statement of requirements (SOR) document which is a request for quotation (RFQ) for all contracted suppliers. The SOR document will include all components required to be produced and all key milestone dates. Once the supplier is nominated (in this case Gestamp Llanelli) the design feasibility will be agreed and released to the supplier. Once issued, the supplier works to the agreed computer aided design (CAD) level. Any alterations made to this post agreement are at a cost to the customer. Following the agreed CAD level, the final CAD release is then ready for tooling and assembly processes to commence. From this stage the supplier will then lead all proto-type and pre-production components which will initially lead to a ramp up in production and to a final start of production (SOP) date where the product is in mass production to the customer and shipped direct into the customers manufacturing site.

The context of this thesis is slightly unusual to the normal procedure described above as Gestamp were already producing the 16MY variant of the product, therefore Gestamp would always be favoured to deliver the new 20MY product as they already have the assets to produce the asset, it would save costs for both supplier and customer.

To outline the production requirements required to produce the final assembly, a break down from the bill of materials (BOM) of all finished components with customer part names can be seen below (Full BOM can be seen in appendix 1):

### 8.2.1 15.7048.02-03-04-05 Crush Can Inner – Outer



Figure 5 - 15.7048.02-03-04-05 Crush Can Inner – Outer

The final assembly requires two crush can welded assemblies. An inner and outer crush can is required to make the final component. These components are carried over from the 16MY variant.

### 8.2.2 15.7170-03 Crush Can Back Plate LH

Although this is a carryover part from 16MY the tooling has been modified to prevent issues found whilst in 16MY production i.e. burrs and splits.

### 8.2.3 15.7170-02 Crush Can Back Plate RH

For 16MY production both pack plates were symmetrically identical. Due to the design change for 20MY the need for x2 M8 studs and x1 M8 nut is now required and therefore the need for the flange up and extra piercings. The resistance welding process will be outlined in section 8.4.1



Figure 6 - 15.7170-03 Crush Can LH

Figure 7 - 15.7170-02 Crush Can Back Plate RH

#### 8.2.4 15.7170-04-05 Rear Bumper Support Bracket LH/RH



*Figure 8 - 15.7170-04-05 Rear Bumper Support Bracket LH/RH*

Although the 16MY Rear Bumper required both support brackets, they have been re-designed for 20MY production. Therefore, new tooling has been manufactured. See section 8.3.1 for tooling.

#### 8.2.5 K15.7661C Rear Bumper Beam



*Figure 9 - K15.7661C Rear Bumper Beam*

Whilst Gestamp Cannock were producing the 16MY Rear Bumper to Land Rover, due to not having any Hot Stamping capabilities Gestamp Llanelli were producing the Bumper Beam and supplying to Cannock to assemble.

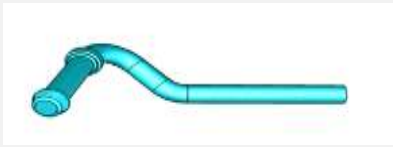
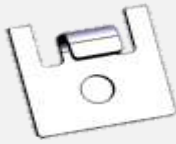
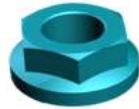
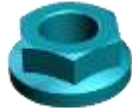
By Gestamp Llanelli already producing the main component of the assembly, it was only advantageous to Gestamp for Llanelli to also assemble the product also. By doing so, a saving on logistics and transport would be made.

The Bumper design will see a design change, see Appendix 2 for breakdown of all design changes.

## 8.2.6 Bought Out Parts

Bought out parts (BOPS) are required for the final assembly. It is common for an automotive assembly component to require fasteners or fixings which are then used in the final assembly build. Gestamp outsource all components of this nature.

The bought out components required for the final assemble are below:

| <i><b>BOP Name/Part Number</b></i>                                      | <i><b>Quantity<br/>required</b></i> | <i><b>Image</b></i>                                                                   |
|-------------------------------------------------------------------------|-------------------------------------|---------------------------------------------------------------------------------------|
| <i><b>BOP 2083 / Hanger Wire</b></i>                                    | 2                                   |     |
| <i><b>BOP 2084 / Guide Tube</b></i>                                     | 1                                   |   |
| <i><b>BOP 1839/ Hanger Bracket</b></i>                                  | 2                                   |  |
| <i><b>BOP 1593/Nut M6 Weld Hex<br/>Flange 08</b></i>                    | 6                                   |  |
| <i><b>BOP 1804 / Bolt M8 x 1.25 x<br/>30.0 PIL WLD Annular ring</b></i> | 2                                   |  |
| <i><b>BOP1600 / M8 Weld Hex<br/>Flange</b></i>                          | 1                                   |  |

For all BOP engineering drawings see appendix 3.

## 8.3 Pressing Processes

From the identification of all components required for the final assembly completed the production processes can be identified. For the understanding of the reader, customer parts numbers included in this thesis are a series of numbers as seen in the headings below.

### 8.3.1 Cold Pressings

#### 8.3.2 15.7048-02-03/04-05

The Crush Can inner and outer left hand and right hand is produced via a progression die. A progression die is where the material is fed along the length of the die whilst the die remains fixed. The material is stopped at intervals along the die which then perform different operations i.e. trim, pierce or flange up/down.

For the crush can inner and outer two dies are required. One die produces a inner and outer left hand crush can and one die produces an inner and outer right hand crush can. As mentioned in section 8.2.1 no new tooling is required to produce this component as its design has not changed for 20MY. See 15.7048-02-03/03-04 die below:



*Figure 10 - 15.7048-02-03-04-05 Progression Die*

### 8.3.3 15.7170-03 Left Hand and 15.7170.02 Right Hand

The crush can back plates are produced via a manual 1000 tonne press. Manual operator production is a traditional method which is becoming a rarity in the manufacturing industry. Gestamp will always look for autonomous production where possible. That being said, sometimes the product might define the process and this is the case for both back plates. Both back plates are made from Domex 7001 and have a material thickness of 3.0mm. With the material having an ultimate tensile strength (UTS) value 1200Nm, only very large manual processes have enough tonnage to produce the component hence the need for 1000 tonnes.



Figure 11 - 15.7170.03 Crush Can back plate LH/RH

### 8.3.4 15.7170-04-05 Support Bracket

The support brackets are produced in the same manor via a progression die. Although, the components design has changed for 20MY which has resulted in a new die needing to be manufactured. See 15.7170-04-05 die below:



Figure 12 - 15.7170-04-05 Support Bracket Progression Die

### 8.3.5 Hot Stampings

15.7661C Rear bumper beam is a hot stamped component. The hot stamped process works by sheet metal being fed through a furnace and heated to a temperature of 700°C. The material is then transferred to a die which is cooled via water ways that run through the die. Whilst pressed the component is quenched and formed and then removed from the die. The quenching of the components is what gives the desired mechanical properties for a lighter but stronger finished component.

Due to the material becoming too hard to then pierce, all piercings required are laser cut from the formed material which reveals the final component.

As mentioned in 8.2.5, Gestamp Llanelli already produce the component. The design changes that are required for 20MY (see appendix 2) are carried out by modifications to the laser cutting profiles. The laser programme is changed to incorporate the new holes and profiles. No alterations to the die are required. See below for photo of 15.7661C hot stamp tooling:



*Figure 13 - 15.7661C Rear Bumper Tooling*

## 8.4 Assembly Processes

Firstly, all fasteners that are required for the final assembled product are added to all child parts. The assembly processes used are shown below.

### 8.4.1 15.7170-02 Resistance Welding

Added to the 15.7170-02 component are two M8 x 1.25 x 30.0mm annular projection studs. This process is completed via pedestal welder. The pressing is loaded into the tooling of the pedestal welder which locates the pierced hole of the component over the lower electrode. The stud is then added manually by the operator. The pedestal welder is then operated which results in the upper electrode coming into contact with the stud and welding the component via the annular projections along the head of the stud.

“Resistance welding is the joining of metals by applying pressure and passing current for a length of time through the metal area which is to be joined. The key advantage of resistance welding is that no other materials are needed to create the bond, which makes this process extremely cost effective” (L.Duffy, 2008)

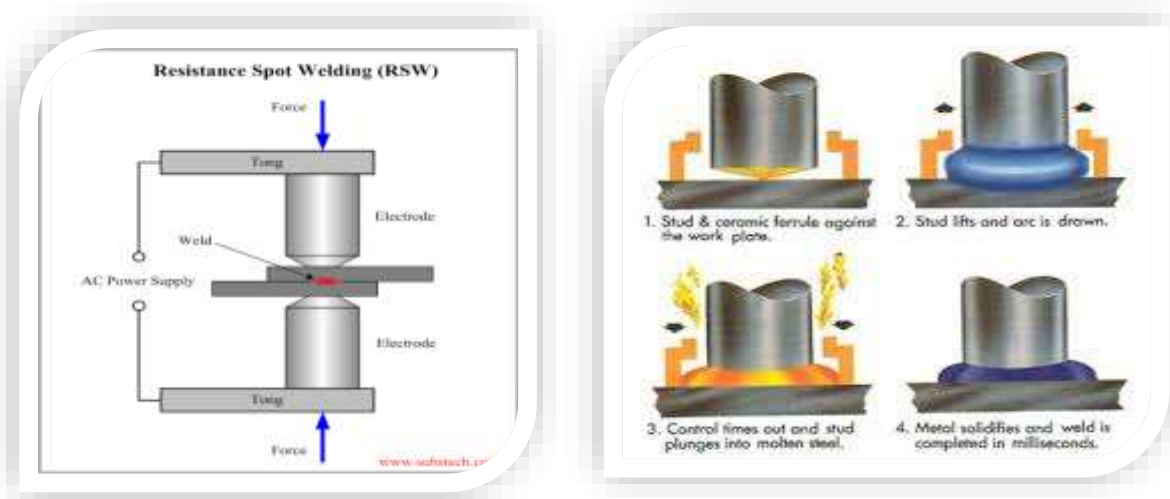


Figure 15 - Resistance Spot Welding - [www.substech.com](http://www.substech.com)

Figure 14 - Figure 15 - Stud Welding - [www.contractconnections.com](http://www.contractconnections.com)

Also added to 15.7170-02 is a M8 (Hex) Weld Nut. The process remains the same as the nut is welded along its underside projections although the nut is fed automatically via a Dengensha Bowl feeder.

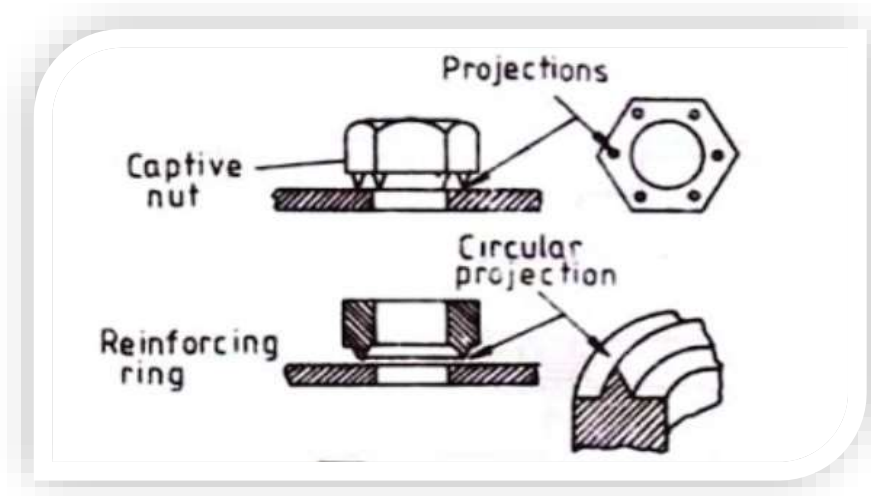


Figure 16 - Nut Resistance Projection Welding - [www.resistancewelding.com](http://www.resistancewelding.com)

The welding process for both fasteners is completed over two separate pedestal welders. See below:



Figure 17 - 15.7170-02 M8 Stud and Nut Pedestal Welder

Once all three fasteners are added to the 15.7170-02 the component is ready for the MAG welding process.

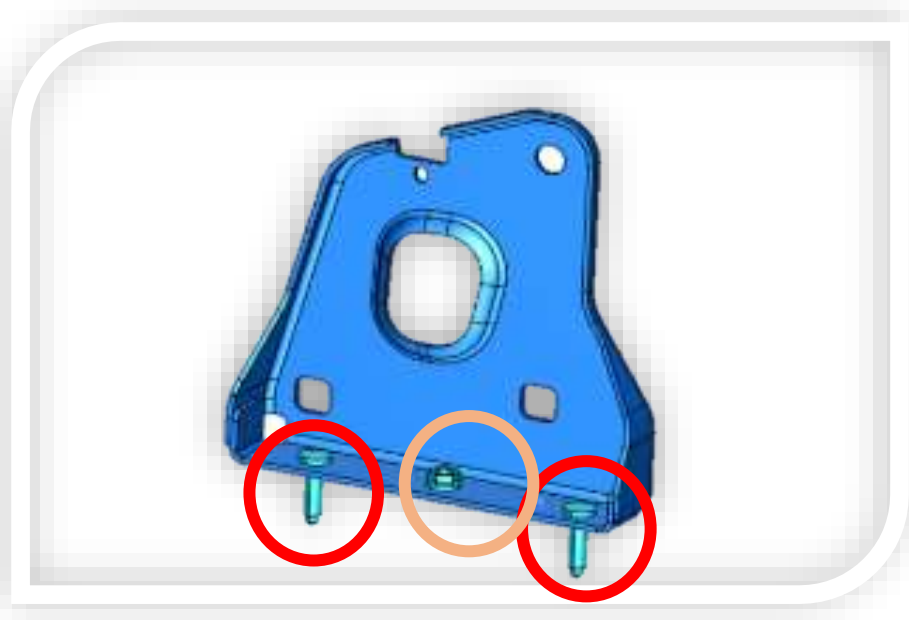
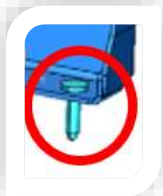
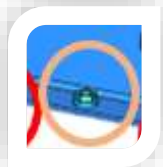


Figure 18 - 15.7170-02 with Fasteners



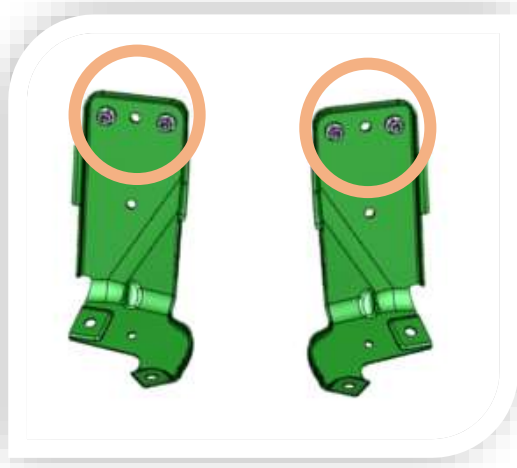
M8 x 1.25 x 30.0mm annular projection studs



M8 (Hex) Weld Nut.

### 8.4.2 15.7170-04-05 Resistance Welding

Similar to the M8 Hex weld nut assembled to the 15.7170-02, the 15.7170-04-05 has two M6 Weld Hex Flange nuts added to the child parts. The process remains the same although alternative tooling and ancillary equipment is required to support the part and different size nut.



M6 Weld Hex Flange



Figure 19 - 15.7170-04-05 with fasteners



Figure 20 - 15.7170 -04-05 Pedestal Welder

Although this is a new component the previous design included the same welded nuts. Due to the M6 nuts being the same as that welded to the 15.7661C hot stamped component the pedestal welder would complete both operations. Whilst this maximises the output of the asset, issues were highlighted that the operator running the cell would often collide with the operator using the pedestal welder as it was located outside the cell. Also due to one operator having to cease work whilst a 15.7661C component required nuts to be added the capacity gain of the pedestal welder wasn't as expected.

The output lost due to the low overall equipment effectiveness (O.E.E), a direct result of the operator not being able to produce, justified the cost of a new pedestal welder.

Therefore, a new pedestal welder would be purchased for this operation which could then be completed away from the assembly asset and loaded to the cell once the resistance welding is completed.

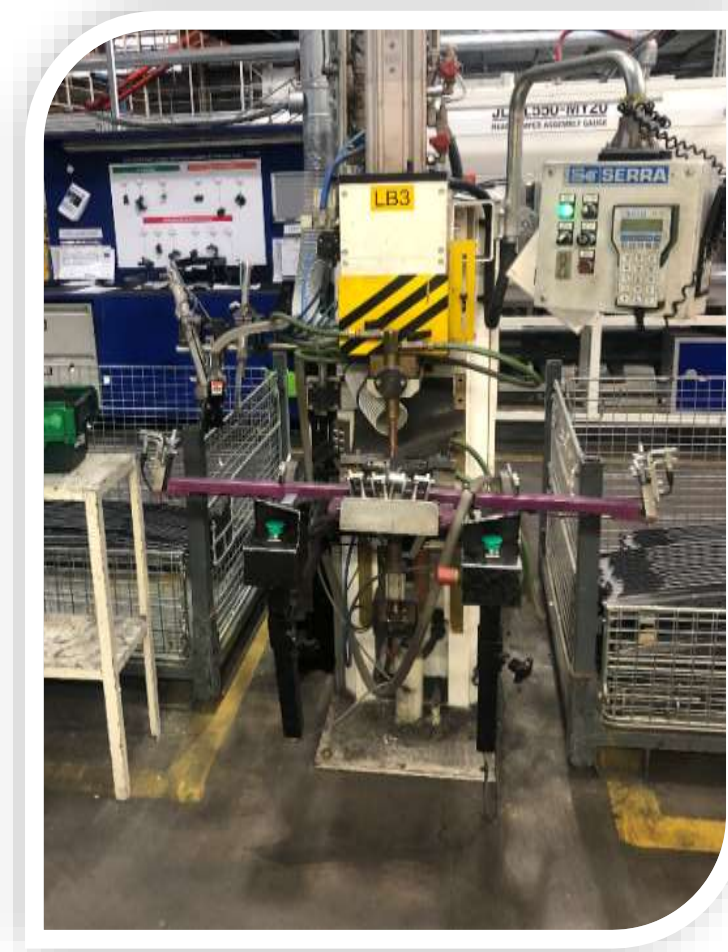


*Figure 21 - 15.7661C Rear Bumper Beam Pedestal Welder*

### 8.4.3 15.7661C Resistance Welding

The 15.7661C hot stamped rear bumper beam also has the same M6 weld hexagonal flange nuts welded to the underside of the bumper. These are welded prior to entering the final MAG welding process and are included in the standard operating procedure found in appendix 4.

The pedestal welder required for this operation is included in the items transferred from Gestamp Cannock and shown in figure 21 above.



Figure 22 - 15.7661C Rear Bumper Beam with x2 M6 Nut Assembly

### 8.4.4 RMW 77 Flex Arc MAG Welding – Sub Assembly Stage

As listed under section 8 of this thesis, one of the assets being transferred is robot MAG weld (RMW) 77 Flex Arc cell.” Flex Arc” is an assembly cell produced by ABB robotics. The cell consists of a rotary turntable and two fully articulated IRB2400 ABB robots. At this stage, both left hand and right hand crush can sub-assemblies are produced. The turn table is split by left hand crush cans being assembled on one side and right hand being produced on the other. The individual station is broken down into two operations.

- OP10 – 15.7048 02-03 are welded to produce the crush can assembly
- OP20 – 15.7170-03 back plate is then welded to the crush can

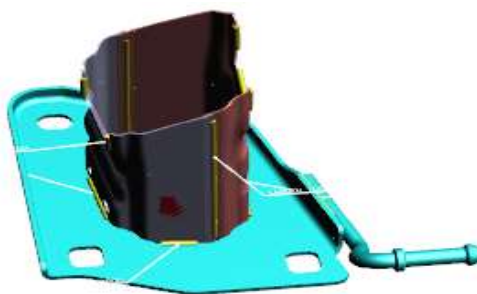


Figure 23 - Figure 23 - RH Crush Can Sub-Assembly

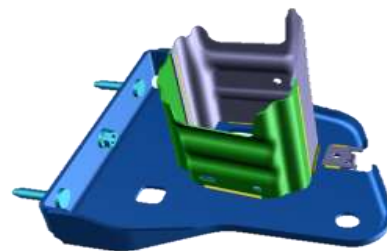


Figure 24 LH Crush Can Sub-Assembly

#### 8.4.5 RMW 78 Flex Arc MAG Welding – Final Assembly

Similar to RMW 77, RMW 78 features the same autonomous cell although only one robot is required. The turn table is also split into two stations.

- OP 10 – 15.7661C Rear bumper Beam to BOP2083 (Guide tube)



Figure 25 - 15.7661C Rear bumper Beam to BOP2083 (Guide tube)

- OP20 – 15.7661C Rear bumper beam to both crush can assemblies



Figure 26 - L550 20MY Rear Bumper Pre-Paint



Figure 27 - RMW77/78 ABB Flex Arc MAG Assembly Cells

## 8.5 Painting Process

From RMW 78 the component seen in figure 16 above is now ready for the painting process.

Gestamp Llanelli are home to an electrophoretic deposition painting facility (eCoat). The process works by the components being immersed in a fluid bath. The bath is electrically charged which causes the paint particles to be drawn to the component. The paint particles then build up on the surface of the component, Land Rover specify a paint thickness tolerance of  $20\mu\text{m}$  to  $40\mu\text{m}$ . To adjust the paint thickness applied to the components the voltage amount passing through the tanks is modified. (J.Chaney, 2005)

Once fully painted the components are transported to an oven for the paint to set. The whole paint plant process at Llanelli takes 90 minutes from parts being loaded to unloaded.

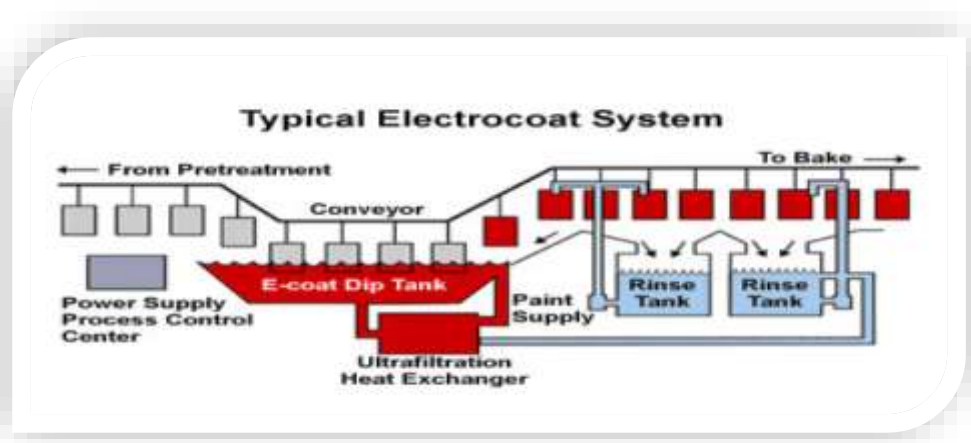


Figure 28 Typical Electro coat System

To verify the initial painting process the part is then submitted to a salt spray test onsite at Llanelli for 6 weeks. The salt spray test is an accelerated corrosion test. The test ensures the high quality component remains over time.

The process works by a salt water solution being applied to the component via a spray nozzle. The environment is used to replicate a corrosive environment, the more resistant the product is the longer oxidation takes to appear. (P.Lomelio, 2017)



Figure 29 - Figure 27 - Salt Spray Booth

## 8.6 After Paint Assembly

The final process is an after paint assembly where 15.7170-04-05 are screwed to the bumper painted assembly. The process works by the operator loading the painted component onto the fixture and securing the part with hand clamps.

Proximity sensors are then required to detect all BOP's fitted to the component as part of a Poke Yoke prevention to remove the risk of sending a defected part to Land Rover. Once all checks are completed, a Desoutter torque drive unit which is calibrated and pre-set with the required torque values is used to assemble both brackets with four M6 x 35mm Studs. If the sequence is not completed i.e. not all four studs are fitted, the clamps will not release. This is also another poke yoke method to prevent selling defected components to the customer.



*Figure 30 - After Paint Assembly Station*

Once the after paint assembly operation is completed the component is now finished and ready to be sent to the customer. See finished component below:



*Figure 31 - L550 20MY Rear Bumper Finished Assembly*

## 8.7 Process Failure Modes and Effect Analysis

PFMEA is a methodical approach to identify high risks on process changes. The analysis identifies functions and their effect on the process. Special characteristics are identified and the effect on the customer.

Each failure mode is then ranked in terms of severity (danger of the effect to the customer), occurrence (how likely is the failure mode to occur) and detection (how easily can the failure mode be identified or not). Failures with a high risk priority number (RPN) require recorded follow up actions to reduce the RPN number and therefore a history of improvement is recorded and the risk is mitigated. (L.Adrian, 2007)

The purpose of a PFMEA is to highlight risk prior to tooling acquisition and mitigate risk prior to the first production part approval process. (PPAP)

Although a PFMEA would have been carried out prior to the commissioning of 16 MY rear bumper, due to the new tooling and the assembly cells becoming capable of running both model variants a new PFMEA is carried out to outline new or underlying risks with the process.

For full PFMEA for L550 20MY Rear Bumper see appendix 5.

## 9 Project Timings and Contingencies

For full project delivery timing plan see appendix 6.

The biggest constraint on this project is time. The basis of this thesis is if a production asset can be transferred inter-company without effecting customer relations, a major disruption in the project or delay in the start of the production could be the downfall of the project which could ultimately effect the relationship between Gestamp Llanelli and Land Rover due to stopping the customer's production lines.

Therefore, contingency planning must be in place to protect Gestamp Llanelli in case of major delays and not being able to supply Land Rover.

Before a contingency plan is put in place all key milestone dates must be highlighted to both Gestamp Cannock and Llanelli project teams.

- Tooling Commissioning at Llanelli – 10/04/2019
- Connection of Assembly cells at Llanelli – 12/04/2019
- Start Run at Rate at Llanelli – 27/04/2019
- Start of Production – 10/05/2019
- 1<sup>st</sup> Delivery to Land Rover – 15/05/2019

Identified from the master project plan, the project must be delivered in a four week period. Starting with the commissioning of the press tools and completing with the first shipment of parts to Land Rover.

Although the project team has experience and competency amongst its project members, a contingency plan must be in place before the project can commence.

Whilst the assembly and tooling assets are being installed at Llanelli plant, Gestamp must still ship 16MY bumpers to Land Rover. Land Rover have disclosed to Gestamp Llanelli that they will build the first L550 20MY Discovery Sport on 24/05/2019.

Therefore, a contingency plan is to be agreed by both plants to firstly ensure the supply of components into Land Rover and to cover the installation period.

Fortunately for Gestamp, the L550 16MY assembly asset is only in production for 16 hours per day. This leaves extra production capacity to produce the bank stock to cover the installation period.

It is agreed by Gestamp Cannock that they are to run the assembly cell for 24 hours per day for 5 days for a period of 5 weeks. By doing so the extra 50% of components produced per 24 hours will cover the period where no product will be able to be produced. i.e. if 1000 components were being produced in both morning and afternoon 8 hour shift, an additional 8 hour shift would produce another 1000 components (50%)

The five week period will also account for any short fall or rise in stock demand and also be a contingency if Gestamp Llanelli were not able to meet the projected timing plan and were to fail on the commissioning of the 20MY product.

## 10 Project Solutions

For the project timing plan to be executed without delay the Llanelli project team firstly has to identify solutions to meet the timing plan. By thorough planning prior to the delivery of the production assets the project is more likely to be successful.

### 10.1 L550 Rear Bumper Cell Location and Utilities at Gestamp Llanelli

The cell location proposal at Llanelli site is a key factor into the project solution. Many factors influence the position of a production asset in a manufacturing environment, such as the previous and following operations and what the next operation includes. The amount of movement required by the operator has to be reduced to a minimum to ensure that the production asset is operating at peak capacity.

Referred to as “Takt time” in the industry. “Takt time is the rate at which you need to complete a product to meet customer demand” (K.Isslington, 2020). The production cell location can impact the takt time, if there is a decrease in takt time and therefore output, Gestamp could face risk of under producing the products required.

A break-down of the area required for the production assets are as follows:

- Assembly Production Cells = 95m<sup>2</sup>
- Pedestal Welders = 15.56m<sup>2</sup>
- Quality inspection = 12m<sup>2</sup>
- Pallets, Racking and Packaging = 76m<sup>2</sup>
- After Paint Assembly = 16.2m<sup>2</sup>

A total of 214m<sup>2</sup> is required for production of the L550 20MY Rear Bumper.

## 10.1.1 Proposed Location at Llanelli

Gestamp Llanelli Layout March 2020.

Proposed Locations for L550 20MY Rear Bumper Production Equipment

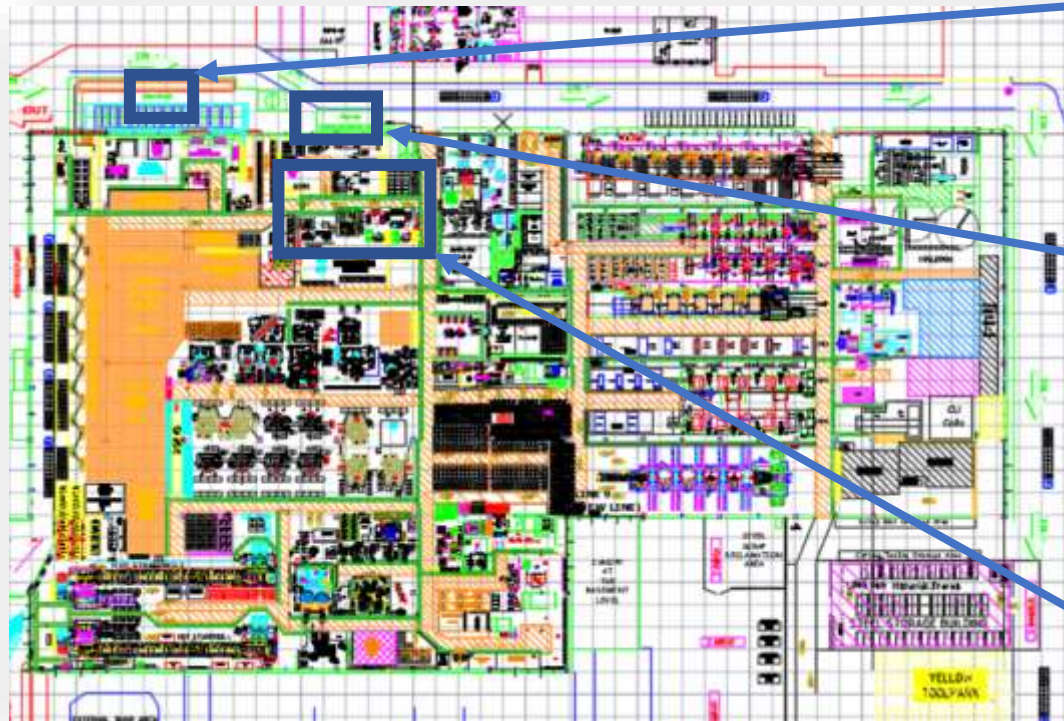


Figure 35 - After Paint Assembly Proposed Location



Figure 34 – 15.7170-04-05 Pedestal Welder Proposed Location



Figure 33 - Assembly Cell Proposed Location

As can be seen above, the location of the assets are strategically positioned at Llanelli. By investigating possible locations at Llanelli, the most cost effective position of the assets have been highlighted below.

#### **10.1.1.1 After Paint Assembly Location**

The location shown in figure 35 above shows that the asset is located at the finished product end of the paint plant at Gestamp Llanelli. The reason for this is to reduce the amount of movement the component has to encounter prior to the finalised assembly. By locating the after paint assembly station in the paint plant section the 15.7170-04-05 hanging brackets and bumper assembly once painted have a minimal distance to travel prior to the final assembly. This is the most cost effective position of the asset with the floor space available.

The utilities required for the after paint assembly station are 110v electrical supply and 6bar pneumatic supply.

#### **10.1.1.2 15.7170.-04-05 Pedestal Welder Location**

The location for the pedestal welder is required to be as near as possible to the paint plant loading station. This again has an impact on the takt time as the operators movement is required to be as reduced as possible.

Therefore, the final proposed location is situated at the main loading station of the paint plant conveyor and therefore ensuring minimal loading time and ensuring throughput of production.

As seen in figure 34, the proposed location for the pedestal welder is situated next to two already installed pedestal welders. This is advantageous as the power supplies required are already installed in the proposed area. Due to not having to connect the pedestal welders from the mains supply a cost saving is created. The 15.7170-04-05 pedestal welders require 200KVa electrical supply and water supply of 10 litres/min.

#### **10.1.1.3 Assembly Cell Proposed Location**

Similar to section 10.1.1.2, the proposed location for the assembly cells are situated next to a paint plant loading station. Therefore, loading the bumper ready for paint can be inclusive in the operation of the assembly cell. This also has the potential for an increase in output and painted parts produced.

The sub assembly and final assembly cell are located as close to one another to reduce the foot fall between the assemblies (see figure 27). Also to be included in 20MY production is the requirement for two additional pedestal welders. These are to be located within 1 meter from the sub assembly MAG welding cell so that finished stock can be packed into a final pallet outside the sub assembly cell.

The power required for two new pedestal welders are 250KVa and 10 litres/water supply. The increases in power compared to 15.7170-04-05 power supply is due to the thickness of material. (1.2mm to 3.0mm).

For A3 shop floor layout before and after installation please see appendix 7 and 8.

## 10.2 Production Performance

Production targets are based on several factors, the sales requirement (i.e. the amount of products needing to be produced to meet customer demand), and the loading and unloading time and automated duration of the cell.

All production assets will have an O.E.E (overall equipment effectiveness) target. For Gestamp Llanelli the target is set at 85%.

O.E.E is calculated by:

$$O.E.E = Availability \times Performance \times Quality$$

By having a metric to base the assets performance against is a clear way of showing progress and performance. O.E.E is a tool that allows the business to track or identify underlying issues and identify root causes.

### 10.2.1 Availability

“Availability” refers to the availability to produce components from the asset i.e. when the assets is generating revenue for the business. When the process is then stopped no value revenue is being created whether that’s due to mechanical failures, no material or operational issues.

The calculation then compares the scheduled run time against the actual.

### **10.2.2 Performance**

“Performance” is the basis of the production run underperforming against the output target i.e. running under optimal performance. The calculation compares the actual cycle time against the ideal and identifies how much production is lost as a result of under-performance.

If the asset is over performing, the output metric assigned has been undervalued.

### **10.2.3 Quality**

Quality is the amount of waste product that is produced i.e. components produced that do not make quality standards. By a comparison of acceptable against rejected components exposes the percentage of time wasted producing a rejected part.

### **10.2.4 Production Targets**

Each production asset will have an individual output target based on the amount of components the asset can produced if it is 100% efficient.

- RMW 77 – Sub assembly cell – 27 PPH
- RMW 78 – Assembly Cell – 32 PPH
- 15.7170-02 Pedestal Welder – 48 PPH
- 15.7170-04-05 Pedestal Welder – 55 PPH

From the output targets above, the restrictive output target is RMW 77. Therefore the maximum number of components that can be produced is 27 parts per hour as RMW 78 final assembly cell cannot run without the sub assembly components produced by RMW 77.

### **10.2.5 Standard Operating Procedure**

To optimise the production process, the optimal loading and unloading method is adopted and recorded. The procedure is then documented and trained to the operators that are operating the automated cell.

With the procedure being documented, if there is a turnover of new labour the new operator can be trained to the optimal procedure and therefore stand the best chance at optimising the output performance. For SOP Document see appendix 9.

## 10.3 Labour and Sales

### 10.3.1 Overheads

To reduce cost, the amount of overheads assigned to a product or process is kept to a minimum and the tasks they are to perform is to be maximised in an efficient manner.

For this project the initial required over heads associated with the production of the assets were employed. Then a time study of the operation is undertaken and this then highlights any indirect labour associated with the production of the asset and also if any cost savings can be highlighted by maximising the efficiency of the work force.

To show this see below for the manning initially proposed for the production of the 20MY bumper:

- RMW 77 – Sub assembly cell – *1 operator (#1)*
- RMW 78 – Assembly Cell – *1 operator(#2)*
- 15.7170-02 Pedestal Welder – *1 operator(#3)*
- 15.7170-04-05 Pedestal Welder – *1 operator(#4)*

Initially, four operators are required to produce the component.

After examining the takt time of the operators, it shows that they have spare capacity as the assembly cell is welding the components. Therefore, they are able to incorporate other processes into the overall production process.

Consequently the manning to be proposed is as follows:

- RMW 77 – Sub assembly cell – *1 operator (#1)*
- 15.7170-02 Pedestal Welder – *1 operator(#1)*
- RMW 78 – Assembly Cell – *1 operator(#2)*
- 15.7170-04-05 Pedestal Welder – *1 operator(#2)*

The proposed manning above shows a reduction of two operators. By completing time studies on the processes, it is identified that the operators have enough available time to complete both processes whilst maintain the optimum output from the final assembly cell. This reduction in manning comes at a £60,000 saving to Gestamp Llanelli.

For production time studies see appendix 10.

## 10.3.2 Sales

For transferring the asset to even being considered a viable option for Llanelli, they must have visibility of the future sales and profitability of the component. Transferring the products to Llanelli plant must be considered viable, therefore future sales/profitability must be known.

The C04 document found under appendix 11, shows the projected forecast of sales for the component for the next four years before a new model variant is released which will see the 20MY become requirement for service components.

Shown below are the Volumes for L550 project taken from the C04 document:

|      |      | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 | 2026/27 | 2027/28 | 2028/29 | Total  | Peak  |
|------|------|---------|---------|---------|---------|---------|---------|---------|---------|---------|--------|-------|
| L550 | 20MY | 70000   | 80000   | 90000   | 90000   | 50000   | 35000   | Service | Service | 0       | 194000 | 90000 |
|      |      | 70000   | 80000   | 90000   | 90000   | 50000   | 35000   | 0       | 0       | 0       |        |       |

The table above shows a peak volume of 90,000 components in the year 2022/23 and 2023/24. Although these volumes can vary depending on the economic climate and popularity of the vehicle, the values shown are the commitment Gestamp have to the customer.

For Gestamp Llanelli, an order of 90,000 component is highly profitable and a high order in comparison to alternative assembly components supplier to different customer.

In addition to this, the production asset must achieve the required O.E.E to produce the amount of components required. Under achieving the output target or efficiency would result in stoppages at the customer due to being unable to deliver the product.

The C04 document also shows the cost of consumables, utilities and equipment that goes into the final piece part price of the product. The piece part price has been removed from the document to avoid discourse of the profitability percentage of the product.

## 11 Commissioning the Assembly Process at Gestamp Llanelli

The key actions to commissioning the assembly assets are highlighted in the completed project timing plan. See appendix 12 for completed timing plan.

A breakdown of these tasks are identified below.

### 11.1.1 15/04/2019 – 22/04/2019

- Position and connection of assembly cells RMW77/78 – (Magnaforce)
- Install New assembly tooling - (MultiMech)
- PLC and Robot Programing Modifications
- Dry Cycle trials
- Cell 78 Initial Welding Op 10 & Op 50
- Cell 78 Macro Testing and dimensional checks
- Cell 78 Jig Adjust
- Cell 77 Initial Welding Op 20 & 60
- Cell 77 Macro Testing and dimensional checks
- Cell 77 Jig Adjust
- Dry Cycle Trials

For the installation of the assembly assets Magnaforce Ltd were hired by Gestamp to carry out the installations. The locations of the assets were established by Gestamp Llanelli. For the Gestamp Llanelli Layout after all assets had been commissioned please see appendix 8.

For the commissioning of the new assembly tooling required to produce the 20MY variant, the installation was sub contracted to a Multimech Ltd. The scope of work Multimech were contracted to cover was inclusive of all weld engineering, installation of new tooling, installation of all new software and the cross compatibility to be able to produce both 16MY and 20MY variants from the current production cells.

As can be seen from the completed timing plan between the 15/4/2019 to 22/04/2019 with Gestamp's support, MultiMech Ltd completed all commissioning on time. Multimech completed all software updates to include the variant change to be able to produce both model variants, commissioned all assembly tooling and verified all welds via macro testing. See appendix 13 for macro report.

All dimensions were verified via co-ordinate measuring machine (CMM) measurement programme. To show the dimensional accuracy of the component a “Percentage of Inspection Points Satisfying Tolerances” (PIST) percentage is shown. The initial measurement report showed a percentage of 89% PIST. See appendix 14 for full measurement report. For the first shipment to Land Rover the component must be 100% PIST. Dimensional improvements were made from 03/05-08/05 under section 11.1.3.

### **11.1.2      22/04/2019-03/05/2019**

- Position and Connect all pedestal welds (X3)
- Commission all pedestal welders (Prospot Engineering)
- Installation of BOP racking
- Set up of BOP parts in racking
- HSE review and approval for start-up.
- Start-up – Run at Rate
- Paint Trial
- Product ready for paint
- Paint plant layout update

Similar to MultiMech Ltd, Prospot Engineering were sub contracted to commission all new pedestal welders. This involves the installation of tooling, setting the welding parameters and finally submitting a components for a “Push out” test to verify the process.

A push out test is a simple test to verify the bonding between the fastener and the base material. For push out test report see appendix 15.

All BOP’s required specific racking as it is the BOP supplier’s responsibility to deliver and remove all products on site at Llanelli. Normally a BOP supplier will deliver the components on a scheduled basis that coincides with customer demand i.e. production levels.

The final verification is the paint process. The 20MY products that require paint must be trialled through the paint process to ensure sufficient paint coverage is applied to the product, this can be quite an extensive process as the orientation and features of the product determine paint run off and the release of air whilst passing through the process. If air cannot escape the assembly whilst in the process it will result in “water marks” or bare unpainted material.



*Figure 36 - L550 20MY Rear Bumper Prior to Painting*

### **11.1.3      03/05/2019-08/05-2019**

- Cap studies
- IPSW Submission (PPAP Checklist)
- PSW P1 & P3

The final stage of commissioning the assembly asset and the most time consuming stage of the process is achieving the production part approval process sign off. Prior to start of production an interim part submission warrant (IPSW) pack is submitted to the customer. The pack shows the quality status of the product at commissioning stage, the customer then can approve or reject for the shipment of these components to be used for prototype builds or pre-production builds. The supplier, in this case Gestamp Llanelli must then submit the full PSW pack to the customer prior to the start of production date which is 10/5/2019.

To submit a PSW all 16 PPAP elements are required. All PPAP elements are shown below:

1. Design record with all specification
2. Authorized engineering change number (AECN)
3. Customer Engineering Approval
4. Process is defined
5. Process is documented
6. Linkages of process are established
7. Process is monitored, analysed, and improved based on data
8. Records are created, maintained, and retained
9. Validation Test Report
10. Control Plan
11. PFD (Process Flow Diagram)
12. Lab Test Report
13. DFMEA (Design Failure Mode and Effective Analysis)
14. PFMEA (Process Failure Mode and Effective Analysis)
15. MSA Study
16. SPC (Statistical Process Control)

(J.Holder, 2014)

## 12 Analysis, Results and Evaluation

### 12.1 Quality Evaluation

For a PSW to be granted in serial production Land Rover require six full measurement reports of six different components all measuring 100% PIST must be submitted. From the initial measurement report showing a PIST percentage of 89% at commissioning stage, the assembly required to be developed further to achieve 100% of inspection points within tolerance. After undertaking several trials the component finally achieved a 100% PIST score. This was completed by the thesis author and the full measurement report can be found under appendix 16.

Although a PIST percentage shows all points are within tolerance it does not show process capability. Therefore, a capability study was undertaken on 35 samples produced consecutively.

“A capability analysis is a set of calculations used to assess whether a system or process is statistically able to meet a set of specifications or requirements. To complete the analysis a data set of numerical values are required to meet a specified process capability index (Cpk) value.” (K.Grennan, 2020)

Cpk is used to estimate how close you are to a given requirement and how consistent the process performance can potentially become.

For the L550 20MY Rear Bumper a capability study on pre-specified measurement points by Land Rover was conducted. The measurement points outlined by Land Rover are shown in a document referred to as a “Supplement K” document by the automotive manufacturers, see appendix 17 for full document. These measurement points are crucial in the final build of the component, failure in these areas result in the component not being able to be assembled to the final car.

Land Rover state that all measurement points must achieve a Cpk value of 1.67 or higher. A Cpk value of 1.67 is a sigma level 5 which equates to a 0.573 PPM (Parts per Million) out of tolerance. For full capability study report seen appendix 18.

As can be seen from the report, the assembly achieves a Cpk value greater than 1.67 on all measurement points and therefore shows full process capability.

The final process report to complete is a welding macro report. A “Macro Etch Report” is used to check weld integrity and weld quality. The cross section of the weld is exposed, the exposed cross section is then polished and nitric acid solution applied. The parent metal and welds will then start to discolour to show a distinctive difference between the weld and base materials. The samples are then placed under a magnifier where weld properties such as penetration, leg and throat can then be identified. See appendix 19 for full macro report.

From the three key quality requirements highlighted above, the component meets all dimensional, welding and process capability requirements set by the customer. To validate these results the reports were issued to the customer within the part submission warrant and signed by Land Rover therefore validating the process. By the signing of this document Land Rover accept the quality of products being supplied by Gestamp and serial production can begin.

C Golding, Supplier Quality Technical Assurance Engineer of Jaguar Land Rover signed the part submission warrant which allowed the first supply of L550 20MY Rear Bumper into Land Rovers Halewood plant.

See appendix 18 for signed part submission warrant.

## **12.2 Process Evaluation**

To evaluate and analyse the production process the O.E.E and performance results produced by the asset are investigated. Now that the asset is in full production a larger data set can be identified and a better understanding of the cells performance gathered.

The initial investigation looks at performance i.e. is the cell meeting the required output? Is the target O.E.E being met?

To gather this information operators are required to fill in downtime cards. Downtime cards record the number of parts produced every hour and the downtime that occurs if any. The operator also records if any scrap components were produced. This data is then tabulated to give the overall equipment effectiveness. As well as giving an O.E.E percentage value, the information gathered is interrogated to identify the biggest losses in down time and the causes. An action plan is then created to remove identified losses.

Referring to the Downtime Data found in appendix 21, it can be seen that the asset initially under performs for the first four weeks of production. This is common due to new

tooling, new operators and also issues can arise which would not have been visible in the commissioning stages.

The output after this 4 week period is then aligned with the output target of 75% due to resolving the downtime causes found via the operator reports. The process will be continually monitored into production to ensure the performance levels are maintained.

## 13 Conclusion

To conclude this thesis, the title “Can a live production asset be transferred inter-company without affecting customer relations” can be now be answered.

By identifying key project members, outlining a strict timing plan and capitalising on existing knowledge of asset transfer, Gestamp Llanelli were able to transfer an asset intercompany without affecting the relationship with the customer Land Rover.

Both Gestamp Llanelli and Cannock understood the importance of protecting the company with enough bank stock to cover the commissioning and transfer period.

Although only a short window of four weeks could be given to Gestamp Llanelli to get the asset into production, the company delivered the first shipment of L550 20MY Rear Bumper to Land Rover on time and to the correct quality standard.

It is very important to outline the later of the sentence above, ensuring the supply of components on time is one milestone but ensuring the product is 100% acceptable is a great task in itself. Therefore, credit can only be given to the project members of Gestamp Llanelli ensuring this project was a success.

Gestamp Llanelli’s current order book is 85% supplied to Jaguar Land Rover. That percentage shows Llanelli’s reliance on Jaguar Land Rover, and how costly it could have been if this project was not a success as it could have affected future potential business at the Llanelli site.

As Gestamp Llanelli have proved the professional and practical approach to inter company assets transfers the company have now been awarded serval more assets to be transferred from the Cannock site. These assets will grow the plants assembly sector by over 40%, generating a large amount of revenue for the business in a financial period where the manufacturing sector is at a low due to Brexit Negotiations.

Future business awarded to Gestamp Llanelli are:

- L494 Rear Bumper – *Land Rover*
- **L405 Rear Bumper** - *Land Rover Sport*
- **L560 Rear Bumper** – *Range Rover Velar*
- L462 Front and Rear Bumper – *Land Rover Discovery*
- **D7A Rear Bumper** – *Jaguar F-Pace*

This thesis is a perfect example of Gestamp Llanelli's professionalism which will show the site prospect into a leading Gestamp plant in the near future.

Proof that customer relationships were not effected in this process is the signed part submission warrant found in appendix 20, without the signed document the customer would not have accepted the product produced by Gestamp.

## 14 Recommendations

Firstly, future actions to improve the assembly assets are to investigate the current downtime information gathered from the production cards and addressing the issues found. In doing so, the cycle time can then be improved and if possible over achieve the cycle time which was originally quoted to the customer. This would result in a more efficient process and also increase the capacity of the asset as more components can then be produced in a shorter period.

Secondly, the data gathered is currently inputted manually via the operator, this can lead to mistakes in regards to durations of the downtime and incorrect faults highlighted. To remove these potential errors, Gestamp Llanelli can move to an electronic automated system where the assembly asset is linked to a network that records all downtime in true time. This would give a more accurate representation of the assets performance.

If the two items highlighted can be implemented, it would create more capacity on the asset. Currently the asset is in operation for 16 hours a day (66% of full capacity). With more capacity being created the assets have more availability to generate more revenue. This would generate more profit for the business whilst reducing facilities costs as the asset is already in operation.

As highlighted in the conclusion, Gestamp have been awarded more business as a result of the success of this asset transfer. Introducing a procedure for asset transfers would benefit the plant as an itemised strategy would be put into place for the business to following during future projects.

A future asset transfer procedure would follow the guide line below:

1. Project team members identification
2. Components required to be produced
3. Assembly processes required
4. Paint Process if required
5. PFMEA of above processes
6. Asset location
7. Asset utilities
8. Understanding the performance and manning of the asset
9. Labour and Sales

To add to this a process flow diagram has also been created. See appendix 22. From this the lessons learnt from this project have been captured for the future asset transfers conducted by Gestamp Llanelli.

This is to be used as guideline to follow to ensure a successful transfer between Gestamp Llanelli and Gestamp Cannock.

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## 17 Appendices

List of all appendices and titles below:

1. Appendix 1 – L550 20MY Rear Bumper Bill of Materials
2. Appendix 2 – 15.7661C Rear Bumper Design Change Presentation
3. Appendix 3 – BOP Engineering Drawings
4. Appendix 4 – L550 20MY Projection Weld Presentation
5. Appendix 5 – L550 20MY Rear Bumper PFMEA
6. Appendix 6 – Initial Project Timing Plan
7. Appendix 7 – Shop Floor Layout Prior to Installation
8. Appendix 8 - Shop Floor Layout post Installation.
9. Appendix 9 – L550 20MY Rear Bumper SOP
10. Appendix 10 – L550 20MY Rear Bumper Time Studies
11. Appendix 11 – L550 20MY C04 Document
12. Appendix 12 – Completed Timing Plan
13. Appendix 13 – Commissioning Macro Report
14. Appendix 14 – Commissioning Measurement Report (89%)
15. Appendix 15 – Push Out Test Report
16. Appendix 16 – PSW Submittal Measurement Report (100%)
17. Appendix 17 – Supplement K Document
18. Appendix 18 – Capability Study Report
19. Appendix 19 – Full Macro Etch Report
20. Appendix 20 – Signed Part Submission Warrant
21. Appendix 21 – Down Time Data
22. Appendix 22 – Asset Transfer Process Flow Diagram

## **Appendix 1**

### **- L550 20MY Rear Bumper Bill of Materials**

## **Appendix 2**

### **- 15.7661C Rear Bumper Design Changes**

## **Appendix 3**

### **– BOP Engineering Drawings**

## **Appendix 4**

### **– L550 20MY Projection Weld Presentation**

## **Appendix 5**

### **- L550 20MY Rear Bumper PFMEA**

## **Appendix 6**

### **– Initial Project Timing Plan**

## **Appendix 7**

### **– Shop Floor Layout Prior to Installation**

## **Appendix 8**

### **– Shop Floor Layout Post Installation**

## **Appendix 9**

### **- L550 20MY Rear Bumper SOP**

## **Appendix 10**

### **- L550 20MY Rear Bumper Time Studies**

## **Appendix 11**

### **- L550 20MY C04 Document**

## **Appendix 12**

### **– Completed Timing Plan**

## **Appendix 13**

### **– Commissioning Macro Report**

## **Appendix 14**

### **– Commissioning Measurement Report (89%)**

## **Appendix 15**

### **– Push Out Test Report**

## **Appendix 16**

### **– PSW Submittal Measurement Report**

## **Appendix 17**

### **– Supplement K Document**

## **Appendix 18**

### **– Capability Study Report**

## **Appendix 19**

### **– Full Macro Etch Report**

## **Appendix 20**

### **- Signed Part Submission Warrant**

## **Appendix 21**

### **- Downtime Data**

## **Appendix 22**

### **- Asset Transfer Process Flow Diagram**