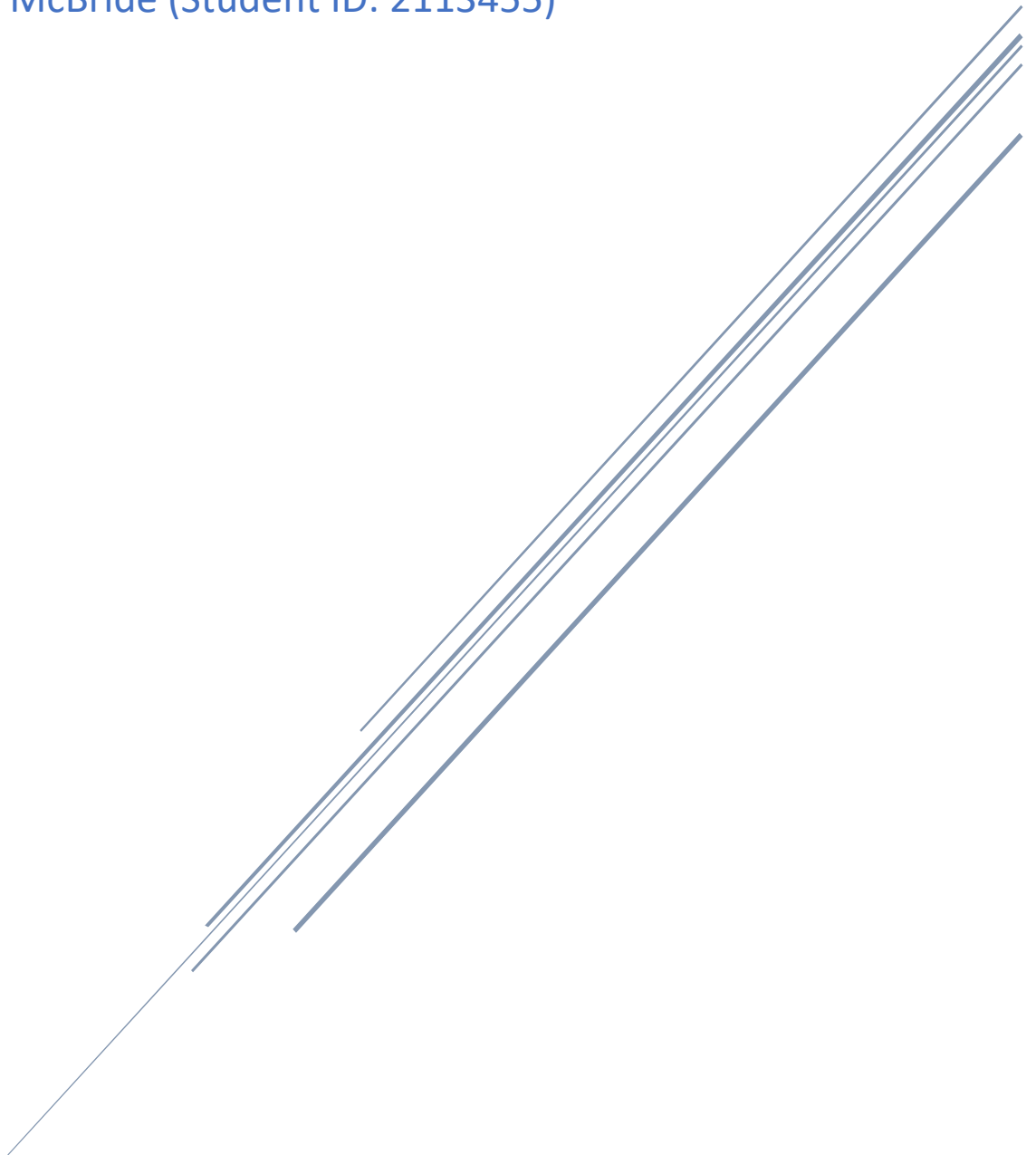


EVALUATING THE EFFECTIVENESS OF CHOSEN MAINTENANCE STRATEGIES FOR DEDICATED EQUIPMENT

Joseph McBride (Student ID: 2113455)



University of Wales Trinity Saint David
BEng Manufacturing Systems Engineering

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Introduction

Renishaw is a global engineering organisation that manufacture a range of products utilised throughout the metrology and healthcare industries. At Renishaw bespoke systems are designed and developed for manufacturing the products offered. As a result, a variety of equipment is implemented throughout the different processes. The equipment used throughout Renishaw's manufacturing solutions is often sourced from suppliers who specialise in the specific field of expertise. All of which have their own specific maintenance requirements to ensure that the equipment operates efficiently and carries out its dedicated function effectively.

This report aims to outline the maintenance strategy currently implemented for the Omnicure S2000 UV Curing System, shown in Figure 1, which is used in several encoder manufacturing systems at Renishaw. Following this, the report will critically evaluate the current approaches and suggest ways in which they can be improved. The cost and resources required to implement the improvements will also be considered within the report. Also, the change management implications of the suggested improvements. Finally, any conclusions and recommendations based on the findings of the report will be communicated.



Figure 1 - Omnicure S2000 UV Curing System

Critical Review of Current Maintenance Practices

Equipment Purpose

As mentioned above, the Omnicure S2000 UV Curing System is utilised throughout various encoder manufacturing processes at Renishaw. The purpose being to cure a variety of adhesives through the means of UV light. Adhesive is used to bond certain components to the encoder body. These components include the index grating and PCB, which are shown in Figure 2 and Figure 3. Depending on the process, the adhesive is either dispensed manually by an operator or through means of automation.

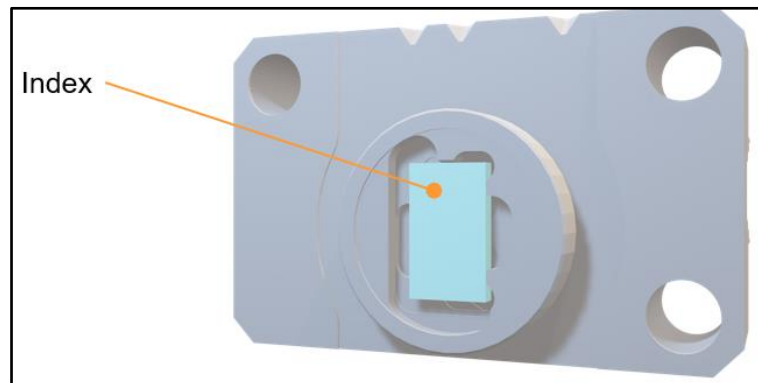


Figure 2 - Index Grating to Encoder Body

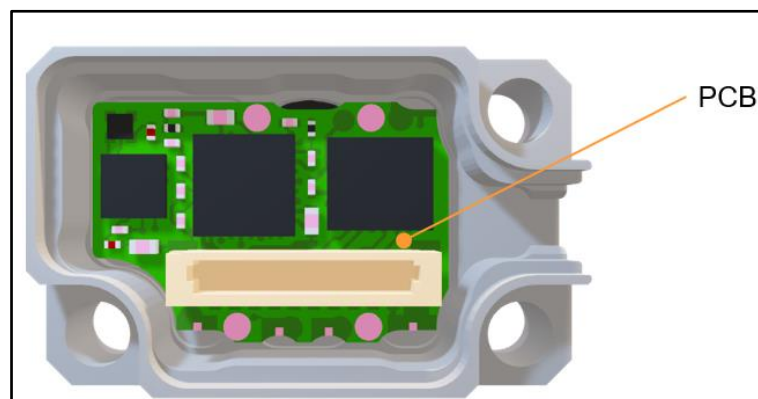


Figure 3 - PCB to Encoder Body

The equipment offers high level process control and consistency which makes it a suitable candidate for curing adhesive within the encoder manufacturing process. A high pressure 200W mercury lamp provides an output of up to 30W/cm². This high-power output enables for the rapid curing of UV adhesives, which is an important factor for efficient manufacturing cycles.

Depending on the amount of adhesive applied to the unit, it may be necessary to adjust the UV intensity accordingly. For example, a larger quantity of adhesive is applied to the encoder body when bonding the PCB compared to when bonding the index. Also, depending on the encoder, a different quantity of adhesive will be applied resulting in either a higher or lower UV output being required. An example of this would be the comparison between the UV intensity variation between the ATOM and RESOLUTE encoders. Due to the body of the RESOLUTE encoder being larger, a greater quantity of adhesive is applied requiring a higher UV intensity to cure.

Current Maintenance Practices

At Renishaw maintenance practices are defined in the Preventative Maintenance Instruction (PMI) for the equipment in question. Currently, for the S2000 UV Curing System the procedure is as follows:

PPE Requirements – UV safety glasses to be worn during procedure to avoid accidental exposure.

UV Intensity Check Procedure from PMI-106 (Renishaw plc, 2024)

Isolate machine power and lock off switch with padlock, shown in Figure 4.



Figure 4 - Power Isolation Procedure

Remove light pipe from UV Curing System, shown in Figure 5.



Figure 5 - UV Light Pipe Removal Procedure

Insert light pipe into UV calibration device, shown in Figure 6, power reading must be $13 \text{ W/cm}^2 \pm 1$. If required, adjust the intensity appropriately to meet the power requirements.

Note – if the intensity has dropped below 5 W/cm^2 carry out push out force checks on four units from the most recent batches. If force is below the defined limit, all batches must be quarantined.



Figure 6 - UV Intensity Reading Procedure

On successful completion of UV level checks, return equipment to operational state and remove padlock in preparation for machine power up.

UV Lamp Replacement Procedure from (Omnicure, 2024)

Remove AC power cord from equipment and take off lamp housing side panel, shown in Figure 7.



Figure 7 - Lamp Housing Removal Procedure

Insert lamp into module container, ensuring it faces towards the front of the unit. The lamp should align with the rim and fit into the mounting groove, shown in Figure 8.

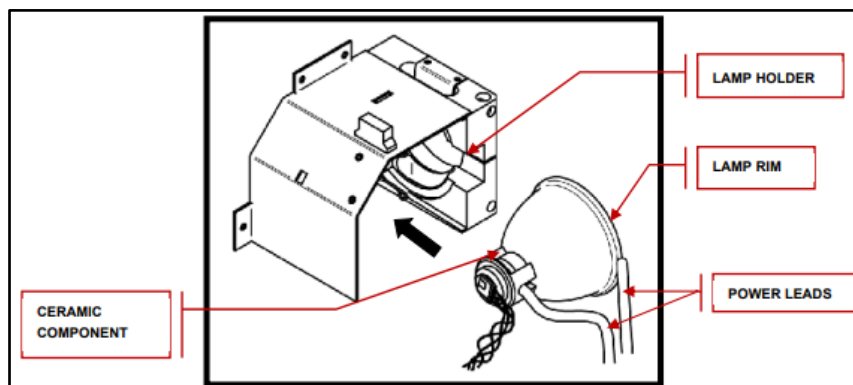


Figure 8 - Lamp Installation Procedure

Ensure the lamp fits into the spring clamp. Following this, locate the power connector and replace the lamp housing side panel, shown in Figure 9.



Figure 9 - Power Connection Procedure

Following the lamp replacement, carry out UV Intensity Check Procedure and adjust accordingly.

Schedules for the current maintenance practices are managed through Syteline. This is an Enterprise Resource Planning (ERP) solution “for production, including machinery, high tech, and industrial manufacturing” (Tipali, 2024) applications. This is common practice within Renishaw, as it allows for each piece of equipment to be assigned a unique identification number along with an appropriate schedule based on the manufacturer's requirements. The specific form used for maintenance schedule management on Syteline is ‘Gauges’, shown in Figure 10.

Figure 10 - Syteline Gauges

As shown in Figure 10, Syteline displays a variety of information including the status of the equipment, equipment category, owner, and location. All of which make for ease of management of the equipment. Also included is the maintenance schedule and history. For the Omnicure S2000 UV Curing System, the interval for carrying out the UV intensity check is weekly. This is illustrated in Figure 11. Maintenance history, shown in Figure 12, details the date the procedure was performed along with the worker and notes from the activity.

	Schedule Types	Last Activity Date	Interv	Interval Period	Estimated Time (hrs)	Next Date
1	Preventative Maintena...	26/03/2024	1	Weeks		02/04/2024

Figure 11 - S2000 Maintenance Schedule

	Date	Last Activity (User)	Activity Status	Activity SubStatus	Activity Note
1	26/03/2024	at151604	Check Out	Preventative ...	
2	26/03/2024	at151604	Process Comp...	Preventative ...	
3	26/03/2024	at151604	Check In	Preventative ...	
4	26/03/2024	at151604	Check Out	Functional Ch...	
5	26/03/2024	at151604	Process Comp...	Functional Ch...	
6	26/03/2024	at151604	Check In	Preventative ...	
7	19/03/2024	at151604	Check Out	Preventative ...	
8	19/03/2024	at151604	Process Comp...	Preventative ...	
9	19/03/2024	at151604	Check In	Preventative ...	
10	12/03/2024	at151604	Check Out	Preventative ...	
11	12/03/2024	at151604	Process Comp...	Preventative ...	
12	12/03/2024	at151604	Check In	Preventative ...	
13	05/03/2024	at151604	Check Out	Preventative ...	
14	05/03/2024	at151604	Process Comp...	Preventative ...	
15	05/03/2024	at151604	Check In	Preventative ...	
16	27/02/2024	at151604	Check Out	Preventative ...	
17	27/02/2024	at151604	Process Comp...	Preventative ...	Intensity increased from 68% to 83%
18	27/02/2024	at151604	Check In	Preventative ...	
19	21/02/2024	It151875	Check Out	Preventative ...	

Figure 12 - S2000 Maintenance History

Current Approach Review & Justification

Now that the current approaches have been defined, pros and cons can be identified. One of the advantages of the current approach is the simplicity. For both procedures, the instructions can be understood with ease by a competent individual without needing any specific training to carry out the activity. Another advantage of the current approach is the schedule being managed through an ERP system, which allows for ease of management. Also, the availability of documentation to carry out the maintenance procedure is another advantage.

There are also poor aspects of the current approach. These include the health and safety concerns associated with the handling of the mercury lamp. If the lamp were to break and a person was exposed to the mercury element it could lead to serious health problems. “Although there is not enough mercury in one bulb to cause significant harm” (Missouri Poison Center, 2023), exposure over a long period through inhalation could result in health issues. Another disadvantage of the current maintenance approach is the requirement to carry out weekly UV intensity checks. This negatively impacts machine downtime on a weekly basis but is also a necessity to ensure reliability with this type of equipment. The current maintenance approach does not specify to clean the UV lamp, which is another downside. Cleaning the UV lamp and light pipe regularly would aid with achieving a consistent output from the equipment in question.

Several factors contribute to the justification of the current maintenance approach. One of these factors being recommendations from the equipment manufacturer. Many aspects of the maintenance procedures are taken directly from the Omnicure S2000 User Guide. Another contributing factor that justifies the current approach to maintenance is recognised procedures for successfully maintaining UV lamps. This includes measuring the UV lamp intensity regularly with a radiometer and logging measurements to identify degradation. Completing these steps will assist with identifying an issue before it becomes a major failure.

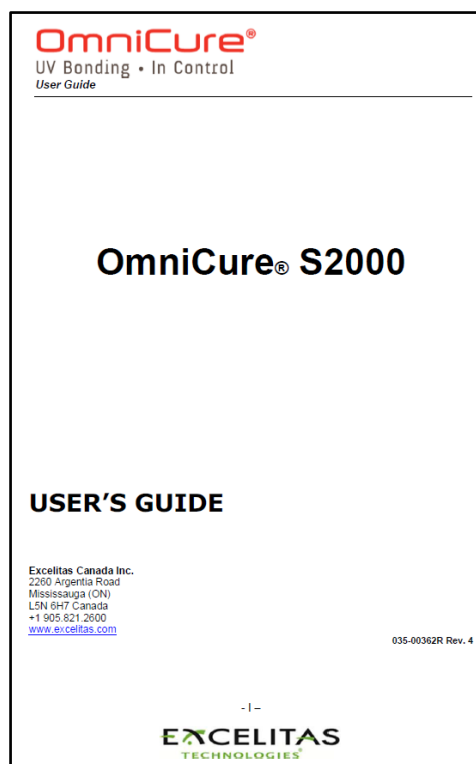


Figure 13 - Omnicure S2000 User Guide

Evaluation of Current Approach & Improvements

After reviewing the current approach to maintenance of the Omnicure S2000 UV Curing System, there are various ways in which the procedures could be improved to ensure the equipment carries out its function efficiently. The first way in which the weekly UV intensity check could be improved is by inserting a step to clean the lamp and light pipe if the intensity is below the required output. One of the reasons for doing so is that contamination, such as dust, to the lamp or light pipe would result in a reduced intensity. Using an isopropanol solution applied to a lint free cloth would be suitable for removing any contamination from the surface. Wearing gloves during this procedure would also prevent from causing any further contamination, such as fingerprints, to the surfaces. Another incentive for implementing this improvement into the current maintenance approach is the aim of reducing disruptions to production, as it is likely to cause downtime at some point. Even though this would increase the time to carry out the maintenance activity, the benefit of eliminating an unexpected stoppage outweighs this.

Another way in which the weekly UV intensity procedure could be improved is by utilising a more precise schedule for carrying out the activity. The benefit of doing so would be reduced production downtime. This specific improvement would not be difficult to implement, due to the schedule currently being managed through an ERP system. An amendment to the 'Gauges' form on Syteline could stipulate for the check to be carried out on a shift change over, when the system is less likely to be running production. The adoption of a more precise maintenance approach is common practice in the manufacturing industry and requires a "well-regimented preventive or predictive maintenance plan" (UpKeep, 2024).

The procedure for the UV intensity check could also be improved by specifying additional actions to take if the reading is not within the required limits. These actions would include changing components that could be the root cause of the poor readings, such as the light pipes. Replacement components are stocked in case of failure, which would allow for easy implementation in the future. The time it takes to carry out this replacement is low, and the inclusion of this step within the maintenance procedure is likely to eliminate the need to investigate the root cause. Including this type of information within the preventative maintenance documentation may be out of the scope, but in the event that component failure is identified, it would be useful to have these types of instructions on hand to reduce the impact on production.

There are also ways in which the current approach to the UV lamp replacement could be improved. For example, ensuring that the procedure is carried out by personnel who have received hazardous substance training. The justification for doing so is that if the UV lamp were to break, the individual would be able to respond accordingly and ensure that exposure to mercury is limited. This improvement could be implemented with ease by the activity being carried out by the Works Engineering team, rather than Production Engineering personnel. The reason being that all Works Engineering staff have received training for responding to chemical exposure and spills, which would allow them to respond safely to a UV lamp breakage.

Cost & Resource Considerations for Proposed Change Implementation

It is important to consider the cost and resource implications of the proposed changes in the previous sections of the report. Table 1 displays a cost breakdown, before and after the change implementation, for the components utilised within the procedures outlined.

Cost Breakdown (Before Changes)		Cost Breakdown (After Changes)	
Component	Cost	Component	Cost
UV Lamp	£2,200	UV Lamp	£2,200
UV Radiometer	£1,000	UV Radiometer	£1,000
Total Cost	£3,200	Lint Free Cloth	£0.02
		Isopropanol (1L)	£5
		Total Cost	£3,205

Table 1 - Cost Breakdown (Before & After Changes)

From this basic overview it can be determined that the cost to implement the proposed changes is minimal in terms of component and material costs. However, this does not accurately reflect the overall cost of the proposed changes since they are likely to affect the total time it takes to carry out the procedure. A more accurate breakdown could be achieved by calculating the current time taken and the time it would take after the proposed changes have been implemented.

Currently, the weekly UV intensity check takes approximately 20 minutes to complete. If the proposed changes were to increase this time by approximately 10 minutes, the procedure in total would take 30 minutes to complete. Hourly indirect costs for a production engineer are around £60. This means that following the change it would cost the company £30 to carry out the maintenance procedure. This can be considered a small price to pay compared to the equipment failing and production being down.

In terms of resource required to implement the proposed changes, the first aspect to consider is which personnel will be carrying out the maintenance procedure. Since one of the proposed changes suggested another department carry out the UV lamp replacement procedure, this would influence their resource allocation. Depending on their current allocation, it may not be feasible for them to take on this additional responsibility. Another resource consideration for implementing the change mentioned above is how it will be managed between departments. This is due to using different systems being used to manage activities and schedules. To effectively implement the change regular communication would be necessary and potential adoption of a common management system.

Conclusions & Recommendations

Based on the findings of this report, there are various improvements that have been identified which can be implemented in the short term. These include making minor modifications to the current procedures with the aim of ensuring that the equipment operates reliably and efficiently. The more complex improvements suggested could also be implemented however, the timeline for this would be more long term. For example, amending the way the equipment's maintenance schedule is managed. Such a change to the ERP system could not be introduced overnight.

Even though multiple improvements have been suggested, the current practices in place are sufficient. This is because failures of the equipment are not common, however, implementing further improvements would only reduce the likelihood of equipment malfunctions in the future. In the long term, it may be more suitable to look for alternative UV curing systems. For example, a unit that utilises LED UV curing may be more practical from a maintainability point of view. The difficulty with this sort of system is the lower UV power output, but as technology advances a more suitable alternative may become available.

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