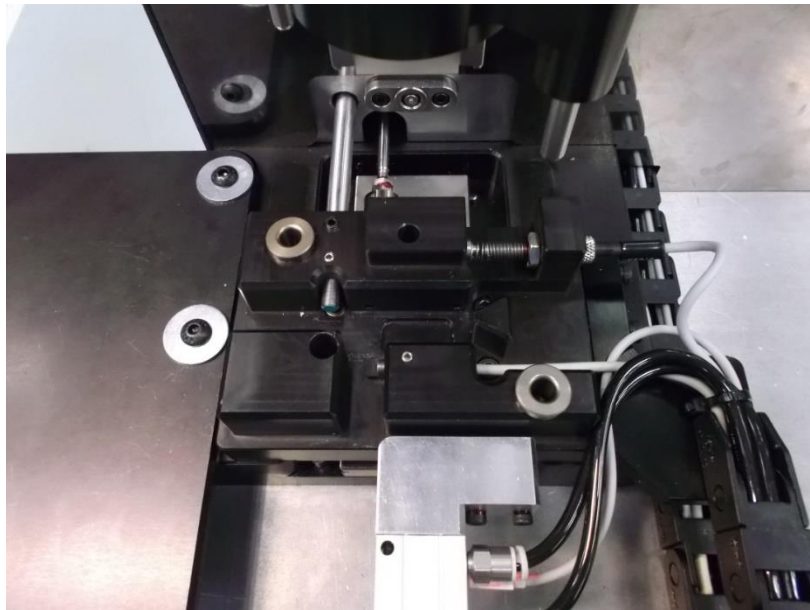




PLANT AND ASSET ENGINEERING

ACMA6007

Title: Evaluating the Effectiveness of Chosen Maintenance
Strategies for Dedicated Equipment

Ryan Harris (2115244)

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Introduction

Purpose

The purpose of the following report is to analyse and assess the maintenance strategies employed for a specific piece of equipment used in a production environment. The objectives of the assignment are listed below:

1. Give an overview of the business and operations, along with introducing the equipment that is to be analysed.
2. Evaluate the current maintenance practices that are carried out on the equipment.
3. Perform a comprehensive evaluation of potential enhancements to the maintenance approach. Looking at alternative methods that could lead to far more effective maintenance.
4. Assessment of the cost and resource required in implementing the proposed improvements.
5. Formulate a conclusion and propose any future recommendations using the report's findings. Looking at strategies such as maintenance process optimisation, equipment reliability and performance enhancements.

Maintenance is critical for enabling smooth uninterrupted operations within a manufacturing environment, maximises equipment uptime, and preserves the fabrication of quality products. Regular maintenance prevents unexpected breakdowns, reduces downtime, and extends the lifespan of key equipment. Regular maintenance also enhances safety by identifying and addressing hazards, along with worn parts that may require replacing. Implementing a strategic maintenance practice increases productivity, minimises production costs and improves efficiency. The HSE (2024) explain that effective maintenance programs make the plant and equipment more reliable.

Introduction to Renishaw and the Equipment Under Assessment

Renishaw plc is a global leader in innovative engineering and scientific technology, renowned for precision measurement and healthcare solutions. Renishaw was founded in 1973, the first product that the company marketed was touch trigger probing for precise inspection of the Olympus engines at Rolls Royce (Renishaw, 2023). Renishaw is a worldwide leader within the metrology, encoders, and machine tool sector of industry.



Figure 1 - Renishaw Products (Renishaw, 2020)

The companies Resolute Encoder stands out among the array of encoders manufactured and marketed by the business. Renishaw (2023) defines an encoder 'as an electromechanical device that converts one format to another'. The resolute encoders outer body is made up of components shown in Figure 2.



Figure 2 - Resolute Encoder Parts (Renishaw, 2023)

The Thermal Lidding Jig, identified by the tooling number T-03154 is responsible for peening the lid to the resolute encoders body. The lid of both the standard and ETR encoder must establish assured electrical contact with the body and remain securely in place during the application of the glue seal. The equipment under assessment (T-03154) is designed so that the resolute lids within the body as required.

Critical Review of Current Maintenance Practices

Equipment Function

As mentioned, the equipment's function is to precisely secure the resolute lid within the body. The lidding process, crucial for ensuring the integrity of the product. It is one of the final stages of the Resolute assembly line. For a visual representation of the assembly line structure, please refer to Appendix 1. This provides a detailed diagram outlining the sequential flow of the encoder build process. The lidding jig is labelled in Figure 3.

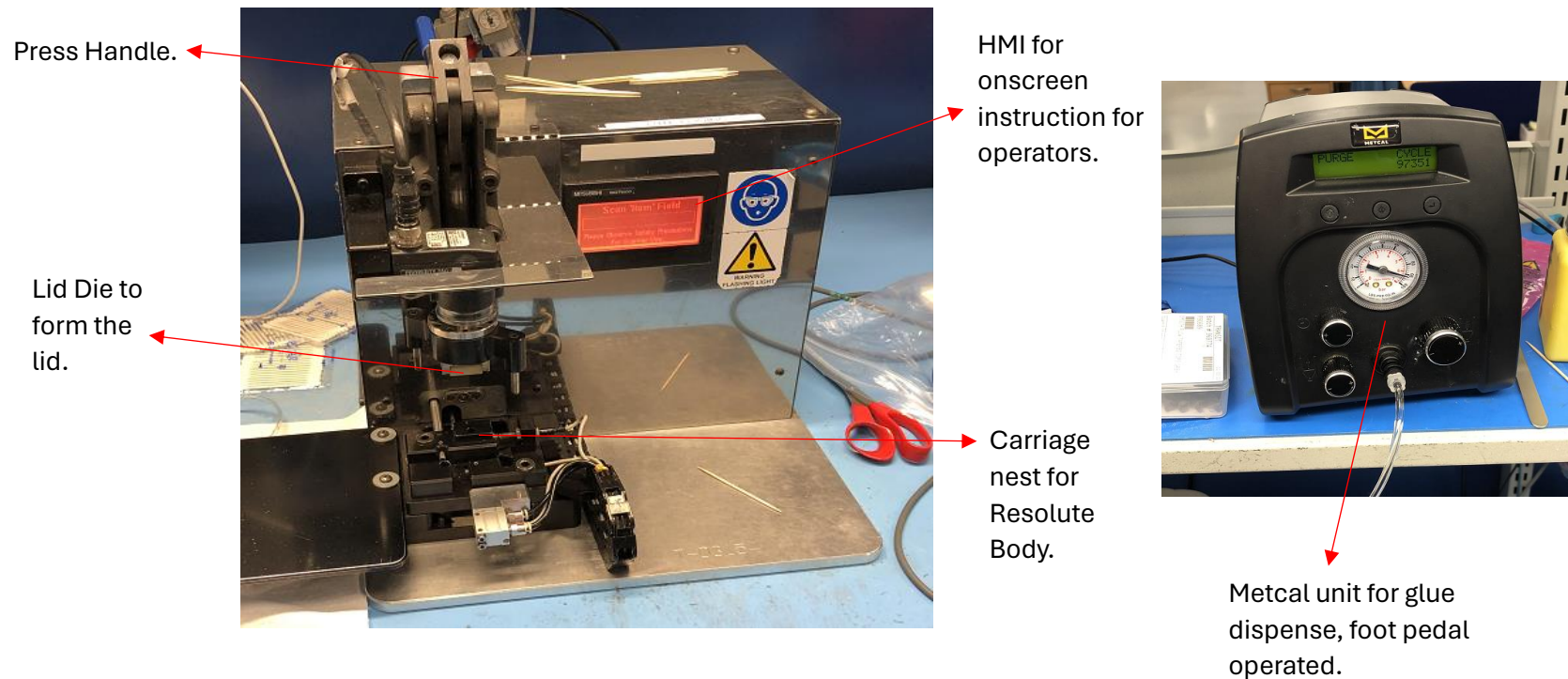
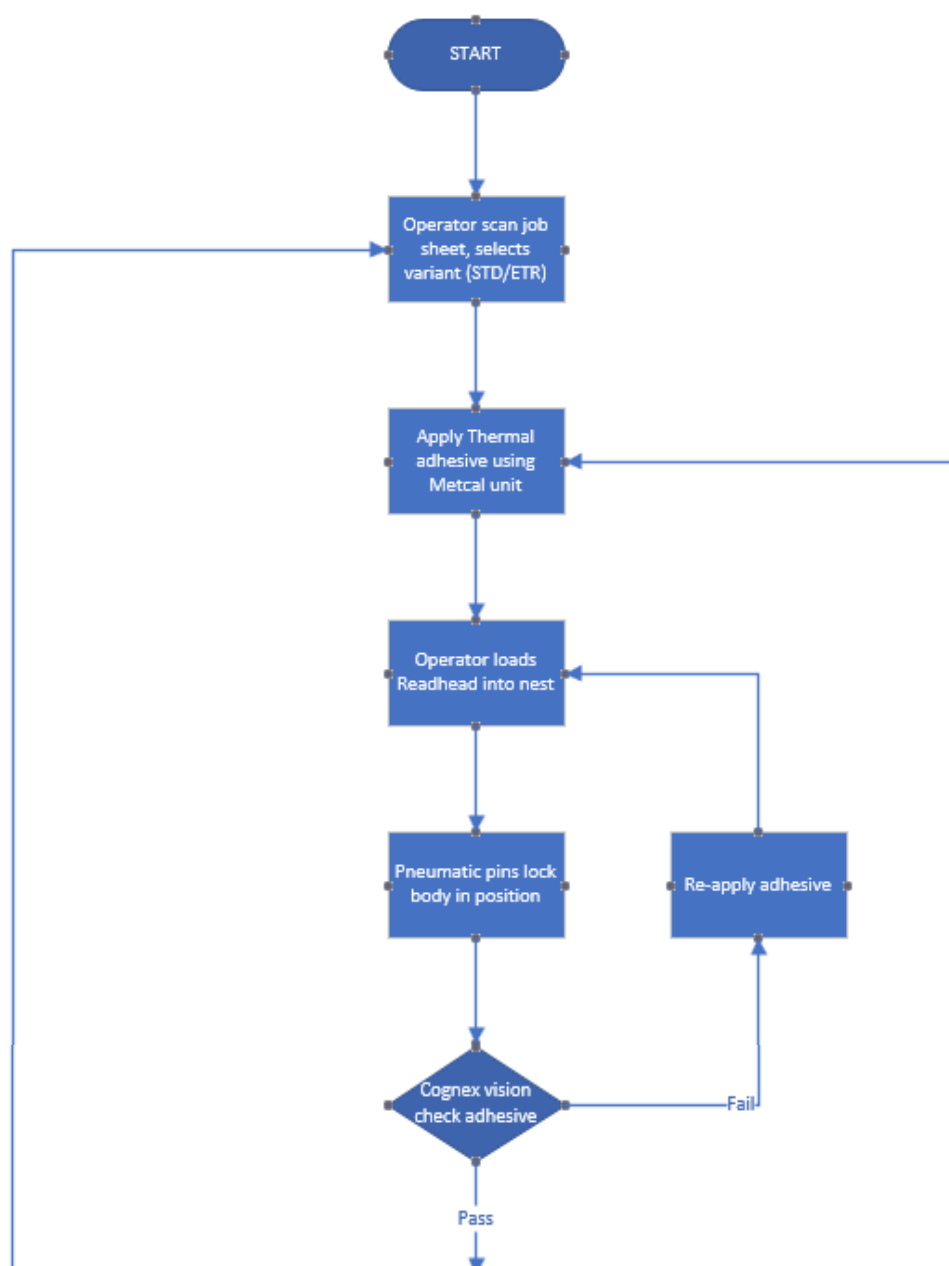
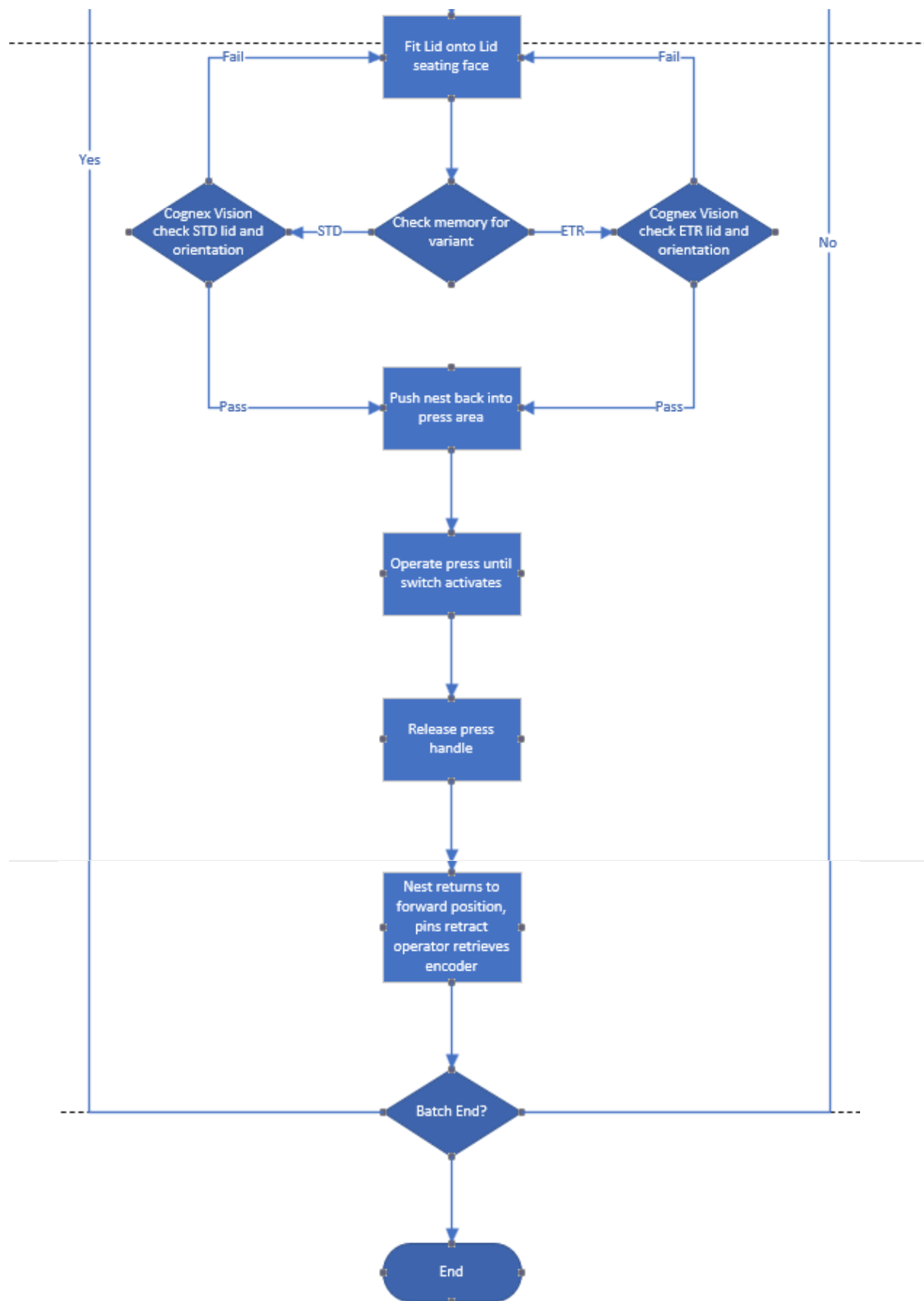


Figure 3 - Thermal Lidding Jig and Metcal unit.

The lidding jig process flow





Current Maintenance Strategy

The existing maintenance strategy involves implementation of the PMI (Preventative Maintenance Instruction), these are carried out on all pieces of assembly equipment throughout the company's vast product range. The PMI for the Thermal Lidding Jig is carried out by Resolute Assembly Technicians on a weekly, quarterly, and yearly basis. These PMIs are documented and stored within Syteline (internal database), which generates and manages the maintenance schedule, sending reminders to the technicians for PMIs that are due.

Thermal Lidding PMI Summary

Referring to Appendix 2, the comprehensive Preventative Maintenance Instruction outlines the following key details:

Health and Safety:

Prioritizing safety, the strategy mandates reading the full procedure before commencing the task, ensure tool availability, adhere to COSHH guidelines, use appropriate PPE, and disconnect power source before any disassembly.

Weekly Maintenance:

Weekly tasks include cleaning the nest area with a lint-free cloth and IPA, ensuring a debris-free operation, and the checking of the regulator for incoming pressure to the jig.

Quarterly Maintenance:

Quarterly checks involve the inspection of the stopping pins and slideway for damage, along with testing the movement mechanisms and application of lubricant if necessary.

Annual Maintenance:

Annual maintenance tasks include checking the tightness of screws and bolts, inspection of sensors and switches and replacing them if necessary.

Strengths

Comprehensive Procedure:

The maintenance instructions cover weekly, quarterly, and annual tasks ensuring adequate upkeep of the equipment.

Health and Safety Detail:

Emphasis on safety protocols, and user reading the procedure laid out. Detail use of appropriate PPE and the disconnection of any power source before commencing the task. Further promoting safe working environment.

Clear Equipment Requirements:

Each of the tasks whether weekly, quarterly, or annually detail the necessary equipment required. Facilitating the preparedness and efficiency during the maintenance activity.

Structured Approach:

The maintenance tasks are logically ordered within the PMI, there are clear steps with images to help aid the technician.

Weaknesses

Lack of Quarterly Equipment:

Quarterly maintenance tasks lack specific equipment requirements, this potentially leads to confusion or oversight in tool preparation. This could ultimately lead to delayed maintenance or even a task being missed out.

Limited Detail in Annual Maintenance:

The annual maintenance section again lacks specific instruction beyond checking screws, sensors, and switches. There are no values to check for nor the correct process for checking switch and sensor operation.

Absence of Troubleshooting:

The maintenance instruction does not detail guidance on the troubleshooting common issues or addressing unexpected challenges when carrying out the tasks. This again may hinder effective and timely execution of the maintenance task.

Training Requirements:

The maintenance instructions do not provide prior training requirements necessary for the carrying out of maintenance tasks. This could impact the quality and consistency of the equipment's maintenance.

Maintenance for the Glue dispense (Metcal Unit):

The way the Resolute lid is peened to the body requires thermal adhesion via the dispense of glue from the Metcal unit. This equipment is shown in Figure 3. Correct maintenance of the glue dispense is essential, as explained by Thomas (2023) glue dispensing machines are complex systems relying heavily on a variety of components. All parts must function in harmony for accurate and reliable glue dispensing.

Lidding Jig Current Operation Breakdown

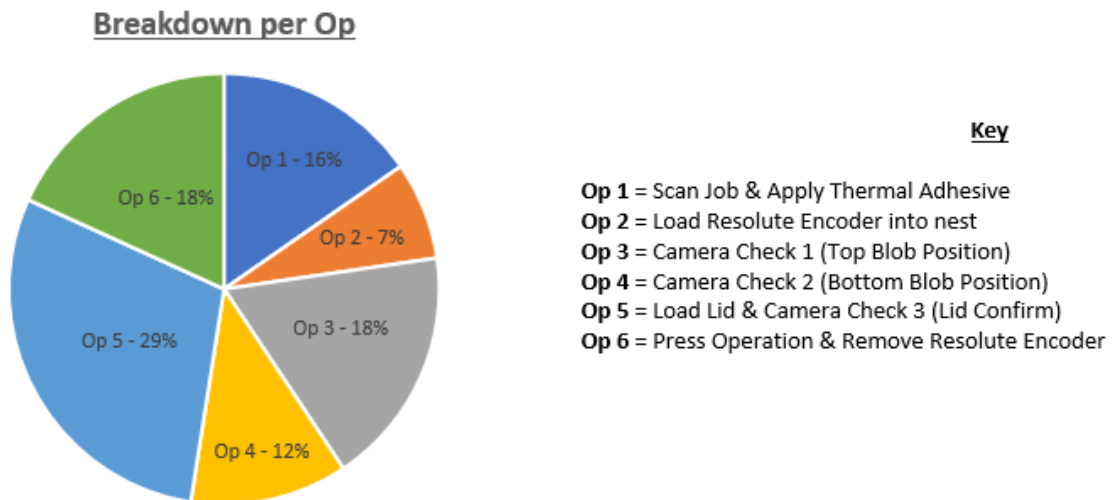


Figure 4 - Pie Chart for Lidding Jig Op Breakdown

During the thermal lidding process, which encompasses the production of 830 resolute encoders over a 2-shift period (day and afternoon shift), breakdown data from the internal Syteline database was examined. The breakdown cost per batch of 30 encoders amounted to £359.63. If this is calculated across the 2 shifts, the breakdown cost attributes to approximately £2,885.50. Op 5, responsible for the thermal glue adhesion and lid been accounted for 29% of the breakdown cost. This operation is frequently impacted by issues such as poor thermal adhesion and inconsistent glue dispensing, primarily attributed to insufficient maintenance of the Metcal glue dispense unit.

Overall Equipment Effectiveness (Current)

OEE is the most valuable key performance indicator (KPI) that a company's production team can leverage for optimizing overall performance (Symestic, 2024).

The OEE was calculated per shift on average, the results of the current process are shown below:

Availability:

Planned production time = 8 hours – 0.25 hours (Morning Break) – 0.5 hours (Afternoon Break) = 7.25 Hours.

Operating time = 7.25 hours – 0.5 hours (Downtime Breakdown) = 6.75 hours.

$$\frac{\text{Operating Time}}{\text{Planned Poduction Time}} = \frac{6.75}{7.25} = \mathbf{0.93 \text{ or } 93\%}$$

Quality:

$$\frac{\text{Good Parts}}{\text{Total Parts}} = \frac{380}{415} = \mathbf{0.819 \text{ or } 81.9\%}$$

Performance:

$$\frac{\frac{\text{Total Pieces}}{\text{Operating Time}}}{\text{Run Rate}} = \frac{\frac{380}{405}}{1.05 \text{ parts per minute}} = \mathbf{0.893 \text{ or } 89.3\%}$$

Overall Equipment Effectiveness:

$$0.93 \times 0.819 \times 0.893 = \mathbf{0.68 \text{ or } 68\%}$$

Availability has a reasonably good score of 93.1% although this could be further improved by reducing the downtime for breakdowns. Maintenance on the Metcal glue dispensing unit will help to improve the score and reduce the cost of Op 5 failure. Quality at 81.9% is a particular area for concern, suggesting that there are issues with product defect and rejection in particular Op 5 Lid peening. Performance at 89.3% is acceptable but there are still areas for improvement such as reducing reject rate. An overall score of 68% requires improvement.

Improving the Maintenance Strategy

Identifying Improvements

Introducing enhancements to the preventative maintenance schedule can significantly mitigate breakdowns related to insufficient glue dispense from the Metcal unit during the lidding operation. One crucial improvement involves the incorporation of a maintenance record sheet. This addition provides a structured method for technicians to document maintenance activities, facilitating better tracking of the maintenance tasks, facilitating better tracking of the tasks performed, identification of recurring issues and how they were corrected. Furthermore, it fosters accountability and promotes a proactive approach to equipment upkeep. As stated by Fatima (2024), accurate record-keeping helps prevent errors in repairs and ensures that technicians are well updated.

Moreover, detailing maintenance procedures for the Metcal glue dispenser, based on instructions from the manufacturer is paramount. This entails guidelines on cleaning, calibration and components inspection will ensure optimal performance and prevent issues such as inconsistent glue dispensing. HSE (2024) state that maintenance should only be carried out by those who are competent to do the work and have been provided with sufficient information. Sufficient information for carrying out maintenance on externally bought equipment should be carried out with reference to the manufacturers manual which details the correct maintenance procedure.

Additionally, outlining procedure for testing sensors and switches, along with criteria for replacement is essential. Regular testing and timely replacement of faulty sensors and switches are crucial for maintaining operational efficiency and preventing any disruption to the operation. Clear instructions on conducting tests, interpreting results, and determining replacement intervals empower technicians to proactively address potential failures, thereby reducing downtime and improving overall equipment reliability. Cyrino (2024) recognises that correct maintenance procedures are extremely important and must provide clear instructions so that the work to be done doesn't deviate.

Alternative Maintenance Approaches

The preventative maintenance instruction for the lidding jig primarily focuses on proactively maintaining the equipment to prevent breakdowns and ensure consistent operational performance. Preventative maintenance involves systematically inspecting, cleaning, lubricating, and adjusting machinery at regular intervals to identify and address potential issues before they escalate to failure. IBM (2024) describe this form of maintenance as the act of performing regularly scheduled maintenance to prevent unexpected failure.

Alternative maintenance methods to preventative include:

Breakdown Maintenance:

In this reactive approach, maintenance activities are only performed when equipment fails or malfunctions. While breakdown maintenance requires minimal upfront investment and resources, it can lead to costly unplanned downtime. Relying solely on breakdown maintenance may result in increased safety hazards. This maintenance work well when all equipment is new and within the manufacturers' recommended equipment lifespan (Tarlengco, 2023).

Centralised Maintenance:

Centralised maintenance involves consolidating maintenance activities under a single department or team within the company.

rganization. The approach allows for coordination, procedures that are standardised and a centralised oversight of maintenance tasks. This approach may often delay response times to maintenance and may prove inefficient because of the centralised structure of decision making. Maintenance is on a master schedule there is little control allowed for maintenance managers (Tag, 2021).

Outsourced Maintenance:

Outsourcing maintenance tasks to external suppliers can offer a more specialised expertise and increase maintenance flexibility. Outsourcing often allows businesses to focus on their core competencies and leverage knowledge and resources from third party suppliers. One of the main issues with this type of maintenance is the loss of control, however, equipment bought by companies often comes with a servicing or maintenance plan depending on the product. This type of maintenance eliminates the need for the company to invest to train in-house staff, avoiding the need to also purchase any specialised tooling and technology for the equipment (Lydon, 2016).

Total Preventative Maintenance Approach:

Total preventative maintenance (TPM) is a strategy that aims to maximise the equipment effectiveness. TPM focuses on proactive maintenance, employee involvement and continuous improvement to optimise the performance of the equipment. TPM establishes autonomous maintenance teams, conducting audits, setting performance metrics, and fostering the culture of ownership among employees/operators that work on the equipment. LeanProduction (2024) explain that getting operators involved in maintaining their own equipment will lay a foundation for improved production (fewer breakdowns, stops, and defects).

Implementation of Improvements

The PMI for the lidding jig has undergone enhancements to improve efficiency and reduce breakdowns in the assembly process. Appendix 3 shows the additions made to the PMI, these include maintenance activities for the Metcal dispenser, added information for sensor and switch checks, and the introduction of a maintenance log.

The addition of maintenance tasks for the Metcal dispenser is crucial as it ensures the correct flow of thermal adhesive paste, reducing breakdowns of the lidding jig and rejected resolute encoders. Proper maintenance of the dispenser, such as maintaining air supply, avoiding moisture exposure, and adhering to cleaning guidelines, preserves its functionality and extends its lifespan.

Additionally, a form of Total Productive Maintenance (TPM) has been introduced by utilising operators to undertake standard Metcal dispenser checks. Their involvement in routine maintenance tasks will help to raise issues with the dispenser that will be promptly identified and addressed, increasing the overall efficiency and reliability of Op 5.

Further detail has been added to help aid checking sensors and switches on the rig to provide technicians with clear guidelines for identifying and addressing potential issues promptly. Quarterly sensor and switch checks help prevent malfunctions and ensure continuous operation of the lidding jig.

The introduction of a maintenance log allows for the recording of maintenance activities, helping better track tasks performed, identifying repeated issues, and schedule preventive measures. This instils accountability and ensures that maintenance tasks are carried out in a timely manner.

Overall, the improvements to the PMI enhance equipment reliability, reduce downtime, and improve product quality. Addressing maintenance needs and fostering a culture of preventive maintenance, the lidding jig can operate more efficiently, increasing productivity and customer satisfaction.

Overall Equipment Effectiveness (Post PMI Improvement)

The OEE was recalculated per shift, the results of the improved PMI are shown below:

Availability:

Planned production time = 8 hours – 0.25 hours (Morning Break) – 0.5 hours (Afternoon Break) = 7.25 Hours.

Operating time = 7.25 hours – 0.25 hours (Downtime Breakdown) = 7 hours.

$$\frac{\text{Operating Time}}{\text{Planned Production Time}} = \frac{7}{7.25} = \mathbf{0.965 \text{ or } 96.5\%}$$

Quality:

$$\frac{\text{Good Parts}}{\text{Total Parts}} = \frac{392}{415} = \mathbf{0.944 \text{ or } 94.4\%}$$

Performance:

$$\frac{\left(\frac{\text{Total Pieces}}{\text{Operating Time}}\right)}{\text{Run Rate}} = \frac{\left(\frac{392}{405}\right)}{1.05 \text{ parts per minute}} = \mathbf{0.921 \text{ or } 92.1\%}$$

Overall Equipment Effectiveness:

$$0.965 \times 0.944 \times 0.921 = \mathbf{0.838 \text{ or } 83.8\%}$$

Having implemented the improved PMI, the downtime was reduced improving the availability score to 0.965. Less parts were rejected due to insufficient glue dispense which increased the quality to 0.944. Having decreased rejects, the performance score also increased to 0.921 with an overall equipment effectiveness of the lidding jig calculated at 0.838. Having improved the maintenance and introduced TPM for Op 5, the process has improved drastically.

Cost and Resource

Having implemented the changes to the PMI, there are additional maintenance tasks that both technicians and operators are required to perform.

Some of the cost considerations include:

Training: Training sessions will need to be provided to both technicians and operators to successfully carry out the maintenance tasks to an acceptable standard. These costs include organising training material, assigning trainers and allowing time away from production.

Equipment/Tools: Procurement of further equipment and tooling must be considered; upfront investment may need to be in place to ensure the correct equipment is available.

Documentation: Documentation is required to be updated such as the PMI itself, as well as setting up the maintenance log.

There are also resource considerations such as:

Allocation of any further Operators/Technicians: to successfully carry out the maintenance tasks, there may need to be extra operators or technicians on hand, this must have minimal impact on production.

Time: Both technicians and operators will be required to have time allocated to perform the extra maintenance without disrupting normal operation.

Supervision: There will need to be supervision to provide oversight to ensuring the maintenance is performed both correctly and consistently.

Change Management

To navigate the changes effectively, emphasis must be placed on effective change management. Effective communication is critical in informing operators and technicians as to the reason why additional maintenance tasks are required to be introduced. Comprehensive training and support must also be provided to ensure the correct maintenance is carried out to the standard required by the process. Encouragement of the proactive maintenance must also be at the forefront of the change, there must be accountability for both the operators and technicians highlighting the vital role played by them in ensuring the efficiency of the equipment.

Conclusion and Recommendations

To conclude, the following report has analysed and assessed the maintenance strategies employed for the Thermal Lidding Jig within Renishaw's Resolute Encoder production line. By delving into the detail surrounding the current maintenance practices, identifying potential improvements, and considering alternative maintenance methods the project allowed for opportunities to further improve both reliability and operational efficiency.

Maintenance is critical in enabling uninterrupted operations within the manufacturing sector. Helping to maximise equipment uptime and ensure the production of quality parts. By introducing enhancements to the previous PMI, such as maintenance activities for the Metcal glue dispenser, detailing switch, and sensor checks, and introducing a maintenance log improved equipment upkeep and operational efficiency. These additions helped to minimise breakdowns that were related to insufficient glue dispense maximising production.

In addition, alternative avenues of maintenance strategies were also researched, including breakdown, centralised, outsourced and Total Productive Maintenance (TPM) highlighting respective positives and negatives for each. Some of the TPM principles have been introduced to the improved PMI to enable optimisation of equipment effectiveness, reduce costs, and enhance productivity.

To successfully implement these changes both, cost and resource needed to be considered. Adequate training, equipment procurement, documentation updates, and effective communication are essential in successful change management. These considerations ensure smooth adoption of the new maintenance practices by both technicians and operators.

In addressing maintenance needs, fostering a culture of preventative maintenance, companies can fully optimise equipment performance. This will allow for increased productivity and ultimately improve customer satisfaction.

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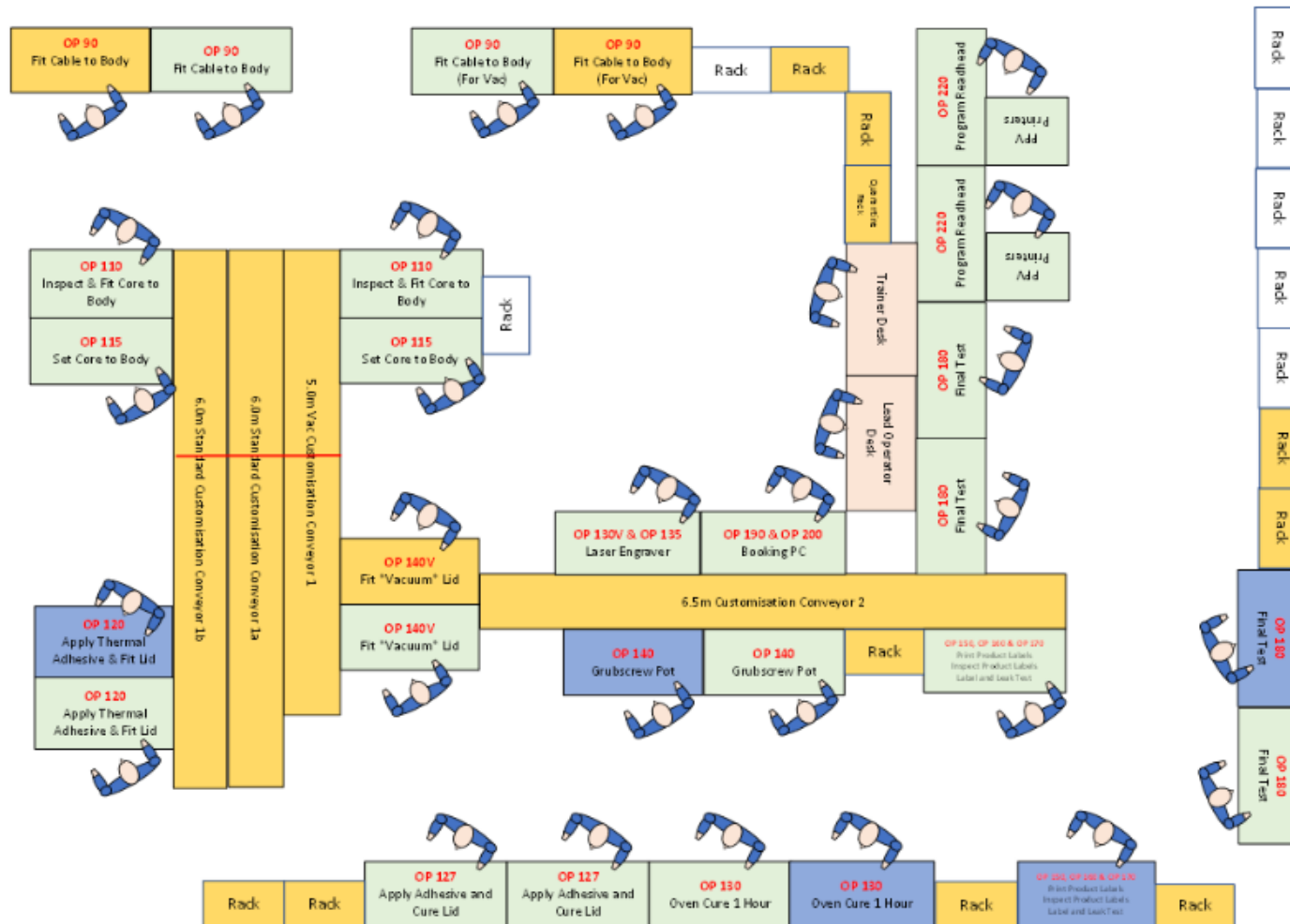
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Appendices

Appendix 1 – Resolute Coring and Customisation Line Structure



Appendix 2 – Current PMI carried out Weekly, Quarterly and Annually

MODIFICATIONS:

Issue	Nature of Change	Date
01	First Issue	18/02/2014
02	Second Issue – Re-written to facilitate the needs of the new Jig T-03154.	02/04/2014
03	Third Issue – Addition of Metcal DX-250 maintenance and maintenance log	02/02/2024

Author:	Job Title:	Signed:	Date:
<i>Nick Bilsby</i>	<i>Production Engineer</i>	<i>N.Bilsby</i>	<i>04/2014</i>

Reviewed & Approved:	Job Title:	Signed:	Date:
<i>Ian Reeves</i>	<i>Snr Prod Eng</i>	<i>I. Reeves</i>	<i>04/2014</i>

Reviewed & Approved:	Job Title:	Signed:	Date:
Divisional Approval (If applicable)			

EQUIPMENT REQUIRED:

DEVICE ID:

T-03154

Is training required?

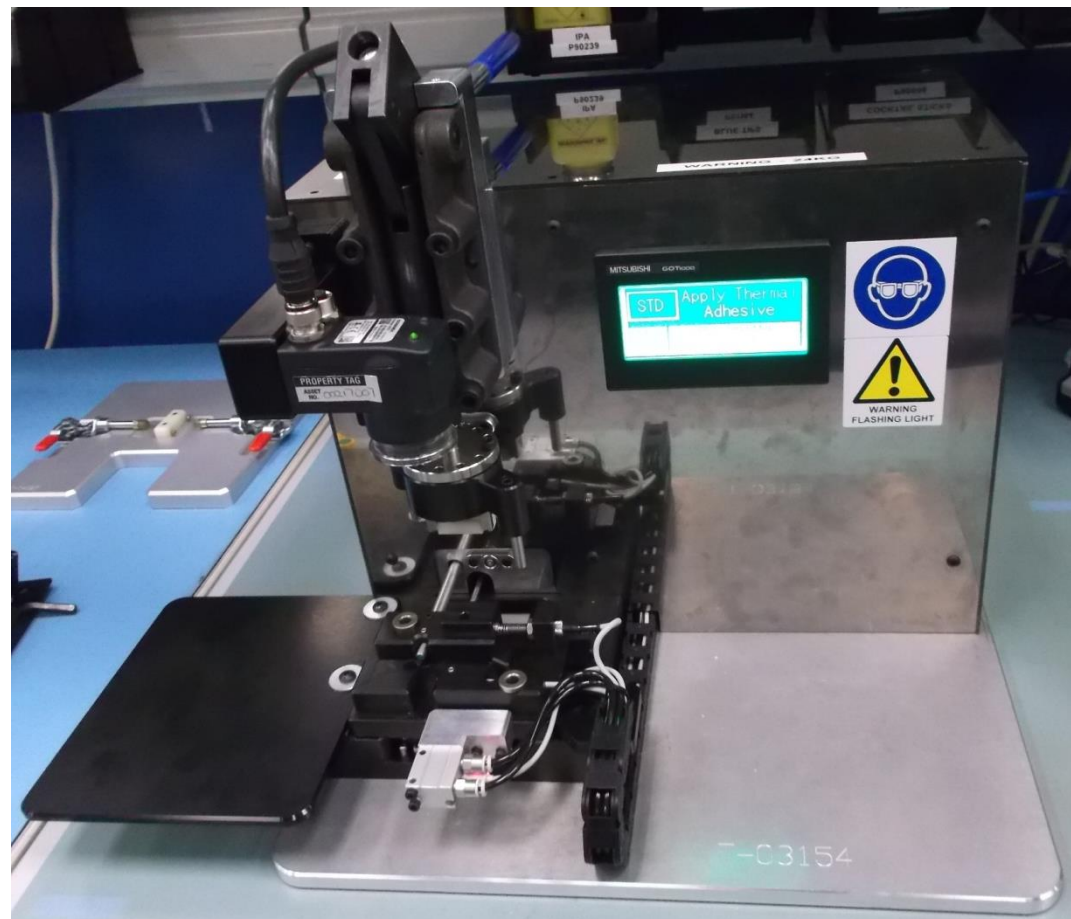
Yes ☐ No ☒

If Yes only people listed below can perform this PMI

I have read and understood this PMI			The Technician is competent in performing this PMI		
Technicians Name	Technicians Signature	Date	Trainer's Name	Trainer's Signature	Date

TOOL No.	NAME	MS No.	LOCATION	QUANTITY
T-03154	Lidding Jig		Resolute Cell	1

Part 1	
Period of PMI	Required
Daily	✗
Weekly	✓
Monthly	✗
Quarterly	✓
Bi-Annually	✗
Annually	✓



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Health & Safety

- *Read full procedure before commencing work*
- *Ensure all tools and consumables are present/available*
- *Observe COSHH*
- *Use PPE where appropriate*
- *Disconnect all air & power prior to any disassembly of jigs*

Weekly Maintenance

1.1 Equipment Required

- Lint Free Cloth (P90192) and IPA (P90239).

1.2 Procedure

1. Clean nest area with lint free cloth and IPA to ensure nest is free from debris (Fig 6a).
2. Check the incoming pressure to the jig is set at 0.3MPa (Fig 6b).

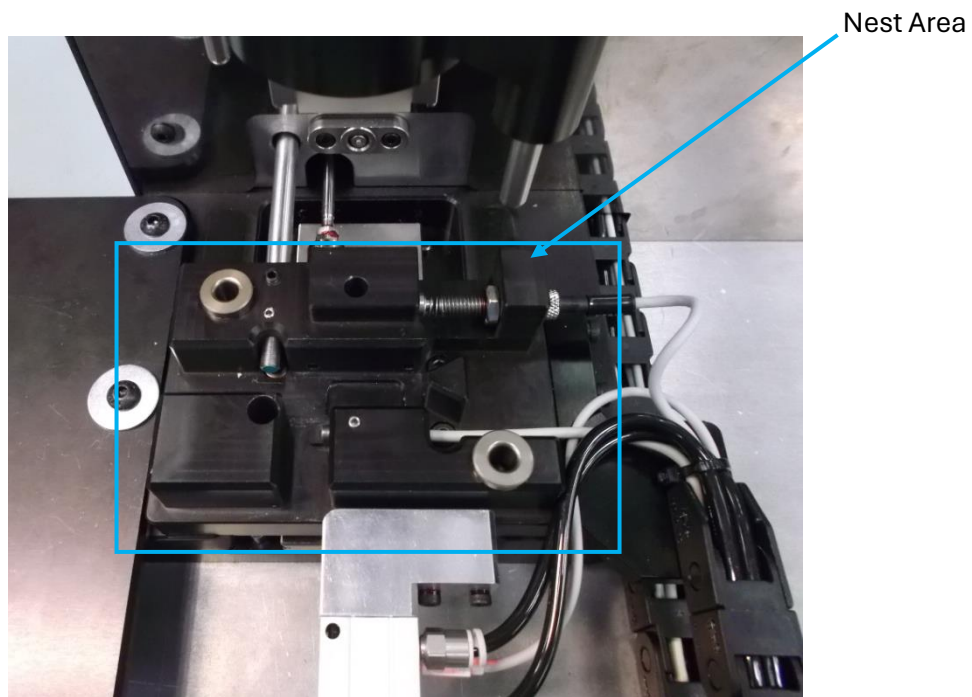


Fig 6a

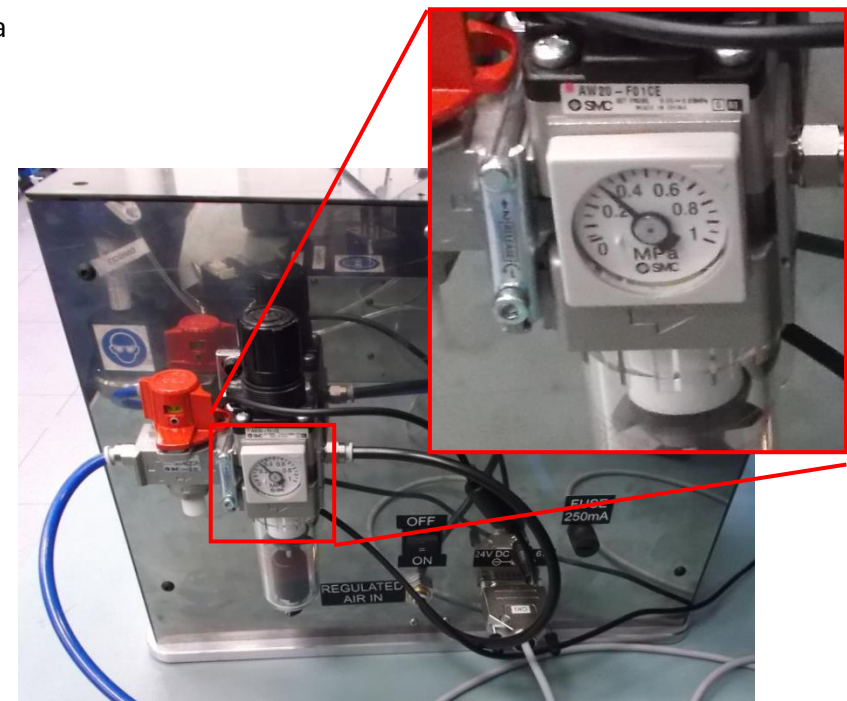


Fig 6b

Quarterly Maintenance

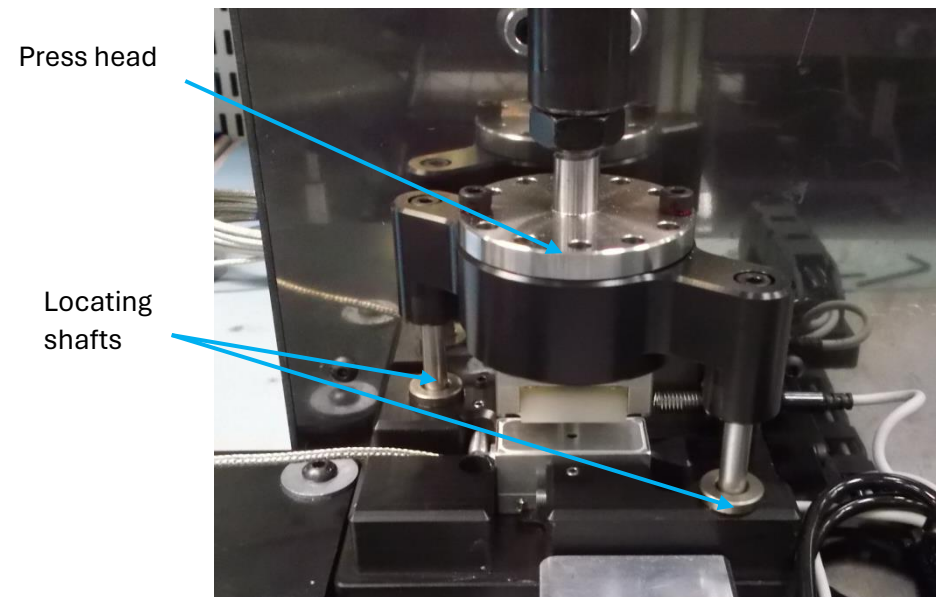
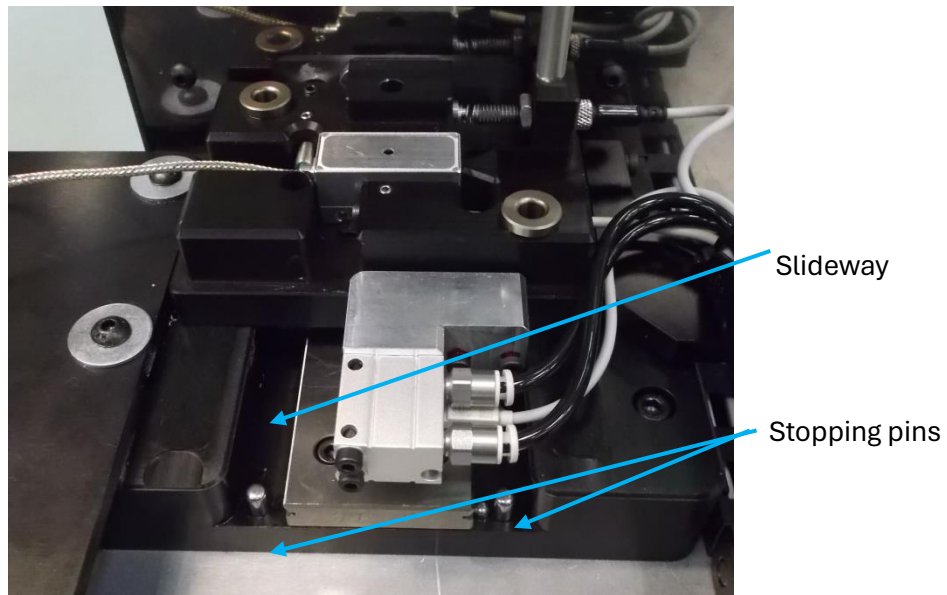
2.1 Equipment Required

- Allen key set

2.2 Procedure

1. Inspect stopping pins and slideways for signs of damage or wear. If damaged, replace parts.
2. Test and inspect all of the movement mechanisms on the fixture. E.g. the motion of the press head & locating shafts.

Note: it may be necessary to apply P-LU15-0005 Superlube if moving parts do not operate smoothly.



Annual Maintenance

3.0 Annual Maintenance

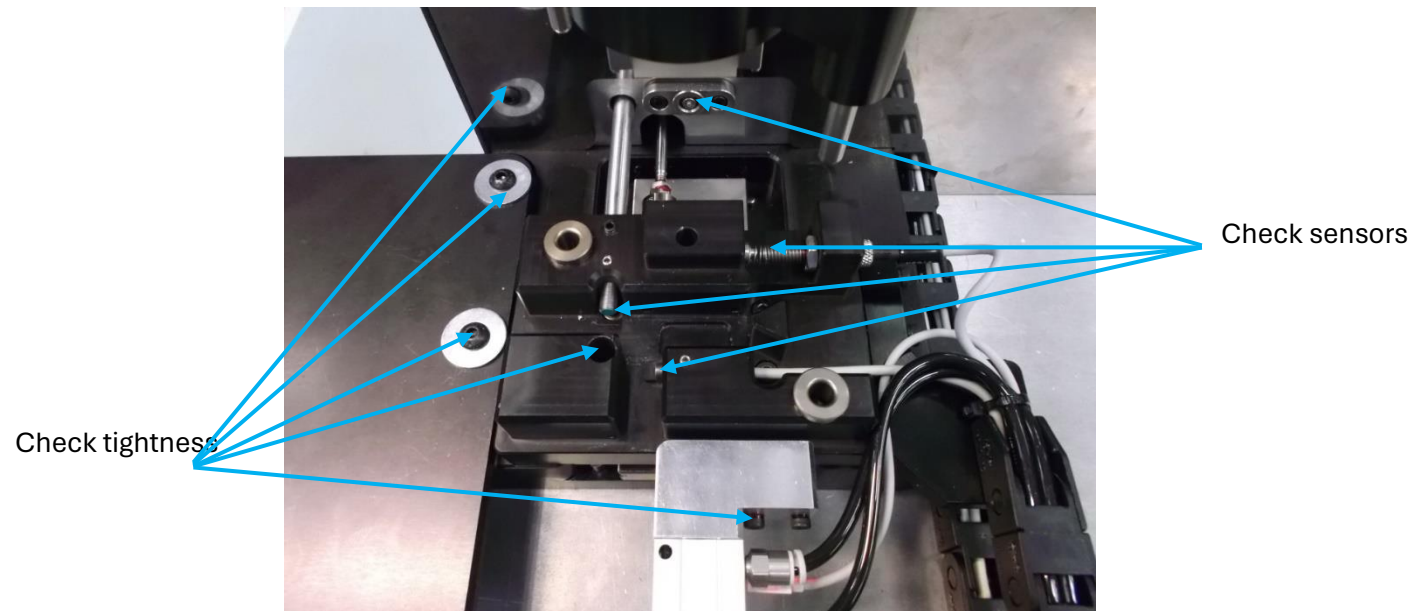
- Annual Maintenance Required.

3.1 Equipment Required

- Allen Key Set

3.2 Procedure

1. Check tightness of all screws and bolts. If loose, hand-tighten with an allen key.
2. Check that all sensors and switches are correctly working and replace if required.



Appendix 3 – Additional Maintenance Tasks Added to Improve the PMI

Metcal Glue Dispenser

The Metcal DX-250 glue dispenser is engineered for minimal maintenance. However, to ensure seamless operation and extend lifespan, it's essential to adhere to the following guidelines incorporated into daily assembly:

Maintain Air Supply:

Ensure that the air supply is consistently clean and dry. Contaminated air can compromise the performance of the dispenser and lead to blockage and malfunction.

Barrel Handling:

Avoid turning barrels upside down or positioning them in a way that allows material to flow back into the air line to internal components. Proper handling of barrels prevents potential damage and maintains the integrity of the dispensers' internal mechanisms.

Moisture and Solvent Exposure:

Prevent exposure to excessive moisture or solvent saturation, this can adversely affect the dispenser's functionality and lead to corrosion or component degradation.

Air supply Pressure:

Do not connect the unit to supplies exceeding 100psi. Operating within the specified limits ensures safe and optimal performance of the dispenser.

Cleaning Guidelines:

Utilize only Amyl Alcohol to clean the exterior surface of the main housing. This specific cleaning agent helps maintain the integrity of the dispensers' materials and prevents potential damage from harsh chemicals.

LCD Maintenance:

Clean the LCD display using a soft lint free cloth to prevent scratches or damage. Regular cleaning of the display ensures clear visibility of crucial information and maintains user-friendly operation.

Nozzle Testing:

Inspect the dispenser's nozzle to verify clean and unobstructed flow of thermal adhesive paste. Any debris or build up within the nozzle can impede the dispensing process, leading to uneven application. Perform nozzle testing prior to each batch running a small amount of adhesive paste through the nozzle and observing consistency and flow pattern.

3.0 **Annual Maintenance**

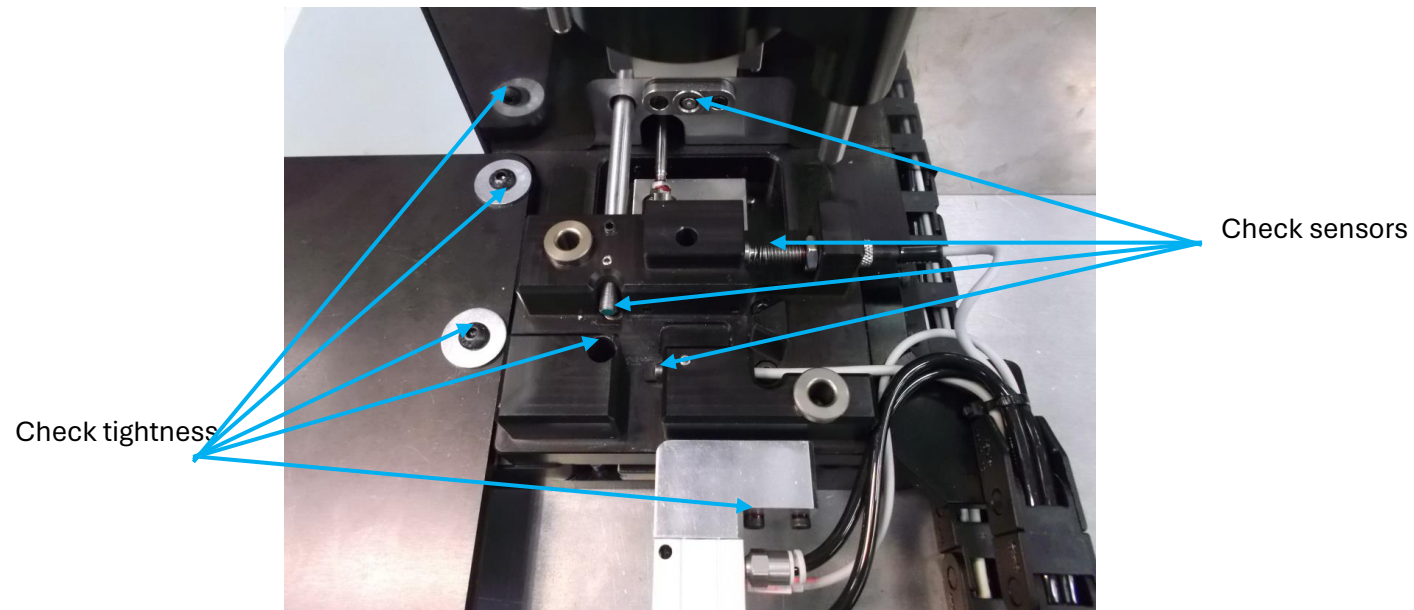
- Annual Maintenance Required.

3.1 **Equipment Required**

- Allen Key Set

3.2 **Procedure**

3. Check tightness of all screws and bolts. If loose, hand-tighten with an allen key.
4. Check that all sensors and switches are correctly working and replace if required.
5. When checking sensors, remove top plate of the thermal lidding rig, trigger the sensors using a metallic object such as a screwdriver and ensure that you get an output light on the PLC output screen. This indicates the correct triggering of the sensors.



5.0 Maintenance Record

Problems, Replacements, Visual Wear, Etc., Changes To Specific Jigs (Include Jig ID's)	Date