Lean Production Management System

A Major Qualifying Project Report
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Abstract

This project discusses the need for and implementation of lean practices at BodyCote's heat treatment facility in Wuxi, China. After visits to the plant and discussion with several employees, the scope of the project was defined as to create an attractive and useful kanban and to use the steps of 5S to re-organize the jigs on the floor. Several options for both aspects of the project were presented, and the final recommendations reflect those that benefit the company the most.

Executive Summary

Given the goals and tasks required by BodyCote Wuxi, we have divided our suggestions accordingly. To provide the best suggestions and ideas, the team had first worked on 5S, followed by Kanban, and finally the ultimate improvements with the changes needed.

The 5S problems presented to the team by BodyCote Wuxi focus on inventory storage and jigs (fixtures) storage. The 5S principles relevant to this area are sort, straighten, standardize, and sustain. In order to provide useful suggestions, the team decided to focus on BodyCote Wuxi's main problem area: the jigs. After visiting the facility a few times and taking measurements, the problems identified include inefficient storage, cluttered storage, and the need for sustainable changes.

BodyCote Wuxi has encouraged us to help them with the signage in order to sustain the changes recommended. The team, having considered this, decided that creating signage along with training for section leaders and employee would introduce sustainable changes within the plant. This goes hand in hand with the intended plant-wide standard of improved knowledge of systems and protocols, who the cell leaders are, and how to interact with different pieces of machinery.

Currently, the jig storage is inefficient as it is necessary to move a whole row of jigs in order to get to one tucked behind near the wall. Refer to Figure 5 to see the current jigs layout. In order to make access more efficient while saving space, measurements have been taken of the specific jigs impacted, and SolidWorks models of vertical shelving were made to fit the available space and jigs. As you can see in Figure 5, they have no vertical shelving presently, and this would reduce the time needed to retrieve jigs, which will increase productivity.

The Kanban problems presented to the team include a Kanban that is very complicated and needs to be reconstructed into a friendlier and more attractive Kanban. When the team was tasked with this issue, BodyCote Wuxi had just recently made a Kanban solution and had been updating and renovating it. Refer to Figure 8 in Appendix 4 to see the current Kanban. As you can see, their current Kanban is a big whiteboard. The production managers have informed us that they want our solution to be more attractive and include updated information on it so anyone reading it would have an understanding of what was going on in the plant. The team also received a worker's input on the current Kanban. The worker had stated the current iteration was okay but a little dirty.

With all this in mind, the team has set out to improve the Kanban by separating it into different sections, each organized by its own category. Refer to Figure 9 in Appendix 4 to see our suggested Kanban. From the Kanban created by the team, one can tell that it would be more attractive and easier to gather information. With color coding binary information, information is gathered from a distance. With different sheets or whiteboards, managers can see specifically what they need to see more quickly instead of looking at a big whiteboard every time.

Chapter 1 Introduction

In the competitive business scene today, companies are governed by competition to make continuous improvement to all aspects of their production. In order to keep up with the competitive pressure, lean manufacturing is introduced as a way to create an advantage. Lean manufacturing has been proven to improve the whole production facility by improving productivity, reducing waste, managing space, improving delivery, and more.

BodyCote Wuxi is not exempt from this trend, and has tasked this team with coming up with ideas and suggestions that will improve their lean manufacturing. BodyCote Wuxi had a goal to reorganize and optimize their production management based on lean production management. BodyCote Wuxi, then, has a few objectives they wanted to achieve and they are to implement a Kanban system in all four of their production cells, implement 5S across the workshop, and reorganize the floor layout of their plant. With all three of these, BodyCote Wuxi then wants to improve the production KPI.

Keeping their needs in mind, our goal during this project was to give BodyCote the best ideas and suggestions possible while keeping in mind how big or small scale the changes to their facility would be. There is no way that the team can suggest huge changes to BodyCote Wuxi so small changes would need to be implemented slowly in order to keep harmony within the company.

In order to achieve all our goals within the timeframe we were given, we have spent seven weeks at WPI preparing for the project by researching necessary background knowledge, and the following seven weeks in China working together with our SHU partners to discuss and brainstorm different ideas for BodyCote Wuxi. A more detailed schedule can be found in

Chapter 12, and the definitions of the metallurgical processes discussed can be found in Appendix 1.

Chapter 2 Background

2.1 About BodyCote

BodyCote is currently an international company focused on thermal processing. Founded in 1923 by Arthur BodyCote in Macclesfield, United Kingdom as a textile business, BodyCote branched out to other industries through mergers and acquisitions around the globe. By the 1970's, BodyCote's main focus had moved to developing and manufacturing bulletproof and flame retardant clothing, and continued to acquire other businesses in different manufacturing fields. In 1979, the first metallurgical and heat treatment plant, Brandburgh, was bought. Over the next 20 years, BodyCote continued to buy facilities and companies with specialties in different types of metallurgical processes. These included vacuum hardening, through Nemo Heat Treatments in 1983 and hot isostatic processing in 1991 thereafter forming BodyCote HIP.

In 2005, BodyCote began construction of a plant in Wuxi, China. In June 2006, the 10,000m^2 facility was the first of BodyCote's two facilities in China. The second is located in Ningbo, and was acquired in 2007. The Wuxi facility is currently the largest commercial heat treatment facility in China, competing only with the smaller job shop facilities located around the country. BodyCote is the only company registered in China to heat treat for aerospace applications. The following processes are offered at the facility in Wuxi for most industrial purposes. Hardening and tempering, deep freezing, carburizing, carbonitriding (adding carbon gas), gas nitriding, gas nitrocarburizing (adding nitrogen gas), vacuum hardening, vacuum annealing, vacuum tempering (in order to reduce oxidation), bright hardening/annealing, and vacuum brazing. These processes are completed in one of four furnaces in the plant. These furnaces are Vacuum Furnace (Figure 1), Mesh Belt Furnace (Figure 2), Universal Batch Quench

Station (UBQ station, Figure 3), and the Nitriding Furnace (Figure 4). Each furnace completes different processes. Neutral hardening, carburizing, carbonitriding, normalizing, and annealing all are completed at the UBQ station. Neutral hardening, austempering, carburizing, carbonnitriding, normalizing, annealing, stress relieving, tempering, solution treating, and aging are completed on the Mesh Belt Furnace. Brazing, and sintering are completed on the Vacuum Furnace, and turnkey nitriding and nitrocarburizing are completed on the Nitriding Furnace.

Figure 2 Universal Batch Quench (UBQ) Furnace

Figure 1 Vacuum Furnace

Figure 4 Mesh Belt Furnace

Figure 3 Vacuum Nitriding Furnace

2.2 Lean Manufacturing Principles

Lean production is the idea of eliminating as much waste as possible throughout a manufacturing system. This can be reflected through changes in the supply chain, manufacturing process or even distribution to the customer. As stated in *Operations and Supply Chain Management* by Jacobs and Chase, "Lean production is an integrated set of activities designed to achieve production using minimal inventories of raw materials, work-in-process, and finished goods." This system builds off a just-in-time (JIT) theory of manufacturing. JIT is a system in which supplies get to the station at which they are needed in enough time that they are needed, but not in so much time that they sit unused for a significant length of time.

2.2.1 Kanban

Kanban is a lean principle introduced in Japan in the 1950s. Toyota, the manufacturing company, was interested in making their processes more 'lean' and so started investigating ways other business maintained stock. After much research, they instituted the kanban system. This is a system of indicators or signs that show when a certain item has reached a pre-determined inventory point, and so should then be restocked. For this project, BodyCote has indicated that a kanban system would be used to indicate when a process was ready to be restarted or a treatment process reached a certain stage.

2.2.2 Key Performance Indicator (KPI)

Key performance indicators are a standard unit of measure used differently in different industries. They can be used as markers of throughput, inventory, or profit margins as decided by the company that uses them. These measures can be used to monitor quality through

checking scrap or rework numbers, to check or maintain on time shipping capabilities through monitoring cycle times to eliminate bottlenecks, and even to compare costs of manufacturing by monitoring raw material prices.

2.2.3 First In First Out (FIFO)

This is a process by which orders are processed on a First Come, First Serve basis. This is used mainly in batch manufacturing or job shop manufacturing. It keeps orders flowing through the factory in the order in which they were received. This is helpful and very efficient if all orders take a similar amount of time. However, if processes take an irregular amount of time or there are unexpected malfunctions in the system, then bottlenecks could become a problem.

2.2.4 5S

The 5S's are sort, stabilize, sweep, standardize, and sustain. They are used as a starting point of identifying areas that need improvement within a system. Each of these "S's" is an indicator of steps to take to make a work area or process more efficient. Sort indicates that everything in the area should be accounted for and decided as necessary to be thrown out or moved to a different area. Stabilize means that each item in the area should be given a clearly marked area such that after use, the item has a place to return to. Sweep is exactly as it sounds; clean the space thoroughly and regularly. Standardize suggests that throughout the area or plant, regulations, indicators and systems are all similar or follow similar processes. Sustaining indicates that the previous processes are maintained and improved upon continually.

Chapter 3 Objective

Our given objective was to implement a Kanban system and set up a reasonable Key Performance Indicator (KPI) in BodyCote's plant in Wuxi. The data acquired during PQP indicated that these systems currently existed in the plant, and were related to quality control or inventory management. However, no clear problem statement was received from BodyCote in relation to the work to be addressed in China. After two visits to the plant in Wuxi, and discussion with Jimmy Qi, the production manager, and Victor Zeng, the general manager, we had a much better understanding of the problem at hand. The BodyCote facility needed our group to increase throughput in the plant, increase the up- time of the machines, organize the inventory on the shop floor, and create a continuous improvement process using 5S principles.

Chapter 4 Methodology

In this section, we discuss the methods used to address the problems presented by BodyCote. Details surrounding the gathering of the background information and the methods of the project preparation before the actual visit to the project site are included. Additionally, flowcharts showing the timeline of milestones completed are shown in Figures 6 and 7.

The project objective before visiting the project site was defined as: reorganize and optimize BodyCote's production management system based on lean production management methods. To achieve a good understanding of the problems stated, the team learned about various lean manufacturing principles including the Toyota Production's pull system, FIFO, CIP, 5S, TPM, and more. BodyCote is a heat treatment company so in addition to lean manufacturing principles, the team also studied various heat treatment principles such as carburizing, nitrocarburizing, carbonitriding, nitriding, and vacuum heat treatment.

With this background information, the team then set up weekly presentations to review the new findings about the different skills needed. The presentations represented collaboration between the Shanghai University students and the Worcester Polytechnic students. Each group presented both findings and information to each other via Skype; ultimately working together to have a common PowerPoint to present to the project advisors. Along with emails between the two university's students, there was also two way communication between BodyCote's managers and the students. The managers assisted with any questions that were raised during the project preparation period by giving valuable information regarding current facility setup and systems in use.

During the time in Shanghai, multiple visits to the BodyCote facility in Wuxi were necessary in order to gather complete data and understand the project goals, as well as provide solutions to the company as they come up, and get feedback as needed.

During the first three site visits, new problems that the sponsor wanted to be addressed would be discussed, as well as clarification of the project goals. BodyCote requested that certain steps relating to different lean principles were taken to solve them. First, there should be a focus on 5S for organizational problems, followed by changes to the Kanban system currently in use. With the 5S and Kanban solutions, BodyCote then requested that several aspects of the plant's KPI be improved with the implementation of the 5S and Kanban solutions.

To tackle the 5S problems, the group had to first understand what the actual problems in the plant were. The main problem that the group and the company wanted to solve using 5S

Figure 5 Current Jig Layout

methodology was jig reorganization. BodyCote uses metal jigs of different shapes and sizes to organize and hold products as they are heat treated. Before and after they are needed for the

furnace, however, the jigs are kept in piles in different places around the plant (Figure 5). These tools need to be organized in a standard way throughout the plant in such a way that they are easily accessible, and with a system that can adapt to the changing needs of the company. This need lends itself to the lean methodology of 5S. The scope of this need is to set up standards for all five parts of 5S. Starting with jigs first, the company would have an easier time implementing 5S in other parts of their operation, as needed. With those standards in place, efficiency would increase. To further define the steps necessary to implement a 5S standard for jigs reorganization, the group broke down the five "S's" of 5S into their respective parts: Sort, Straighten, Sweep, Standardize, and Sustain. For each of these categories, multiple action points were discussed and proposed to the company as options to implement in the plant. Another part of 5S is worker involvement. This is important because the workers would be the ones using the system. The standards proposed would need to be sustainable from the standpoint of the workers. With this set plan and a list of ideas and options, BodyCote then decided on which one was the best solution for their plant. Further discussion, details and focus was put into that solution.

For the Kanban problems, the group had realized that the Kanban BodyCote had wanted was different than a traditional Kanban. A traditional kanban usually involves a bin or marker of some sort that informs workers that more inventory is needed at a certain location in a plant or step in a manufacturing process. The Kanban BodyCote asked for was a whiteboard with an Excel-sheet like grid with rows and columns labeled for relevant data, and places for workers and supervisors to put in different information including inventory and machine down time. Realizing this difference in projected need, adjustments were made to our understanding of

Kanban and more brainstorming was done. After this time of discussion, we had a set plan and a few pictures and charts depicting the changes to the Kanban board for BodyCote to choose from.

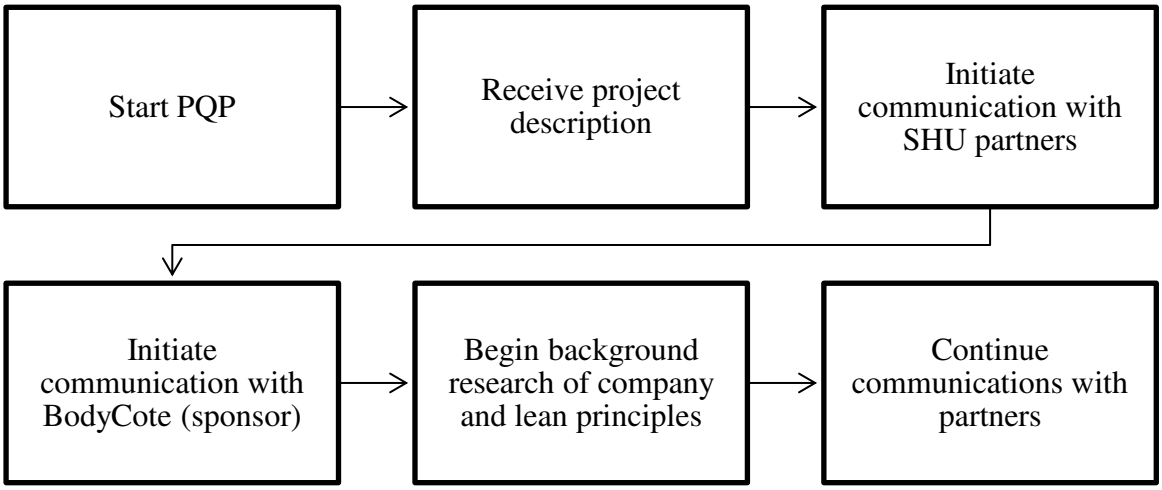

Figure 7 PQP Timeline

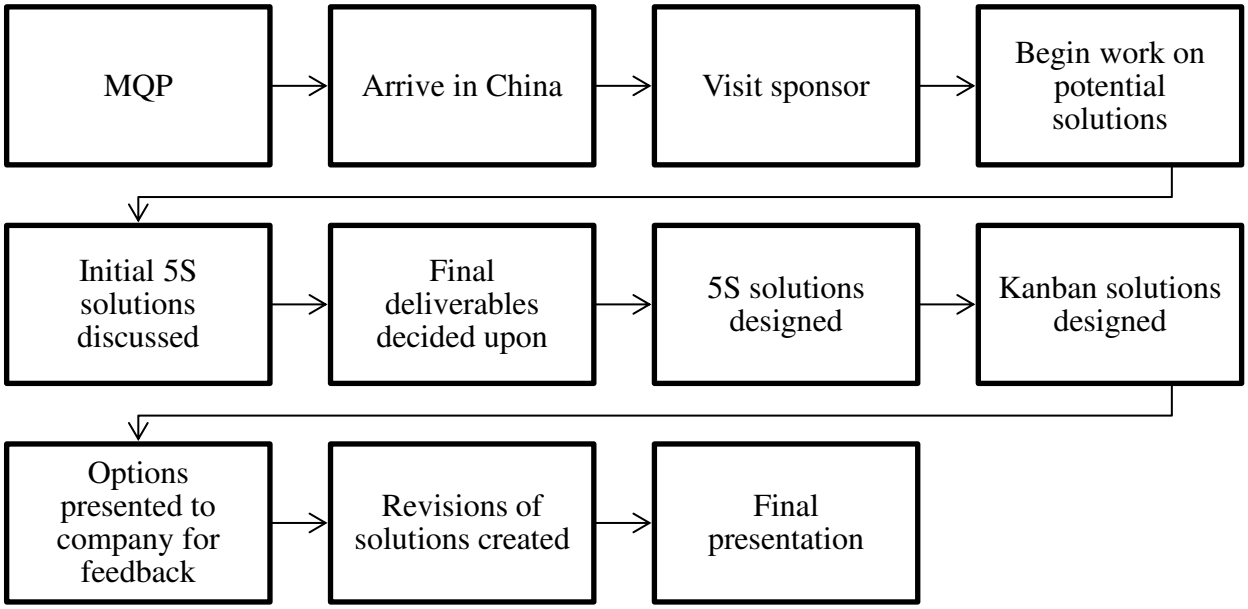

Figure 6 MQP Timeline

Chapter 5 Results

5.1 5S

After discussion of what the company would need to better organize the fixtures in the plant, as well as inventory on the floor, and any other organizational issues that could come up, several options were suggested. Since such varied applications were seen as end-goals, a set of

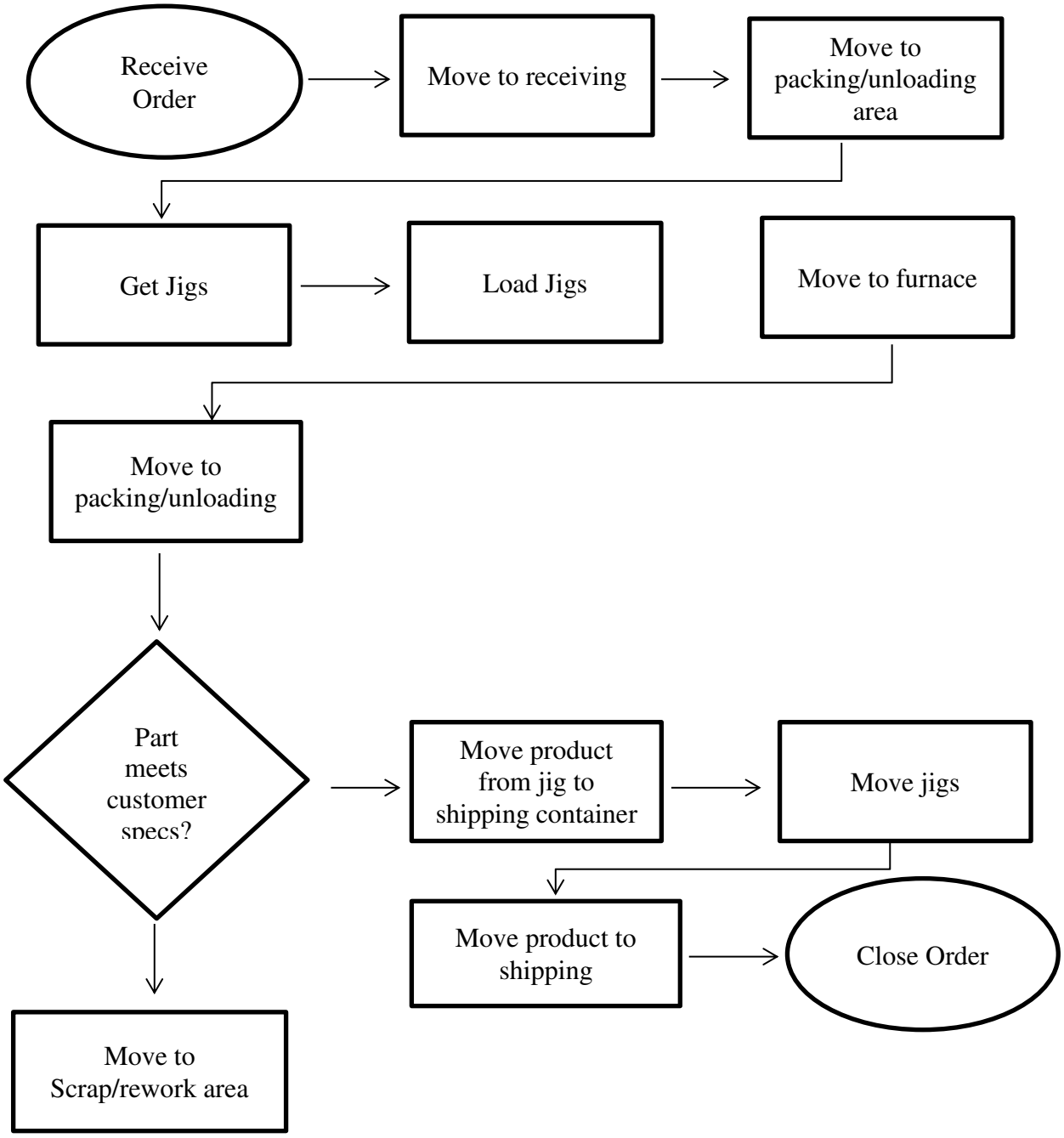

Figure 8 Current State Flowchart

broad suggestions for solutions were presented. Each option was presented as a single phrase, with the potential for further development left up to the company. These solutions were presented in an effort to streamline the Current State flowchart as shown in Figure 8 by eliminating any non-value adding steps.

5.1.1 Sort

This is the initial step taken in the 5S process. Through one or more of the following, the system or items can be sorted to unclutter the workspace.

Option 1: Sort by broken or not broken

As part of this solution, the jigs (or other tool to be organized) would be sorted into the general piles of broken and not broken. The broken jigs would then be discarded or fixed as needed. Further actions needed would be to sort the remaining jigs based on some other criteria as needed.

Option 2: Sort by used or not used

This option would involve sorting the jigs by whether or not they were used. The unused jigs would then be placed in a specified area for one month to make sure they were no longer needed in production. At this point, they would be disposed of. The jigs still needed would be placed in a more central location and further organized.

Option 3: Sort by machine

For this alternative, jigs would be placed near the machines that use them, to reduce need for travel to and from a storage area. The jigs used by multiple machines would be placed in

between those machines, or in a central location. Additionally, the jigs would be ordered by frequency of use to maximize ease of access.

Option 4: Sort by frequency of use

This option would entail sorting the jig by frequency of use, and discarding the least used. The remainder would then be divided into groups based on the number of times per week or month they are used. These groups would then be placed in the order of use so that the most used was always easily accessible.

Option 5: Sort by specific or not specific

For this solution, the jigs would be sorted by whether they have a specific use, or if they are for general use. Those with a specific use would be placed close to where they are used, and those with a general use would be placed in a central location. This would minimize unnecessary transportation.

These potential solutions could be used in conjunction with each other, or individually as needed in the situation. Additionally, they are only the stepping stones to finding the areas needing the most improvement.

5.1.2 Straighten

The goal of the second step in 5S is to logically order the fixtures or inventory in such a way that retrieval is fast and efficient. This could look different for different areas of the plant or for different items.

Option 1: Vertical shelving

This shelving would maximize the use of floor space. Where before there could only be a single stack of jig, or a row of jigs, this shelving would allow for many jigs to be placed such that a forklift could access all jigs on the shelf quickly and easily, without any unnecessary movements. The current method used forces the workers to move any jigs from their place in the line to open space on the floor, creating a safety hazard, get the jig or jigs they need for the current order, then move the other jigs back to their place in the line. This unnecessary and time consuming process could be eliminated by placing all jigs on vertical shelving that allows easy access to all jigs, regardless of how recently they were used.

Option 2: Place jigs near machines that use them

Placing jigs near the machines that use them also eliminates unnecessary travel or shuffling of unneeded jigs. The machines that need only one or two types of jigs during regular use would benefit from this, as the workers would be able to prepare the order close to the machines without needing to move the jigs until the product and the machine was ready. This would maximize the employee's time as well as the uptime of the machine. Additionally, for machines that use several jigs, a vertical shelving unit could be installed to save valuable ground space.

Option 3: Wheeled platforms

Wheeled platforms would make transportation of jigs easier and less expensive. Well built and maintained platforms for storing and transporting jigs would make it possible for single workers to move the jigs needed for a specific order without a forklift. This would reduce overhead costs, while also speeding the process. Since it would be possible to move single

pallets of jigs at time without a forklift, less floor space would be needed for storage or transportation.

Option 4: Unique shelving for each type of jig

This option could be more expensive than the others, but would result in a more organized floor. Each jig has a unique shape or pattern, and shelving would be made to fit that pattern. This would ensure that after each use, the jigs were returned to the proper location. Additionally, these shelving units could be placed near where the jigs would be used to minimize travel distance and time.

Option 5: Color coded markings on the floor or carts

Color coding is a way to make organizing easy, and identification from a distance faster. Certain furnaces would be denoted by a color, and all jigs used in conjunction with that furnace would be stored in an area denoted by that color. Or all bins, storage containers or moving pallets of a certain color would be reserved for use by jigs of a certain type. Another way to organize by color coded markings would be to color code shelves, so all jigs used by a certain machine or for a specific product would be stored on a shelf with a certain color.

5.1.3 Sweep

This step would include instructions or recommendations for maintaining a clean workspace. Currently, BodyCote has good cleaning standards and has not asked us to modify or present alternate methods.

5.1.4 Standardize

This step makes changes to the way information is communicated within the plant. The following suggestions are ways to show the proper method of storage or ways to interact with the machinery in the plant. This standard way of communicating throughout the plant should make it possible for anyone to identify errors quickly, as well as correct potential problems.

Option 1: Signs or posters

These signs or posters would be posted near or on the system or items to which they pertain. They would be a combination of pictures and words to describe the correct method of operation. The organization of each set of instructions would be standard throughout the plant such that, if needed, a person from a different area could operate unfamiliar machinery correctly.

Option 2: Pictures of proper methods

This suggestion is very similar to the above. The difference however, is that these pictures would show both the correct and incorrect way to operate the machinery or system. The incorrect pictures would be surrounded by a red marker or border, while the correct pictures would have a green border. This would give the operators a sense of what the finished good should look like or what the errors look like.

Option 3: Training of workers

Training the workers is possibly one of the most important steps to take to standardize the method of work in the plant. Good standards of training from the beginning of employment set a precedent of employer expectation. Additionally, it prevents errors as the new employee gets acclimated to the work.

5.1.5 Sustain

The final step to take for long term improvement is to make the changes sustainable within the plant. That can take many forms, and our recommendations are as follows.

Option 1: Employee training - continuous or quarterly

As a part of this option, there would be quarterly training scheduled. The topic would be at the discretion of management or the shift leader, and would reflect the needs of the group to be trained or the company as a whole. The training could be on safety, machine maintenance, the importance of lean, or led by workers particularly skilled at specific tasks to standardize the method of production in some way. These sessions could also include management, so that there is better understanding of what is happening on the floor.

Option 2: Section leaders

This solution is to foster responsibility among the workers. For each shift, each area has a nominal leader that takes charge of all the things that need to be done during that shift. They would report to the floor manager, they deal with problems with the workers, inventory or machines, and this position would rotate among qualified associates.

Option 3: Quarterly review – management/worker dialogue

The goal of this solution would be, in addition to continual improvement, communication between the workers and management. This would enable employees to get a better understanding of the way their actions affect the company, and the management to understand how their suggestions to improve process flow can be realized on the factory floor. This two

way dialogue could make sure that mechanical or process failures are dealt with rapidly and correctly, as well as give the employees a sense of the why of the work they are doing.

5.2 Kanban

The Kanban ideas and changes requested by BodyCote Wuxi, the main change and ideas they want the group to come up with are: to update and make their current Kanban more attractive, simple, and more useful; to come up with ideas for a new Kanban such as a four sided information hub with production plans and status of production, and change point information. The team also came up with ideas for monitoring the facility utilization ratio and field management. With careful consideration by the team after communicating with BodyCote Wuxi, our Kanban suggestions are as follows for the main UBQ Kanban. The original Kanban is shown in Figure 1s with a pros and cons table analyzing the old and the new Kanban in Tables 1 and 2 in Appendix 2. These and the following tables and figures for this section can be found in Appendix 3.

One idea is to color code all the headings, break apart the UBQ sections so that the machines are in their each respective column and that the system check status is in a row. The last change to it would to move the non-operational indicator to the top of the sheet. The reasoning behind color coding all the headings is to make the Kanban more attractive. Breaking apart the UBQ sections would help the viewer follow what the Kanban is showing as it would be streamlined to read. This way, all of the sections flow together. The last change is to move the non-operational indicator to the top of the sheet so it would be more convenient for the reader and it would be at a better place. This idea is shown in Table 3.

A second idea is to also color code all the headings, and then break off delivery information to a separate whiteboard, and to combine the anomalies and description sections and move them to the top of the chart. The reasoning behind color coding all the headings is the same as before as it would make the Kanban more attractive for both the workers and viewers. The reasoning behind breaking off the delivery information to a separate whiteboard is to give room for other information to be bigger and show the delivery information elsewhere. By doing this, the main Kanban board would be easier to read as the information would be more focused. The delivery information does not need to be on the same board as it does not really relate to one another. Combining the anomalies and the description sections together and moving it to the top of the chart would save space on the bottom and eliminate the need for two separate boxes. This idea is shown in Table 4.

One more idea is to color code the Kanban by machine, color code the binary information, and to make the information transfer the responsibility of the shift leaders. The main reason behind color coding the Kanban by machine is to make it very easy to read and each section would be recognizable with a different color. In addition, color coding the binary information would be very useful to be able to tell if there are any issues at a quick glance. Compared to the old Kanban, the new system would make it more appealing and gives errors or success a bigger visual impact. The last change would be more of a responsibility shift and ownership with the board. In order to have the Kanban board to display relevant information at all times, the shift leaders need to have the responsibility of information transfer so that all the boards would be updated as well as copying over information to keep as permanent records for continuous improvement. This idea is shown in Table 5.

The final Kanban design decided upon and presented to the sponsor is a combination of the above ideas. The board is divided into columns by machine, then

For the four sided information hub, BodyCote Wuxi had provided us with a model of the cabinet they plan on getting for their facility. This model can be seen in Figure 10. On the four sides of the information hub, the team decided on putting the production status, the delivery plan, the facility utilization ratio, and the field management Kanban information sheets on the four sides. In this way important information would be easily accessible and be divided in a manner which makes sense.

For the production status Kanban table, the team came up with a new idea as there was not a previous table used by BodyCote Wuxi for this purpose. This is the case with the rest of the Kanban discussed later as there has not been a previous Kanban used for this purpose. For the production status Kanban table, the focus for it was for the UBQ stations so there would be six different production status tables. This table would show Monday through Sunday with the machine and production status. The main information provided by this table would the quantity of the product, the planning and actual time of the production, and any reasons for downtime and any problems that might hinder the production. This table can be seen in Table 6.

For the delivery plan table for one of the sides of the cabinet, the team decided to use the one that was separated from the main Kanban design sheet. With separating the delivery plan from the main Kanban, the benefits have been discussed earlier but the main benefit is to make it easily accessible and readable at a glance without looking at a bunch of other miscellaneous information. The delivery plan is designed to show simply the status of one product with the manufacturing number. Also noted on the table are the quantity and the quality of the product

with comments and remarks about any problems or concerns related to that certain product. This table can be seen in Table 7.

For the facility utilization ratio, a pretty simple but useful concept was drawn up. The main reason for the facility utilization ratio was to make sure that the facilities in BodyCote Wuxi would have a product in it for heat treatment whenever the machine was running to run as efficient as possible, having a 100% utilization ratio. The graph for the facility utilization ratio has the number of days in one month on the x-axis and the percent utilization on the y-axis of the graph. If the facility utilization was plotted each day, BodyCote Wuxi can use it to figure out if there is a pattern to when the facility was not utilized 100% and what sort of preventive measures or actions they can take to ensure that the facility would be used 100% of the time. This graph can be seen in Table 8.

In terms of the field management Kanban, the concept of this is to manage the facility in its entirety. The basis for this field management Kanban is to show the production value, the production design, whether a delivery is on time or not, the safety of the workers, workplace awareness, cleanliness, equipment maintenance, the amount of defected products, customer concerns and problems, and the quality system audit. This table can be seen in Table 9.

The last Kanban change involves the change point. BodyCote Wuxi had also requested the team to come up with an idea to quantify any changes that might happen on a daily or weekly basis in order to reduce the amount of problems that might arise in the future. For this solution, the team had looked at designs for change point boards in which you can see the most current one while having the past change points in the pockets of the board. This way, you can focus on

the current one but still have the past data in an accessible manner. This design can be seen in Figure 11.

Chapter 6 Recommendations/ Conclusion

6.1 Implementing the new Kanban System

The steps necessary to take to implement the suggested Kanban systems is two-folds. One part of it is to first implement it with training of employees, cell leaders, and different management departments. The second part of implementation is to focus on the continuous improvement of the various Kanbans as new problems or patterns arise.

The main Kanban board for the UBQ stations would be implemented first by replacing the current one with the new one. There is no way to ensure that everyone would use the Kanban board the way it is intended to be used so a training program for the use of boards should be implemented across the facility to ensure the success and actual use of the new boards. This training program would teach employees about the importance of Kanban systems. Making sure that everyone knows why the company is implementing new lean tools and how it would affect them is important to fully understand the Kanban system. To ensure the use of the new Kanban board, the team recommends the company to offer incentives and give responsibility to workers to have some ownership of the board.

The next step for the Kanban board implementation would be continuous improvement. In order to ensure the success of the new Kanban system over a period of time, there needs to be continuous improvement. This involves everyone that interacts with the board including both managers and workers. A part of this continuous improvement is to keep permanent files of everything in order to keep track of how the facility is running and how the production is going. Another part of this is to keep reviewing the Kanban boards every few months to see if there are

any useless sections or if there are any sections that might need to be added to ensure the full use of the Kanban board. Additionally, any kind feedback regarding the system should be recommended and required in order for continuous improvement. In the future if the Kanban system is successful for the UBQ stations, it should be adapted to implemented into the three other production cells as well.

In terms of implementing the four information hub, it should be strategically placed in a location that would be easily accessible and be useful in terms of the storage space inside the cabinet rather than just a cabinet for four sheets of Kanban. The cabinet itself should have useful tools and documentation inside and the four Kanban sheets attached to it should be updated all the time to ensure that the information is relevant. For the productions status sheet, it should be the same as the actual Kanban board. This is a much smaller and easier to navigate Kanban board so it is a good idea to have the four sided cabinet in a convenient location. The other three sheets should also be actually used into to take full advantage of the information hub.

To implement the change point board, the company needs to gather cards to fit into the board to fully utilize it. Similar to the other Kanban systems, this change point board also needs to be placed in a good location as there would be a lot of involvement with the use of the board. This board needs a new card every day and to record any change points and problems that have occurred. The good thing about the board is that it can store the old cards for future review and record keeping. This ensures that future continuous improvement could be made to the production facility rather easily.

6.2 Benefits of a new Kanban System

The team suggests instituting a Kanban as a double sided whiteboard, with machine uptime information and current process information on one side, and delivery and lead time information on the other. Additionally, a four sided container with multiple shelves inside for specific tools or information, and different information on each exterior side of the box would further facilitate flow within the company. The accessibility of information as given by these two devices would make it faster for workers to understand what is needed to be done for each order. This would result in increased throughput as each machine would be fully utilized through proper preparation in reaction to the information.

6.3 Implementing 5S

The steps to implement the suggested 5S improvements could be done over a period of time determined by the company to maximize the benefit and success of the transition from the current to proposed system. The first step would be to decide what method or methods of each proposed step would be, so that a plan could be formulated. Once a timeline has been decided upon, the following actions should be taken.

The jigs should be sorted by the decided upon system. Once sorted, labels, colors, symbols, or signs should be assigned to each grouping of jigs. These should be systematic and plant wide, such that throughout the plant, the color associated with one type of jig or one furnace is only used for that type on all signs, posters, labels, etc. After this is complete, the new system for jigs organization should be implemented. A new shelving system can be incorporated into the plant to make storage and retrieval more efficient, color coded markings on the floor are drawn, wheeled storage units are used or some combination of those can be used. In

addition to the changes to the physical plant by the hardware necessary, employees would need to adapt to the new protocols instituted. This would be through training in the proper usage of the new system as well as the safety protocols that would need to be developed and applied. After the new system is installed, and employees are trained for its use, a systematic cleaning of the area is suggested. This ensures the area is ready for daily use by clearing away all the debris that could accumulate during the transition and / or assembly period.

After the area is cleaned, the pictures, signs, colors or symbols initially assigned to the different types of jigs should be attached to the fixture or placed in a readily visible location. Additionally, pictures should be taken of the correct placement and arrangement of tools and parts in their correct location, so there is a way for employees to ensure they are using the proper method of storage. This will ensure the desired standard for operation is maintained over the life of the structure or system. Training for the employees should be an extension of standard forklift operating procedures currently in use in the plant, and include a key or guide to the color coding or symbols used.

As part of a sustainable solution, employees should be a part of the implementation, training for and maintenance of this system. As they are the people coming into contact with this method, their input is invaluable as to which steps are most important, or what solutions work better than others. Additionally, this system will only be as effective as the employees are willing to change. If there is little or no incentive for the employees to change, then though this system will cut down on locating and transporting jigs, only small changes in throughput will be noticed. The employees should be informed of this opportunity to have a voice in the processes and procedures in place so that all changes are implemented in the most effective way.

6.4 Benefits of 5S

The full benefits of implementing the suggested 5S process would take some time to show. The process for improving the plant could extend over a period of months for all the necessary steps to be put in place, however, the improvements in process capability and throughput could be seen much more quickly. The potential benefits of these steps would be a more organized plant, increased productivity, increased uptime of machines and a more lean process, as shown in Figure 9.

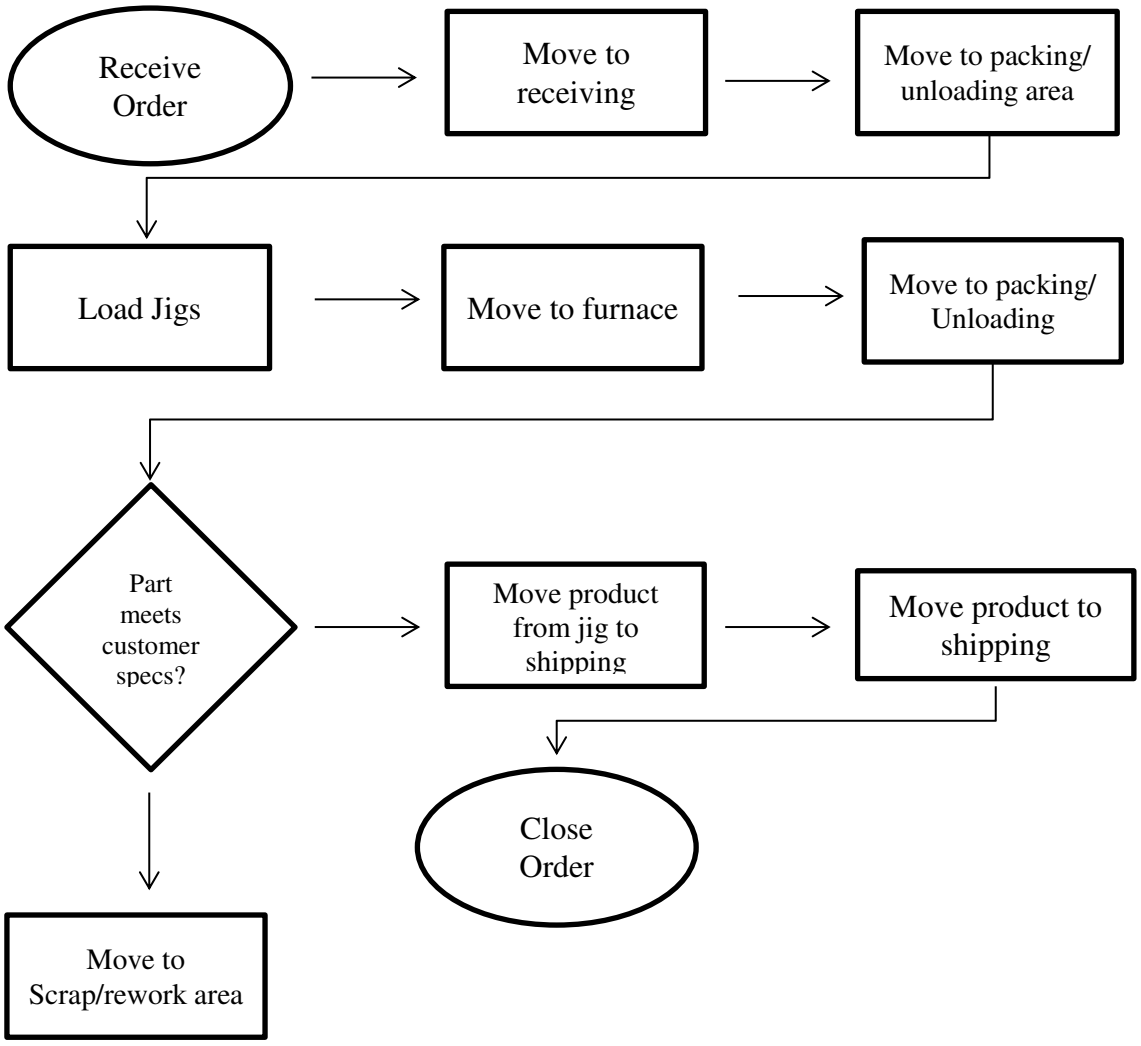

Figure 9 Future State Flowchart

An organized plant comes as a direct result of excess or unused jigs being discarded, and the remaining jigs having a standard for how they are stored and accessed. The measures put in place to maintain this standard ensure that the materials in the plant are always stored in a neat way. This logical organization means that employees will always know where to find the tools necessary for each order, eliminating the time they currently spend searching for those supplies. Additionally, the new shelving system would make jigs more easily accessible, again lessening time spent identifying which set of jigs are needed, and also eliminating the time spent moving jigs in the way. This would allow employees to spend more time on value-adding activities. This increased time for productivity would reflect in increased throughput, and decreased downtime of machines. The additional time the employees now have would give more time to loading and unloading product from jigs, quality checking, and packaging for shipping. The preparation for product to go into the furnaces would be complete in plenty of time for the necessary furnace to be loaded, increasing the turnover rate.

6.5 Future Improvements

In addition to the above suggestions, the following are potential changes to the plant or systems to improve process capability. The first suggestion is to convert the suggested Kanban system to a computer system. The system would be plant wide, and connected to each machine digitally. The software would collect data from the machine as well as information in put by the associates. Each order would be tracked by a barcode so that all information relating to a certain customer could be tracked as well. This system would also output a weekly, monthly, quarterly and yearly summary of all products going through the plant. A digital system would reduce the need for large whiteboards or other items to be staged around the plant, as well as reduce the amount of paperwork needed, or the chance for error because handwriting is illegible. However,

this system would be very expensive to implement, and all employees would need to be trained in its use, which would decrease production capability as all errors are worked through in the first three to six months. However, after this installation period, throughput could increase, information regarding process capability would be more accurate and increased data regarding machine capability and scrap would lead to early problem identification and solution.

A second potential for improvement would be to change the layout of product and tools on the plant floor. Decreased time spend on non-value adding activities such as moving product throughout the plant and finding the tools or goods needed increases the time that can be spent on value added activities. Suggested changes to the layout are as follows.

Re-organizing inventory layout on the floor is one potential improvement. Currently, the majority of inventory in the plant is kept in one area. This is helpful in that this area is centrally located and a convenient staging area. However, this means inventory needs to be moved at least four separate times while in the plant. Keeping inventory on shelves near the furnaces in which it will be processed would minimize unnecessary movement within the plant, as well as facilitate preparation for placing the parts into the furnaces. Additionally, it would serve as a visual reminder to the associates for what action needs to happen at different furnaces.

An alternative to that would be to organize the existing pool of inventory into sections based on which furnace it is going to, rather than which customer it is coming from. This will facilitate quick transfer of products as needed, without taking up more space. The sections could be further organized by using color codes based on the customer. This could be implemented through paint on the floor or buckets to hold the parts.

Chapter 7 References

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Chapter 8 Appendix 1

Definitions

Nitriding – heat treatment in which it diffuses nitrogen into the surface of the metal to create case hardened surfaces

Carburizing – heat treatment in which it increases carbon on the surface of either iron or steel. It increases carbon diffusion on the surface which makes it hard on the outside and soft on the inside when it is quenched.

Carbonitriding – increases surface hardness of a metal; atoms of carbon and nitrogen diffuses interstitially into the metal, creating barriers to slip which increases hardness and modulus near the surface.

Normilization – Part of annealing in which metal is cooled in air after heating to relieve stress

Annealing – heat treatment in which a material is heated above the critical temperature, mained for some time at a suitable temperature, and then cooling. This increases ductility and is a step before cold working

Tempering – Heat treatment in which it reduces excess hardness by heating the metal back up again but at a lower temperature than it was in hardening. Temperature dependent for how hard you want it to be

Chapter 9 Appendix 2

9.1 Kanban Tables and Charts

9.1.1 Current Kanban

Table 1 Current System Pros and Cons

Current Kanban System			
	Large whiteboards		
Pros		Cons	
• Shows relevant information		• Too much information	
• Centrally located		• Not visible from far away	
• Detailed		• Not always helpful	
• Able to be updated and used by all		• Workers don't use	
• Information groupings are related		• Information not organized by category	

9.1.2 Proposed Kanban

Table 2 Proposed System Pros and Cons

Proposed Kanban System			
1. Whiteboards		**2. 4 sided cabinet**	
Pros		Cons	
• Shows relevant information		• Worker's discretion to use	
• Centrally located		• Only as accurate as the information on it	
• Detailed		• Not enough information shown	
• Able to be updated and used by all		• Multiple sides difficult to read	
• Visible from a distance			
• Binary information available at a glanc			
• Color coded for ease of use			
• Information organized by category			

Table 3 Kanban Option 1

Delivery plan

Products Number	Furnace number	Quantity	Status		Remarks
			Qualified time for delivery plan	Not Qualified wait for being isolated	

备注：质检合格填写发货时间，若不合格在不合格处打勾V

Bodycote

Date ____

Production Process Status

Kanban illustration

Production Status

Monitor check time（Every 2 hours）： Day time First Second Third Forth Fifth Sixth night time First Second Third Forth Fifth Sixth

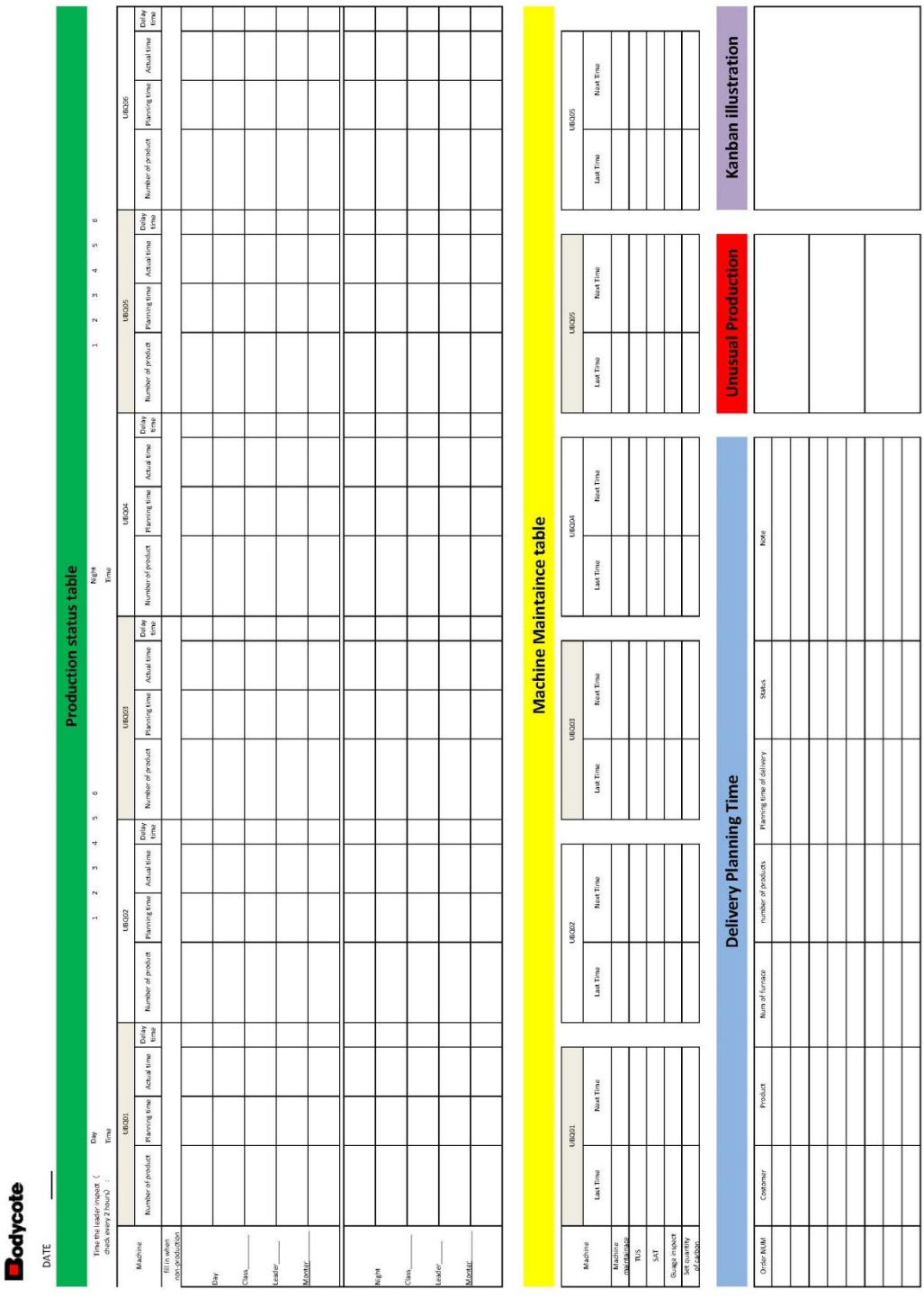
Duty Officer	UBQ01				UBQ02				UBQ03				UBQ04				UBQ05				UBQ06			
	Products number	Plan into furnace time	Actual time	Delay or not	Products number	Plan into furnace time	Actual time	Delay or not	Products number	Plan into furnace time	Actual time	Delay or not	Products number	Plan into furnace time	Actual time	Delay or not	Products number	Plan into furnace time	Actual time	Delay or not	Products number	Plan into furnace time	Actual time	Delay or not
Day Group ____ Duty Officer Monitor ____																								
Night Group ____ Duty Officer Monitor ____																								

有关延迟说明：有延迟则打勾（√），若无则空白

Furnace Status

Furnace	Maintenance		TUS		SAT		Instrument Verification		Charking		Furnace Status		
	Last Maintenance time	Next Maintenance time	Last TUS time	Next TUS time	Last SAT time	Next SAT time	Last time	Next time	Last Charking time	Next Charking time	Production	Non-production	
												Maintenance	Wait
UBQ01													
UBQ02													
UBQ03													
UBQ04													
UBQ05													
UBQ06													

Table 4 Kanban Option 2



Bodycote

Date ____

Production Process State Kanban

Production Status Table

On duty forman（inspection every 2 hrs）：

Day Time 第一次 第二次 第三次 第四次 第五次 第六次

Night Time 第一次 第二次 第三次 第四次 第五次 第六次

Persons Responsible	UBQ01	Planned Time	Actual Time	Delayed/ Not	UBQ02	Planned Time	Actual Time	Delayed/ Not	UBQ03	Planned Time	Actual Time	Delayed/ Not	UBQ04	Planned Time	Actual Time	Delayed/ Not	UBQ05	Planned Time	Actual Time	Delayed/ Not	UBQ06	Planned Time	Actual Time	Delayed/ Not
白班 班组————— 责任人_____ 班长_____																								
夜班 班组————— 责任人_____ 班长_____																								

Equipment Status

Equipment	Mainenance		TUS		SAT		Gague Check		Set carbon output		Equipment Status		
	Last Maint. Date/Time	Next Maint. Date/Time	Last TUS date/time	Next TUS date/time	Last SAT date/ time	Next SAT date/ time	Last Check	Next Check	Last Check	Next Check	No problem in Production	Problem In Production	
												In Shop	Wait for Repair
UBQ01													
UBQ02													
UBQ03													
UBQ04													
UBQ05													
UBQ06													

Delivery Schedule

Order Number	Customer	Product	Furnace Num.	Quantity	Planned Delivery Time (Lead Time)	Status	Remarks

Anomalies Described

Description of Kanban

Table 5 Kanban Option 3

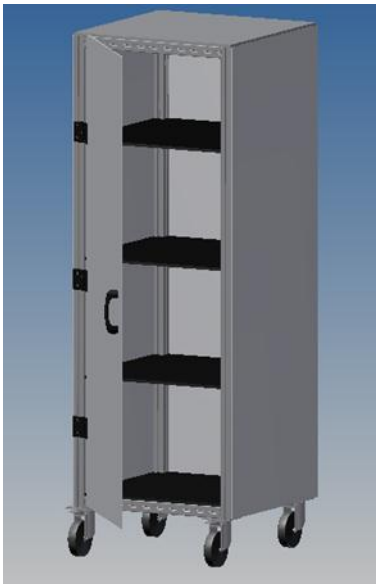


Figure 10 Information Hub

Table 6 Production Status Kanban

Machine：UBQ 1	Stop or not	Number of products	Overall planning time	Overall actual time	Reasons for incomplete
Monday					
Tuesday					
Wednesday					
Thursday					
Friday					
Saturday					
Sunday					
					Notes：Fill in per day

Table 7 Delivery Plan Kanban

Number of products	Furnace number	Number (how many products this machine produce)	Status		Notes
			(in good quality) planning delivery time	(in bad quality) sent to isolation region	
Notes: fill in delivery time if in good quality, fill in √ if in bad quality					

Table 8 Facility Utilization Ratio Kanban

Month: _____

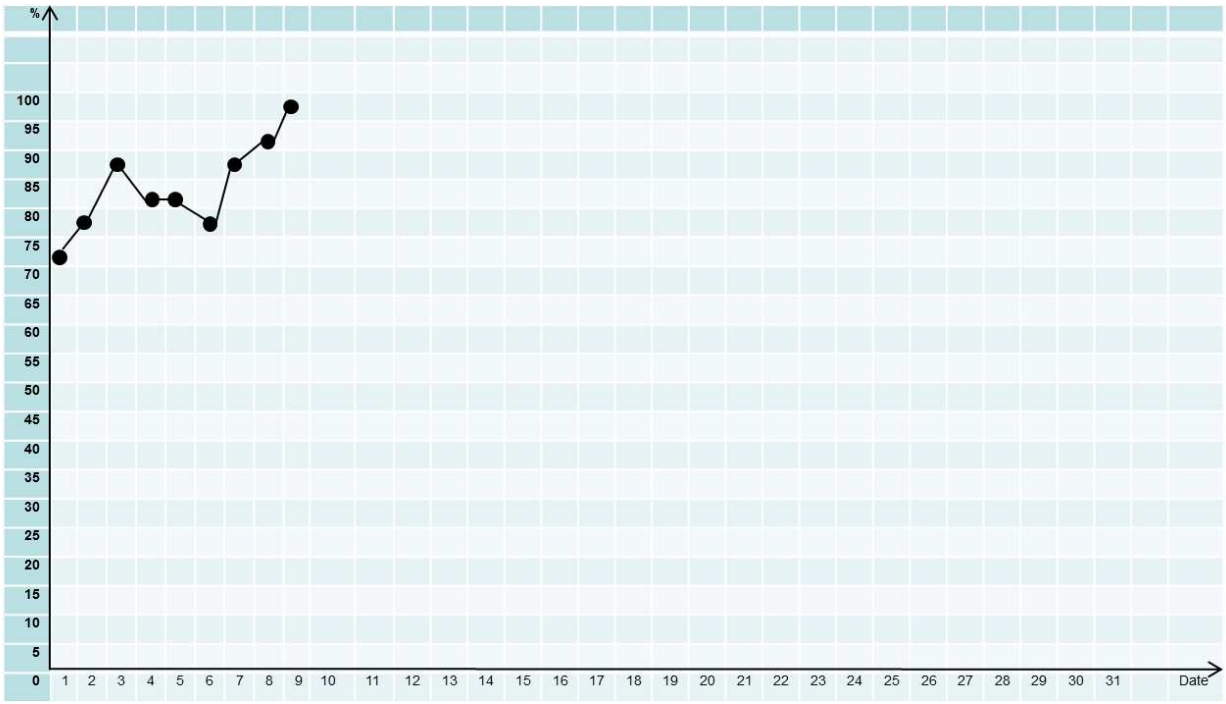


Table 9 Field Management Kanban

No.	indicators	define	Result
1	Out value	The products in storage within a certain period	
2	Production planning	Actual complete number	
3	Delivery on-time	Whether delivered on time	
4	Production accidents	Times of the accidents	
5	Keep production working site neat and orderly	If it is or not	
6	Equipment maintenance	Times of the equipment maintenance within a certain period	
7	Products sampling pass rate	Qualified number/total number	
8	Handle quality problems	If the handling of quality problems is timely and effective	
9	Meet the Quality System Assessment	Numbers of items that do not meet Quality System Assessment	

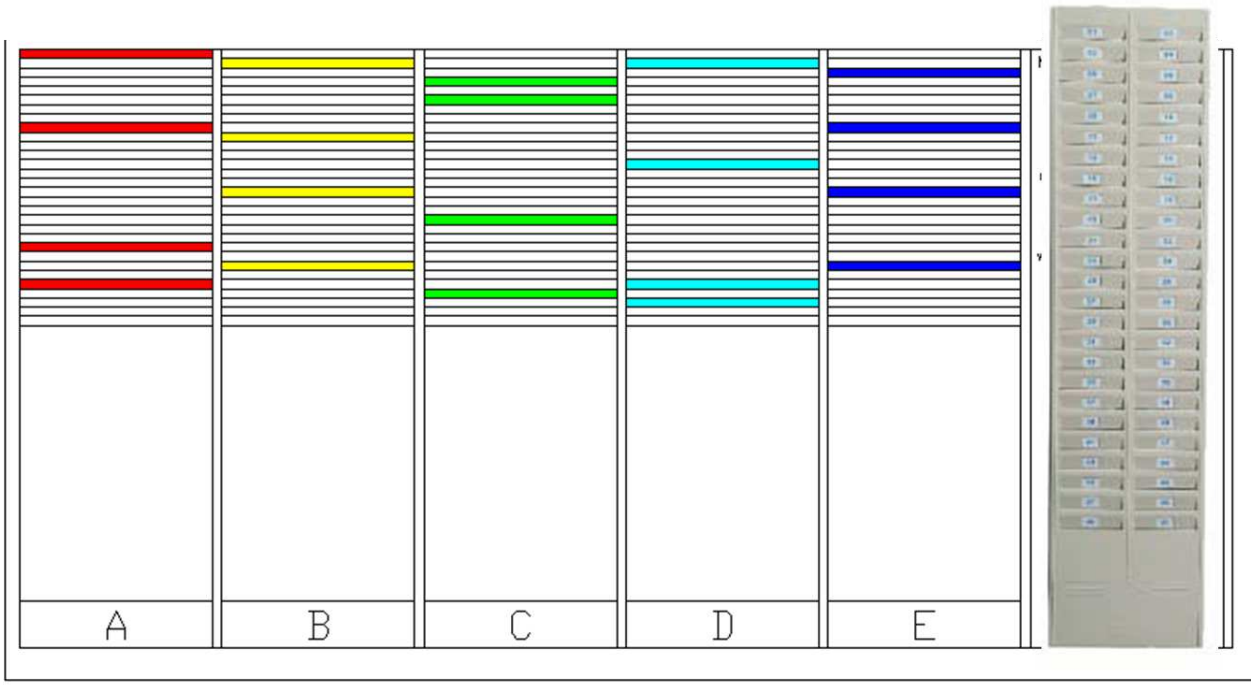


Figure 11 Change Point Kanban

Chapter 10 Appendix 4

Current State Kanban

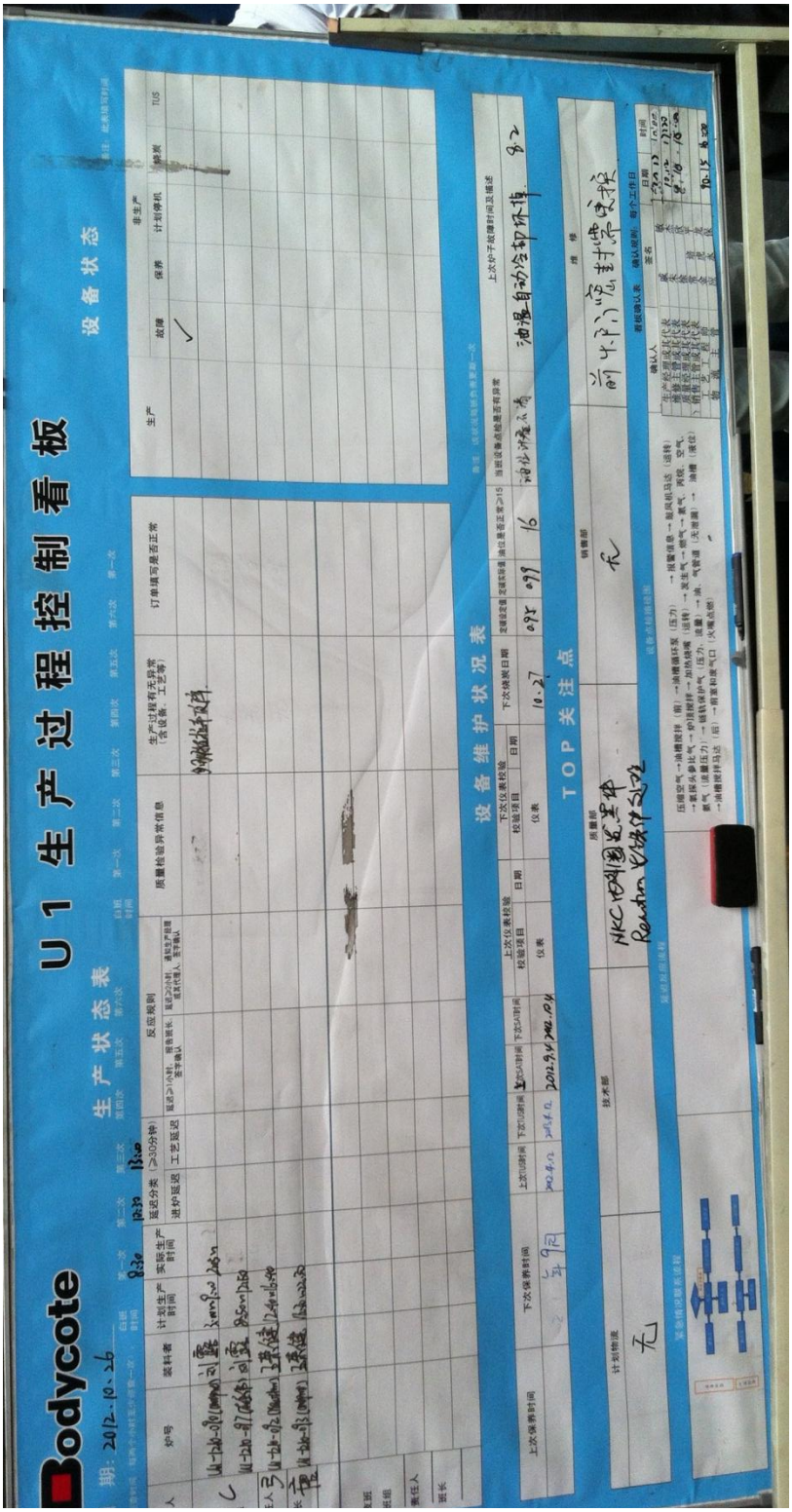


Figure 12 Current Kanban

10.1 Proposed Kanban

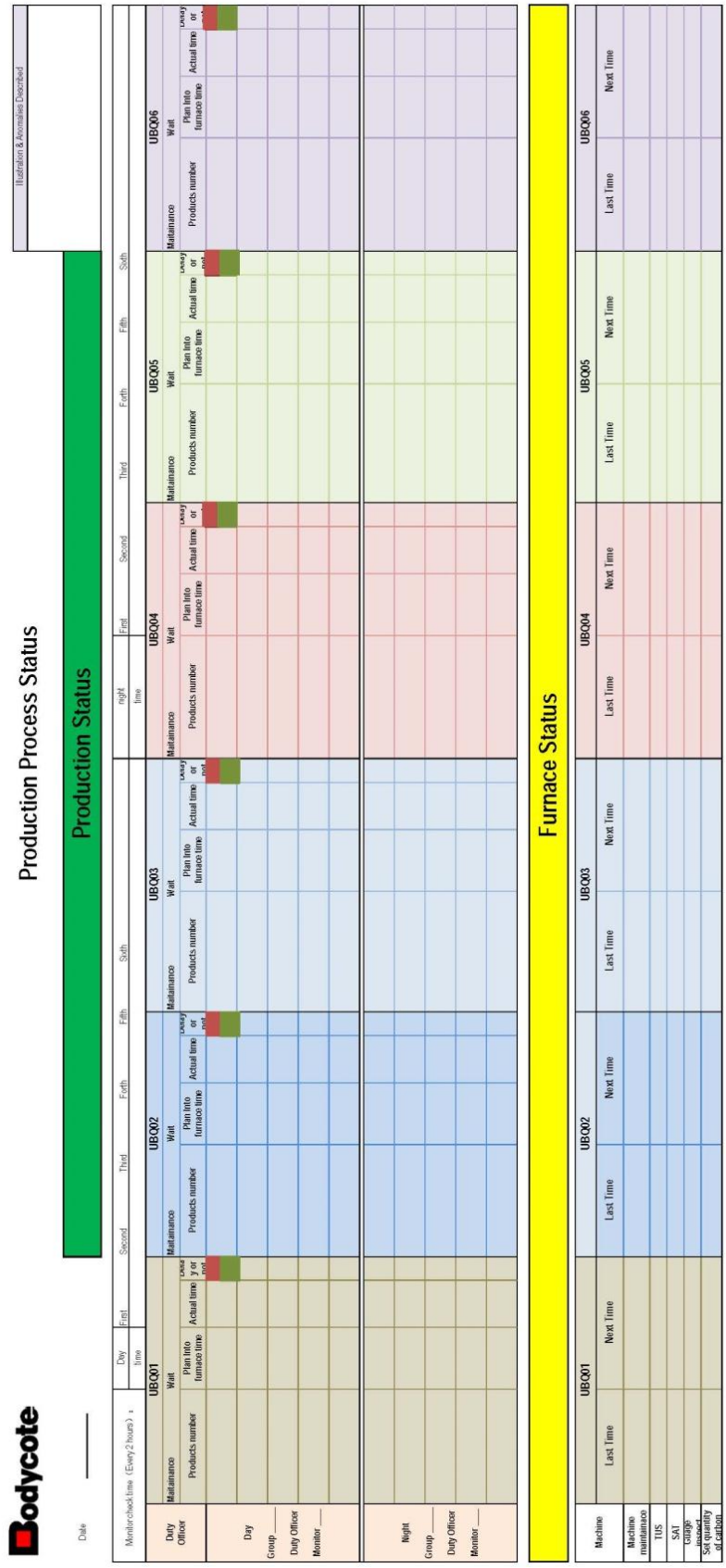


Figure 13 Potential Kanban