DEVELOPING STANDARDIZED WORK IN CASTING DEPARTMENT

CASE STUDY OF LUVATA SWEDEN AB FINSPANG

WRITTEN BY JELENA KURILOVA

MASTER’S THESIS IN THE FIELD OF QUALITY TECHNOLOGY AND MANAGEMENT
DEPARTMENT OF MANUFACTURING MANAGEMENT AND ENGINEERING
LINKOPING 2010
LIU-IEI-TEK-A—10/00820—SE
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SUMMARY

This thesis is one part of a lean project initiated by Luvata Sweden AB in Finspang casting department. The primary goal of that project is to increase the production efficiency, reduce costs and improve the quality of the copper coil. The aim of this thesis is to develop standardized work in casting department at Luvata Sweden AB Finspang. The research is based on lean thinking and organized in three steps.

FIRST STEP: This step implies value stream mapping (VSM) of the current manufacturing process. VSM technique is applied in order to create an overview of the entirety production flow in a casting department, to visualize non-value added activities and to identify process wastes.

SECOND STEP: By using lean tools as: Waste Management, SMED and Visual Management, thesis work intends to “clean” the production process. 7 Wastes or seven forms of “Muda” were studied at Luvata Finspang. The source of 5 wastes were identified and reduced/eliminated. SMED (single minute exchange of dies) analysis was carried out for a changeover during a casting montage in order to reduce the changeover time and streamline the montage process. Spaghetti diagram was applied particularly to inspect the best location for all montage materials, equipments and tools in a casting floor. Ensuring the efficient implementation of Waste Management and SMED practices Visual Management technique was used. This mean expresses the information about production process, its real-time status and results in a way that could be understood by operators in a shop floor. It is important to “clean” a production process before the standardized work can be developed, since the purpose of standardized work is to represent the best practice: method and sequence for each process.

THIRD STEP: The last thesis step focuses on developing standardized work sheets as a steering tool for operators to follow the best practice while executing their tasks in each work center (melting, casting, rolling) and during the casting montage. The standardized work sheets are designed to show the approved way to perform the specific procedures and are expected to motivate operators to perform theirs job in the common way. That would consequently reduce high variation in operators’ performance.

It would probably take several years before any reasonable improvements could be observed. However the developed standardized work sheets are already placed in the shop floor and successfully used by operators – this is my small contribution to a big improvement project!

KEY WORDS: Lean manufacturing, VSM, Waste Management, SMED, Visual Management, Standardized work sheets
PREFACE

With this column I want to express how I appreciate a great contribution of everybody involved in this thesis. I counted at least 34 persons I must say “Thank You”.

My first thanks belong to each of 25 operators, who I was working with for the last five months, especially Stefan and Per. They, among the first one, brought me in to the casting process and shared their ideas about the possible improvements. Special thank goes to both two engineers and a project manager (Jonas 1, Jonas 2 and Per-Olof) for their cooperation and support in creating the Standardized work sheets. I would also like to thank the initiator of this thesis and my company supervisor Dick Carlsson for providing me all necessary resources and giving his time to execute thesis work. I highly appreciate the knowledge about the management of the production flow gained through the frequent conversations and workshops with him. It was a feeling of being treated as a highly valuable lean specialist whose ideas are very welcomed.

I also want to thank Bozena Poksinska my University supervisor for her help in writing this report and guiding me in this thesis world. I am thankful for her support and inspiration during the entire thesis period. I also want to thank my opponent Himawan. His and Bozena’s feedback and ideas made this report interesting to read.

Finally I want to thank my friends and colleagues for their kindness in helping me to correct the report language and supporting me during the whole time in Linkoping University.

LINKOPING, JUNE 10, 2010

JELENA KURILOVA
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<td>FIFO</td>
<td>First in first out</td>
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<td>OEE</td>
<td>Overall Equipment Effectiveness</td>
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<td>SMED</td>
<td>Single minute exchange of dies</td>
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<td>SWOT</td>
<td>Strengths, weaknesses, opportunities, threats</td>
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<td>TPS</td>
<td>Toyota production system</td>
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1 INTRODUCTION

1.1 Background
Luvata Sweden AB in Finspang is a division within the global Luvata Corporation and produces copper strips for automotive and electrical applications. 2005’s economical downsizing in automobile manufacturing business directly affected Luvata Sweden AB production facility in Finspang. This economical regression turned out in a dramatic metal price boom and made Luvata to face new challenges. In addition the customer demand for quality jumped to a significantly higher level and pushed metal fabrication business to seek out new solutions.

At that time Luvata Finspang had serious problems of lengthy transportation, low quality, a lot of scrap and excessive stock as well as high work-in-progress, and long manufacturing and delivery lead times and the stop times.

All that forced Luvata to initiate the lean production improvement campaign locally called LPS (Luvata production System). Today Luvata develops further its operational excellence through the LPS. The target of LPS is to increase the production efficiency and to minimize wastes within the operations, to concentrate on quality and reduce costs.

1.2 Objectives
The purpose of this thesis is to develop the standardized work in casting department by means of VSM, Waste Management, SMED and Visual Management.

The objectives of the research work are further divided into four steps:

1. Map the present value stream in the casting foundry;
2. Identify the possible wastes and suggest techniques to eliminate them;
3. Implement SMED for stop/changeover times;
4. Develop and visualize the standardized work sheets for operators.

The research procedures can be described in three steps: VSM → Waste management + SMED + Visual Management → Standardized work sheets.

The VSM stage is about creating the overall view of the production flow. The next step is to “clean” the process. The Waste Management technique is applied in order to identify and reduce/eliminate production wastes and support the standardized work operations. SMED step is performed to reduce the changeover time and “clean” the montage procedure. Visual Management tool is used to facilitate the standardized work practice in the shop floor.
The Standardized work sheets are developed to become the main source of information about the standardized work and are expected to reduce variation in operators’ performance. Here is a visual representation of three research steps with the lean tools used upon each step:

1. **CREATE THE VIEW OF CURRENT STATE**

2. **CLEAN THE PROCESS BY USING TOOLS**

3. **REDUCE VARIATION IN OPERATOR’S PERFORMANCE**

![Figure 1.2 Research steps]

### 1.3 Research questions

The main questions for the thesis are:

- How to identify the possible sources of waste and reduce/eliminate them by using VSM?
- How to standardize stop/changeover procedures by using SMED?
- How the standardized work operations can be developed?
1.4 Delimitations

The thesis work aims to develop standardized work in casting department at Luvata Finspang. This thesis focuses only on VSM, Waste management, SMED, Visual management and Standardized work sheet tools and techniques. The future state VSM is not created. The waste reduction/elimination solutions are developed for all the wastes one by one. These solutions consider only the standardized work practice and do not present the long-term overall production improvements. The new changeover/montage time, improved by the SMED initiative, was measured only once due to the limited thesis work time. The standardized work sheet for casting montage is not enclosed in this thesis work since the montage machine and montage procedures are under the patent.

The thesis work investigates only the operators’ work and does not consider the machines' performance. The comprehensive study of the machines' performance could affect the thesis findings.

The time limitation is important factor. The copper coils production process is very intensive, it runs 24 hours per day and 7 days per week, therefore it is not possible to observe the process the whole time. The thesis result may be different if this research could be held for a longer time.
2 \textbf{THEORETICAL FRAMEWORK}

2.1 \textit{Lean production system}

Lander and Liker (2007) assume that in practice lean is most often treated as a set of tools to remove “waste” from the processes. According to Shah and Ward (2007) lean production is a multi-dimensional approach that encompasses a wide variety of management practices, including just-in-time, quality system, work teams, cellular manufacturing, supplier management, etc. in an integrated system. Pettersen (2009) in his article made the analysis of the lean literature and concluded that among the authors dominates a view that lean is more than a set of tools, since it is a philosophical approach to lean. Therefore lean production is also considered as a philosophy of continuous improvements and respect to people.

2.1.1 \textit{Origin}

The origin of lean production is Japanese manufacturing method called Toyota production system (TPS). Womack \textit{et al.} (2007) described that in the middle twenties the entire Japanese production was in crisis, and at that time Toyota Motor Company manufactured three times less automobiles than the world leader Ford’s vast Rouge. An engineer Eiji Toyota came to study the Rouge mass production principles to adapt to Toyota production, however together with Taiichi Ohno concluded that it would not work out in Japan. Nevertheless both of them claimed that there should be other option to improve production in Toyota.

During the period of crisis and recession the significant decisions were proposed regarding the workforce. According to Morgan \textit{et al.} (2006) among the most efficient means dominate the lifetime employment status introduction and a new payment system, when the salary increases with the years spent at Toyota. These wise maneuvers made the employee costs predictable for the enterprise and motivated workers to stay in the same company for a long time. This caused a creation of cooperation, flexibility and trust atmosphere since the necessary lean production conditions were established.

2.1.2 \textit{Objective}

Pascal (2002) admits that Toyota Production System, or Lean, term was popularized by Womack, Jones and Roos in 1990, and means doing more with less – less time, less human effort, less machinery, less material – and at the same time delivering the products customer demands. According to the lean philosophy this could be reached only after reducing costs.
Lean production is a system when all parts are highly integrated and share a clear vision of what should be done. It also implies transforming a system of the interconnected activities into a “thinking way”, where the heart of the system is the involvement of team members and their interest in the seeking of improvement. Pascal (2002) argues that team members’ involvement in the shared and standardized improvement activities brings the biggest success.

So to make it clear - Many researchers agree that the key success of the Japanese manufacturing methods were based on two main principles:

- Cost reduction through the elimination of wastes
- Efficient use of employees’ capability

Lander and Liker (2007) admit that the cost reduction was mainly achieved through the use of just-in-time production, in particular pull system, one-piece flow, leveled schedule and jidoka. The efficiency of workforce was built on a system of respect for people with the attempt to eliminate useless motions, ensuring employees’ safety, and involving them in improving their jobs.

Pardi (2007) believes that the superior performance in terms of productivity, quality and work satisfaction of the first Japanese plant in the USA played a crucial role in sustaining the highly attractive view on Japanese manufacturing methods. It was obvious that the Japanese model could be applied in other countries under the name of lean production.

2.2 Lean principles
With the aim of guiding the managers through the lean techniques Womack and Jones (2003) summarized the principles of “lean thinking” as following: specify value, value stream, smooth flow, pull order system, and pursue perfection. This resolution let the confused managers to tie major lean principles and techniques together into entire system and adjust to company’s business.

2.2.1 Value
“Muda” or wastes is opposite to value and brings a clear message to the managers, since it emphasizes the activity which absorbs resources but do not add value. Liker (2004) advice using the word waste for mistakes which require: re-work, production of not-ordered items, unnecessary process steps, movement and transportation without purpose, waiting, products that do not meet the needs of customers.

The value definition is a starting point when turning to lean thinking. In general all the “W” (who, where, when, why) & “H” (how) questions could be addressed to the value. Managers must know all the answers otherwise their “conscious attempt to precisely
define value in terms of specific products with specific capabilities offered at specific price through the dialogue with specific customer" should not be initiated (Womack and Jones 2003). To specify value is activity number one on the lean checklist for beginners. The original Japanese idea to specify value through separating it from the waste is very helpful.

Within lean enterprise everything that does not add value to the product has to be eliminated. Ahlstrom (1997) claims that the most important source of waste is inventory, especially work-in-progress inventory, since it hides problems. He describes Ohno’s proposal to compare hidden inventory with the rocks under the water level, since there is a problem to see them. The advice here is to reduce the water level (inventory) to expose the rocks (problems). Ahlstrom (1997) adds that the causes behind the existence of inventory must be removed first. The effective way to reduce inventory is to reduce set-up times, use preventive maintenance towards the machinery as well as change layouts to reduce transportation.

2.2.2 Value stream
One of the effective ways to identify waste is to create a value stream for the product. Through the set of organized actions required to produce specific product the problem solving, information management and physical tasks are brought together. Here the production process is shown from the product perspective, rather than machine function, so the non-value adding activities are eliminated since they are waste.

Rother and Shook (2003) have developed a method to create a typical value stream analysis. The simplest way to map the value stream is to draw the sequential-parallel production steps with the arrows showing the direction and the time per operation. The idea of the value stream map is to “clean” the process, in other words, to get rid of all the wastes. While mapping the value stream Basu (2004) adds that it is possible to see every step for a physical product and discover which activities are unavoidable and which can be eliminated immediately. The value stream table shows time data for each value stream step: storage, actual processing time, process rate and the total as well as cumulative value. Since the production processes vary from company to company and from country to country there is no single best way to map the value stream. Womack and Jones (2003) advises to initiate the stream thinking: “stop looking at comprehensive activities and isolated machines and start looking at all the specific actions required to produce specific products to see how they interact with each other”.

2.2.3 Flow
Flow is another component of lean production system. It conveys the aim of redesigning and operating customer order fulfillment processes to minimize waste and optimize customer service. It is therefore the principle mechanism to reducing customer order lead times by safely controlling inventory.
The production flow mapping for the entire item with only value adding activities came from Womack and Jones (2003) minds. The assumption is based on the efficient flow with smart production steps regarding the place, quantity, time of production that creates value not only for the department but for the entire company business. The reengineering movement involves shift from departmentalized thinking to process focus.

According to Liker (2004) after the value is defined and the value stream is mapped the focus should be directed towards the product itself, its design, and order-taking, production, and location issues. The prerogative is to think beyond the boundaries of the traditional functional organization and follow the continuous flow of the specific item within a team of specialists. Womack and Jones (2003) claim that lean approach is to create truly dedicated product teams with all the skills needed to conduct value specification, general design, detailed engineering, purchasing, tooling and production planning in one room. This approach enables the team to elimination organizational barriers and follows the standardized practice improving it every time.

2.2.4 Pull
According to Liker (2004) a pull system is one in which production is triggered to refill what has been taken to fulfill customer demand. Therefore a process pulls product from upstream, and the production rate equals the customer demand rate. The pull ordering system refers both to the inside and outside customers. When the flow is set according to the efficient production process there is no need to produce items that are not ordered and correspondingly it is easier to forecast the time when the production should be initiated to satisfy customer’s needs. Here the concepts of production leveling – optimized production schedule with the 90% production time and 10% changeovers are applied as well as the kanban cards or signal cards showing the demand for production initiation are used efficiently. Just-in-time production, Material Requirement Planning system are other methods to pull.

2.2.5 Perfection
Perfection is the fifth principle that Womack and Jones (2003) emphasize. They state that lean perfection drives enterprise to re-think radically against its whole value stream and to re-configure process actions so to keep the incremental or fundamental changes updated and improved. It is important to estimate the gap between company’s current reality and excellent performance as well as to concentrate on elimination of the wastes. Lean perfection is the concept where everybody is involved; enterprise has a bright vision of better future and a will to improve the present state.

Ahlstrom (1997) wrote that zero defects is all about perfection, superior quality and doing right from the first time. To achieve high productivity, the product needs to be fault-free from the first step of production. The most important characteristic of a lean production system regarding the quality is the lack of employees’ dedication to control
the quality. A goal of the zero defects is to boost the process capability and gain the maximum control over it. The proactive actions are demonstrated in order to keep manufacturing processes under control, prevent re-work and after-production inspection.

2.3 Lean tools – House of Lean

Liker (2004) illustrated the most common lean tools in the form of house (see Figure 2.3 Lean House). The goal of lean production is set in the roof and consists of reaching for the best quality, lowest costs, shortest lead time, highest safety and high morale. The left pillar encloses Just-in-Time principle which consists of production planning and leveling tools like takt time, continuous flow, pull system, quick changeover and integrated logistics. The right pillar deals with Jidoka which prevents a defective part from proceeding into the next work station as well as insists on separating people from machines. People are in the centre of the lean house concept since people see waste and solve problems that lead to continuously improvement of the processes. In addition it is important to consider the characteristic of a lean work organization since the responsibilities are decentralized to multifunctional teams. The foundation of the house has to be stable for the pillars to stand steadily and consists of the tools like 5S, standardized work, and leveled production.

Figure 2.3 Lean House. (J. Liker 2004)
2.4 Value stream map (VSM)

According to Basu (2004) value stream map is a visual representation of all steps required to produce a product from the raw material until customer delivery. It shows both value-added and non-value-added activities. Summer (2009) advises to gather data on cycle and changeover time, batch sizes, operators’ and products number, scrap and others. The production flow illustration will help to discover the areas that are in need of improvement.

Rother and Shook (2003) describe a value stream mapping process that is highly used by practitioners worldwide. They explain the examined process in several steps starting with mapping of the current state of the process, evaluating it in respect to the lean value stream, and then drawing the future-state or desired value stream.

The overall value stream tends to improve the production process in the whole facility and not a separate part of it. The value stream mapping can be easily done even with paper and pencil. Straightforward drawing of the process makes product’s value stream visible and enables to see and understand the flow of material and information at the same time. Bicheno (2004) stress the importance of mapping the information flow besides the material flow since it tells what to do next. Among other advantages of the value stream mapping there is the ability to better visualize production flow and to identify source of wastes. Value stream mapping is a qualitative tool that helps to describe how the facility should operate in order to create flow (see Appendix 1 - 2).

By drawing the current state the information is gathered on the shop floor. This information is used to create a future state as well, since the future ideas come with mapping of the current state flow. The final step is to follow the implementation plan, which describes how to achieve the desired state of the flow. Improvements in the value stream level follow as soon as the future state has been reached.

When drawing a current-state map a set of symbols or “icons” is used. Several differently shaped data boxes are helpful to show information regarding each process step: the number of produced items, cycle time, changeover time, number of people and other typical process data. This process box drawing helps to find the accumulated inventory and the locations of flow stops. Rother and Shook (2003) advice to use a “warning triangle” icon to mark the place and quantity of inventory. Next step is to incorporate the broad arrow indicating the movement of goods – transportation between process steps or transfer of finished items to the customer. Beside the material flow arrow the information flow arrow takes place as a narrow line. There is also a striped arrow to point out the push movement of the material; this push arrow usually appears between the processes in the factory. The timeline is drawn under the process boxes and inventory triangles showing how much time is spent during the production steps or between them and the total production time.
Bicheno (2004) points out that lean manufacturing is about making only what is required by the next process. The accent here is to link all the processes in a smooth flow and eliminate deviation. Rother and Shook (2003) have developed a set of guidelines to tie up the processes. First element to consider is a takt time, which “synchronizes pace of production to match pace of sales”. It provides the information regarding the rate at which the process should be producing. The next step is to create a continuous flow, where the item passes without delay through each step – one piece at a time production. Where continuous flow is not possible supermarket-based pull system should be used. Rother and Shook (2003) also insist on scheduling for the production upstream in the flow, so the quantity is known from the beginning. Leveling the production flow means alternating between the smaller batches of different products, segmenting them by the common characteristics. That practice helps to respond much more quickly to the customers’ requirements. At the same time by running the leveled production the changeover time has a trend to improve enabling to keep fewer inventories and solve faster problems.

2.5 Waste Management
Pascal (2002) claims that waste elimination is one of the most effective ways to increase the profitability. The seven wastes concept originated in Japan was developed by Toyota’s Chief Engineer Taiichi Ohno. He stated that in order to eliminate waste it is essential to understand what waste is and where it exists as well as what is the source of waste. The typical waste found in manufacturing environments consists of:

2.5.1 Motion
Wasted motion has both a human and machine element (Pascal 2002). This waste is related to workplace ergonomics and is seen in all examples of walking, lifting, stretching, twisting, bending and reaching. From the poor ergonomics arise health and safety issues. The employees’ tasks with excessive motion have to be redesigned. At the same time the waste of machine motion is usually caused by the big distance between specific machines that require unnecessary machine/item movement, therefore the location factor has to be considered.

2.5.2 Waiting
The waste of waiting occurs when goods are not moving and the worker has to wait for material or machine to process a part. According to Baudin (2002) typically in traditional batch-and-queue manufacture the total production time is wasted on waiting for the process. Waiting causes delays and increases the lead time. The main reasons for that are poor material flow, too long production runs, and too great distances between work centers. Linking processes together via a value stream map can radically resolve the problem.
2.5.3 Conveyance/Transporting
Conveyance waste includes the large-scale waste caused by the inefficient workplace layout, too big batch size. Liker (2004) claims that transporting product between processes is a cost and adds no value to the product. Transportation can be difficult to reduce if the equipment is too complicated and too big to be moved, however production in small batches could be applied to improve the conveyance problem. If the machines can be relocated it is important to figure out which processes should be next to each other. Mapping product flows can make this task easier to visualize.

2.5.4 Correction/Rework
The waste of rework is related to fixing the defective products. It has a direct impact on the bottom line, comprises all material, time, and energy and causes scrap while creating tremendous costs to organization. Pascal (2002) admits that the additional costs include waiting for inventory, re-inspecting, and rescheduling as well as capacity loss. Through employee involvement and continuous improvement actions it is possible to reduce rework.

2.5.5 Overprocessing
Often term overprocessing is related to doing more than customer requires. Many organizations use expensive equipment instead of more appropriate simpler tools. In addition companies attempt to reach high asset utilization by recovering the high cost of this equipment. Production in exceed appears when keeping the products in storage is practiced, overfilling the capacity and producing just to boost the specific department’s production turnover. However it is estimated that investing in smaller, flexible equipment and combining steps can greatly reduce the waste of inappropriate processing.

2.5.6 Inventory
Waste of inventory appears when keeping unnecessary raw material, parts and Work in Progress and that causes overproduction and waiting. Moreover excess inventory tends to hide problems, which must be identified and resolved in order to improve operating performance. It also increases lead times and consumes productive floor space. By achieving a smooth flow between processes it is possible to improve manufacturing services and cut inventory.

2.5.7 Overproduction
Liker (2004) refers to Taiichi Ohno and point out that the overproduction is the reason of all manufacturing problems and a root cause of other waste: motion and waiting. Overproduction implies manufacturing an item before it is actually required. Overproduction is highly costly to the manufacturing plant, since it involves the extra workers and machines, extra parts and materials, extra energy, oil and electricity, extra forklifts, tow trucks, pallets and skids, large warehouse maintenance. The “Just in Time” principle is applied to solve that problem, because here every item is made just as it is
needed. The simple solution to overproduction is to stop production. The idea is to link the schedule and production in a way that the produced item is immediately sold/shipped and in that way capability of machine’s changeover/set-up is improved.

Underutilization of Employees potential as a waste has been added to Ohno’s original seven wastes. Only by relying on employees’ creativity, applying their ideas into practice, involving them in decision making organizations can eliminate the other seven wastes and continuously improve their performance.

![Image of 7 Wastes (Luvata Production system 2007)](image)

**Figure 2.5** 7 Wastes (Luvata Production system 2007)

### 2.6 SMED

According to Summers (2009) setup time is the time needed to start the first good part after the last good part is finished in the previous series. Setup time is a non-value adding activity and thus is considered as waste that has to be reduced or eliminated. The Single Minute Exchange of Dies (SMED) is a standard approach to reducing changeover times. It was first developed by Shingeo Shingo within a project which involved the exchange of dies at car manufacturer Toyota. SMED analysis enables operators to examine the sources for long changeovers and one can develop a plan to manage this problem. According to Basu (2004) successful implementation of SMED can bring extremely good results in changeover time reduction. King (2009) advices to follow these four steps in order to implement SMED analysis:
1. Identify external tasks in order to move them outside of the changeover time. Some of the tasks usually done during a changeover can be done before or after the actual production process. These tasks include things like bringing all of the necessary tools/parts to the equipment and moving them back. These external tasks take a lot of time therefore excluding them from the changeover shortens changeover time considerably.

2. Check if any remaining internal tasks can be modified as external tasks, such as pre-assembly of any apparatus or tooling required, and any required preheating of new components that could be done before being installed on the equipment.

3. Simplify the remaining internal tasks. Standardize the equipment and spare parts, use marking to speed up the activities. Practice poka-yoke (mistake-proofing) techniques to be sure that the item is installed correctly.

4. Perform internal tasks in parallel. If at least two operators perform tasks at the same time, the total changeover time can be reduced as well.

The concept behind SMED is to study everything that happens during a changeover to decide what activities can be moved outside the changeover time and how the remaining internal tasks can be simplified, shortened and done in parallel. The advice from the author is to start with development of a detailed process map and timing diagram. In that process video recording is also a very effective tool, since it provides visual information of what actually happens during the changeover. Point-to-point diagram or “spaghetti charts” highlights the excess motion and wrong location, and therefore is an opportunity to reduce the time operators spend walking and moving or bringing tools/parts.

King (2009) makes a summary of the kinds of tasks often required in a process line. It includes:

- Collecting tools
- Getting replacement parts
- Cooling down or heating the equipment
- Mechanical modifications
- Calibrating, adjusting
- Discarding used parts
- Putting tools away
Groote (2006) represents a few problems in understanding the changeover:

1. “Changeover is not avoidable and has to be accepted even if it creates bottlenecks”- due to that reason changeovers are usually avoided by running very large batches that creates even bigger problems;
2. “Reduction of the changeover time is only a problem of production” - however this is not true. It is also a design problem, location of the specific items matters a lot;
3. “Changeover time is an actual time of exchanging a few parts“ - nevertheless changeover starts at the moment the last item of product A is produced and lasts until the correct product B is produced;
4. “Changeover is a technical issue and is costly” - changeover is a combination of organization, method and technology, therefore it is important to consider all three aspects when reducing the changeover times of machines.

The product changeovers are often costly; moreover, sometimes they consume a lot of time. Therefore running long production campaigns seems to be a wise solution to minimize the overall penalty incurred with changeovers. This causes higher work-in-progress and finished goods inventory. It also creates other forms of waste: motion, when the material must be conveyed to a remote storage location, overproduction, reduced operational flexibility and profitability.
It is important to reduce the change campaigns so to boost the capacity and in that way meet customer's needs. Following Shingo's methods and techniques Toyota reached a tremendous success in changeover time reduction from three hours to fifteen minutes and later to three minutes.

2.7 Visual management

Poling and Nash (2007) claim that the most practical way to visualize information is to display it through the simple visual aids such as standards, examples of good and bad, and methods for inspection. The variety of the visual aids depends on the creativity of the manager/team members and is designed to achieve the desired results.

One point lessons concept is short visual presentations that are designed to show what should be inspected and how to perform the inspection. These lessons are often created on paper and rely heavily on photos with very little writing. The reason to use the visual pictures is to guide the employee through the process. Through a standard visual work order employees immediately know exactly where to go and what to do. This means they begin their duties instantly, and this improves shift's efficiency and productivity. In other words visual tools provide all workers with clear and concise communication.

In many manufacturing processes sample boards showing different product qualitative/quantitative characteristics guide workers to differentiate the various levels of parts and produce only good pieces. Additionally this action enables workers to identify and remove defects from the process. Other types of recommended visual aids include photographs, drawings, and diagrams, samples of substitute parts, go/no go gages and simple electronic tests. The underlying concept is the attempt to provide employees with the clear information needed to best perform their tasks. Since verbal and written instructions sometimes cause confusion it is difficult to work efficiently. Visual instructions offer the simplicity employees need.

According to Neese (2007) common visual management tools consist of:

- Production Andons - display real-time line performance to goals
- Target quantity compared to actual production
- Jidoka lights - turned on by shop floor employees if an abnormality occurs on the line
- Baywatch - give supervisors an eagle's-eye view of the whole floor
- U-cell manufacturing assembly
- Supermarket to easily and quickly find materials
- Color-codes, labeling
- Arrows on the floor to guide the production flow
2.8 Standardized work

In the lean standardized work focus is on reducing waste within a process. Standardization is not a process of creating standard work instruction, but it is the basis for continuous improvement. According to Liker (2004) standardized work is a key facilitator of building the quality after the process variation has been reduced. The practical evidence is directed from Toyota zero defects production, that is done through the standardized work. In this case standardized work sheets are usually selected as a mean to solve the deviation problem. The sheets have little writing and provide mainly the visual information on the standardized task performance. If the tasks are performed accurately according to the standardized work sheets and still produce variation the standardized work is improved and developed further – that is a base for continuous improvement. These sheets are mainly used for operator trainings and are put outward for the team leaders to audit if it is being followed by the operator. Liker (2004) claims that any good standardized task procedures have to be developed by operators and have to be simple and practical enough to be used every day by the ordinary operators. Moreover, set standards connect people, equipment and material to develop the most efficient sequence, location and practice. The aim of standardized work usually is to improve productivity, reduce variation in the work performance and improve the quality of the product.

The Insyte Consulting group offers the typical process of implementing standardized work:

- Study the process and document the specific steps (problems and process wastes);
- Analyze the problems, take action to solve the problems and reduce/eliminate the waste;
- Implemented the identified solutions into the work;
- Establish new standards and measure the results;
- Repeat process cycle in an effort to achieve continuous improvement.

The Insyte Consulting group shows the benefits of Standardized Work:

- Increased productivity;
- Simplified training of new operators;
- Established basis for continuous improvement;
- Reduced scrap and rework;
- Improved safety.
Standardization implies a very fixed organization of work and the fully standardized work tasks. In the lean enterprise the common practice is to display each standard operation on a sheet which states the sequence of the operations, right location and correct actions worker must perform. Pardi (2007) admits that such standard work performance is evaluated and developed further by the team members.

Pardi (2007) studied two ways of setting the standards in the operations (see Figure 2.8.2) First he describes the bottom-up sequence (A) of standard task design, where the ideas for the standard operations come from the shop floor and the operators are the main initiators of the changes. In the bottom-up sequence the whole team communicates to their team leader their intentions to modify the standard work. If the team leader considers that as an attractive proposal he delivers the idea to the higher boss or directly changes the standard work sheet.

The second way to design standard operations is top-down (B) sequence. Here a group leader comes up with a new design of the standard task to boost the production results. Usually these ideas have another impact on the team, since often they imply shift reduction or takt time adjustment that makes people struggle with a new set of things. At the end the team members have a right to propose minor modifications for the designed standardized work tasks.

The vital difference between bottom-up and top-down activities is the greater involvement of the supervisors and the senior management in the first approach and building an organization with a stronger role for team members in the second approach.
2.9 Standardized work sheet

Liker (2004) describes the standardized work sheets or cards as the sheets of paper with the illustration of the specific process or location in the company. The visualization of the standard procedures is efficiently reached through several pictures of the critical process steps with little marking (writings, arrows) directly on them. This way of demonstrating the right task performance is straightforward and implies no additional reading and memorizing. The standardized work sheets are used for training of new as well as experienced operators and to determine the best way of doing their jobs. Since these standardized sheets are developed by the operators and team leaders they are highly practical and concrete. Moreover, it is more the practice than exception to change and improve the standardized sheet information, since after the improvement campaign is initiated it becomes obvious that there is more space for improvements.

The location of the standardized work sheets is also important – it could be either close to the machine or office work center or in both places simultaneously. Liker (2004) insists on putting these sheets away from the operators and let team leaders control operators' performances. However Toyota has the standardized work sheets in many different places while going down the production process. Such way of showing the right tasks is very proactive and enables transparency of information and fast understanding of the visualized production process.
2.10 Spaghetti diagram
Magnusson et al. (2003) finds spaghetti diagram as the visual representation of actual production flow. Spaghetti Diagram is done within a group of operators and those that use the process. The basic to create a spaghetti diagram is to record the main steps of the people working in the process, to use directional arrows for the routes and to put it on the paper. It is important to include all routes even if the diagram becomes cluttered. It is also advised to record a time for each activity, define the specific place for material as well as calculate the distance of the route. After finalizing with the current state a separate spaghetti diagram showing the ideal state should be created. Here all non-value added tasks are eliminated or reduced if possible. The Spaghetti diagram visualizes the actual routes, distance and permits to cope with identified obstacles.

2.11 Ishikawa diagram
Dale (2003) describes Ishikawa or fishbone, or cause-and-effect diagram as a tool that shows the causes of a defined problem. The purpose of Ishikawa diagram is to break down root causes or potential factors causing an overall effect. Causes are grouped into several typical categories: man power: employees/operators involved in the process, methods: how the process is performed as well as policies, procedures, rules, regulations, machines: equipment, tools, instruments required to get done the job, materials: raw materials, parts used to produce the final product, measurements: data generated from the process that is used to evaluate its quality, milieu: conditions, such as location, time, temperature, and culture in which the process is operated.
3 METHODOLOGY

3.1 Qualitative research method

According to Maxwell (2005) there are basically three types of qualitative research: descriptive, exploratory and explanatory. This thesis aims not only to describe the particular context, but also to define and apply the solutions to identified problems. The basis for investigation is the case study, which deals with the problem explanation and solutions development. Most of the data collected has a qualitative character, but in the case study methodology it is possible to use both qualitative and quantitative data.

The aim of the quantitative research is to collect quantitative information about items in a population and generalize the results. On the other hand qualitative approach is used to understand and find an answer to complex questions. This thesis deals with qualitative approach and solves the problematic issues of the specific company. During qualitative research the evidence data is collected to support future findings. The advantage of qualitative research is its ability to provide comprehensive description about the individual performance, attitude, opinion and relations.

<table>
<thead>
<tr>
<th>Table 3.1</th>
<th>Comparison of qualitative and quantitative methods (M. N. Marshall 1996)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td><strong>QUANTITATIVE</strong></td>
</tr>
<tr>
<td>Philosophical foundation</td>
<td>Deductive, reductionalist</td>
</tr>
<tr>
<td>Aim</td>
<td>To test pre-set hypothesis</td>
</tr>
<tr>
<td>Study plan</td>
<td>Step-wised, predetermined</td>
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<tr>
<td>Position of researcher</td>
<td>Aim to be detached and objective</td>
</tr>
<tr>
<td>Assessing quality of outcomes</td>
<td>Direct tests of validity and reliability using statistics</td>
</tr>
<tr>
<td>Measuring of utility of results</td>
<td>Generalizability</td>
</tr>
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</table>

Mack et al. (2005) claims that qualitative methods are normally very flexible. It is easy to switch to different questions in order to improve the interaction between the researcher and the study participant. Qualitative methods ask mostly open questions leaving the respondents the freedom to answer what they think is appropriate, more than simply “yes” or “no.” In addition the relationship between the researcher and the participant is often informal; therefore participants have a motivation to provide a larger explanation and more details about the specific topic. Consequently the researcher has to listen
carefully what participants say and respond immediately by asking why and how and other questions.

In quantitative methods, while studying a random sample provides the most appropriate conditions to produce the general results of the population, it is not the best way to understand the complex issues related to the specific problem area and specific population.

Marshall (1996) says: “Choosing someone at random to answer a qualitative question would be analogous to randomly asking a passer-by how to repair a broken down car, rather than asking a garage mechanic - the former might have a good stab, but asking the latter is likely to be more productive”. He believes that during the scientific research it is vital to use the previous experience. It is fair to admit that to enrich previous experience in this thesis work the scientific literature on lean manufacturing was closely examined. However the practical knowledge of implementation of lean tools has been gained through the research work and can be considered as a valuable source of experience in the further research work.

This thesis intends to test the research hypothesis and to solve the defined problems. Facing that fact the research questions were developed and the analysis of the casting production and employees’ operations was performed. The thesis conditions also imply the practical implementation of the main solution - the development of the standardized work sheets that could be used as a mean to make the working standards transparent and available to everyone.

### 3.2 Case study research

According to Yin (2009) cases studies investigate a contemporary phenomenon in depth and within its real-life context. The case study inquires coping with the technically distinctive situation in which there are many variables of interest. It also relies on multiple source of evidence such as triangulation and provides the basis for data collection and analysis. According to Gummesson (2000) in order to study any particular process it is required to use observations and participations in line with the employees, sometimes even intervening the actual process. This is the core of the action research, since participant observation imply active information gathering and analysis, both of the performed operations and the operator. In-depth interviews and observation are also an important part of action research.

Research of Luvata Finspang has a single-case design and is organized around the casting foundry solely. It concentrates on studying the well-formulated theory of standardized work and lean production. Even if there were some studies done in the metal industry before the case in Luvata Finspang is unique, and the challenge here is
to apply the existing theory on the particular foundry, rather than extend the theory or develop a new one.

Yin (2009) emphasizes that within the case study research it is important to prepare sufficient questions and ask them during the action, not just before or after it and listen what the respondents say, paying big attention to their body language. Yin advises to record the data for detailed studying afterwards and to take other appropriate actions such as illustrations, recording the interviews. That would enable the close to the real interpretation of collected information. The author also claims that it is efficient to create and follow the case study protocol that would provide the general overview of the case study issues, field procedures, case study questions and a guide to the case study report. During the case study in Luvata Finspang the case study protocol was not used in the formal way, although some most important points were considered and applied in practical research design.

The problem of researcher is to distinguish what collected data to use in the analysis. The fact based data is extremely important though tricky to define. Therefore the methods used to assemble the facts are sometimes questionable. The research based on facts is more reliant; however there is confusion when separating real facts from the facts based on the interviewers’ opinions. As a solution Gummesson (2000) reminds about the triangulation term. In practice, triangulation means application of two or more methods on the same research question to increase the reliability of the result. Therefore if the data collected with multiple methods differs the research has to be redesigned and repeated.

3.3 Data collection methods

Yin (2009) also presents six sources of evidence used in doing case study: direct observation, participant observation, interviews, archival records, and documentation and physical artifacts. During the research in Luvata Finspang foundry following sources of data were used:

- **PRIMARY**: participant observations, in-depth interviews;
- **SECONDARY**: literature study, documentation study.

### 3.3.1 Primary data collection methods

The participant observation was a time-consuming way of collecting the data. It took more than two months to observe the operators’ tasks and take notes. Two to three days per week for three-four hours employee observation (working together) of the operator’s work in each production center was performed: melting, casting and rolling as well as additional 5 observations of the montage process were added during the third thesis month. It was rather difficult to document the data properly, since it is hard to write down
everything that is important while interacting with participants and observing their performance. Moreover, in the beginning it is hard to notice what is important to write down or ask, due to complexity of the unknown processes and comprehensive information. Therefore instead of relying on the memory, the data was immediately written down after each observation was completed. Additionally pictures of the working areas as well as process illustrations and filming were correspondingly considered as useful tools and were used to learn the production process and to identify the problems. The participant observation is a very valuable source of data since it involves conversation with actual employees in the real work centers and observation of genuine task’s performance. Nevertheless the documented data can be biased, since it is produced within limits of a subjective exercise. Therefore there may be a difference between reporting what has been observed versus interpreting what has been seen.

In parallel with participants’ observations 10 in-depth interviews with engineers and casting chief and more than 25 informal interviews with operators were held. The purpose of the informal interview with operators was to facilitate the deeper understanding of their performed activities as well as to gather additional information, such as their opinion about the processes problems and the possible improvements. However while interviewing the observation operators might express their own personal opinion or could try to perform according to the rules just to show that they do follow them. So a place for observed bias (personal opinion, saying what has to rather than do) is open.

According to Marshall (1996) there are three broad approaches to selecting a sample for a qualitative study: convenience, judgment and theoretical sampling. It is fair to say that judgment or purpose sampling was applied in this thesis. During the research work the most efficient and experienced operators and engineers (key informant sample) were selected for observations and to answer the research question; moreover, some less experienced operators (deviant sample) were selected in order to define the weak areas of performed tasks and find a concrete solution to improve the task execution. The big advantage was an opportunity to study a big number of operators, whose working experience reaches 10-30 years in the same particular company. The Casting department chief was a reference person who recommended the useful potential candidates: both key informant samples and deviant samples. That is also a subject of snowball sample technique.

In addition to the interviews with operators frequent interviews-meetings with the casting department chief and technical personal were held. During the in-depth interviews there were several pre-established questions, such as:
• What is the biggest problem in each work center considering operators’ manual machine execution?
• What has been done in order to solve the performance variation problem during the last 3 years and what is done now?
• What are the most frequent reasons for the break-downs/unplanned stops in casting department?
• What are the biggest issues during the changeover/montage?
• How the standard tasks in the work centers have to be carried out according to instructions?
• What are the duties of the operators during their working time?
• How do the results of the executed work vary depending on alloy casted?
• Which shift is the most experienced and what is the reason for a variation of the casted alloy quality between shifts?

Even though the questions were structured according to the plan, the situation governed the informal design of interview and the interviewers were free to ask the appropriate question without any specific occasion. The informal interviews provided a basis for quick respond and new direction of the research.

In the research process it is important to maintain confidentiality of the participants. During the research in Luvata Finspang the confidentiality of the operators was treated as a rule and it ensured that participants can not be linked to the provided data, therefore no name or other personal information was collected.

3.3.2 Secondary data collection methods
Since the lean production techniques and tools are thoroughly studied and explained in the official literature it was very useful to make a constructive study on that topic. Therefore the books on lean and related topics were selected for the report. The general knowledge on Lean principles was gained from Womack et al. (1996) and Pascal (2002). The method of value stream mapping was studied with the help of Rother and Shook (2003). Waste management techniques were collected from the studies of Womack et al. (2003). SMED analysis is based on Groote (2006) findings. Standardized work sheets are designed according to the suggestion from Liker (2004). Other important books and articles, which influenced this work, may be found in the reference list at the end of this thesis.

In addition several exclusively practical articles were collected online and used as a reference: Insyte Consulting group “Standardized work”, King (2009), “SMED in the process industries” and Neese (2007), “Driving Lean through the visual factory”. Some data was also collected using Lean tools: Spaghetti diagram and Ishikawa diagram.
The documentation study consists of a great variety of the documents: notes, calendars, diaries, administrative documents, reports, internal records, minutes of meetings, formal studies of the same case and articles in mass media or newspapers.

For the case study in Luvata Finspang all available online internal documents were studied and the collected information was frequently updated with the weekly company’s reports. Moreover, some tables and diagrams with the quantitative data were borrowed from the company’s intranet database. Additionally several formal studies on standardized work issues were gathered through the Luvata global site as well as separate local studies in other departments of foundry.
4 CASE STUDY OF LUVATA SWEDEN AB FINSPANG

4.1 About Luvata
Luvata is the leading international metals supplier of solutions, services, components and materials for manufacturing and construction. Luvata’s solutions are used in industries such as power generation, architecture, automotive, transport, medicine, air-conditioning, industrial refrigeration, consumer products and construction. The company’s continued success is attributed to its longevity, technological excellence and strategy of building partnerships beyond metals. Employing over 7,000 staff in 18 countries, Luvata works in partnership with customers such as Siemens, Toyota, CERN, Shaaz, and DWD International. The product range consists of 14 advanced manufacturing solutions starting with industrial, architectural, heat transfer fabrications and finishing by the renewable energy solutions and superconductors.

Figure 4.1 Luvata locations by countries (Luvata Sweden AB 2009)

Luvata operates in 18 countries: Austria, China, Finland, France, Germany, Italy, Korea, Malaysia, Mexico, Netherlands, Poland, Russia, Singapore, Spain, Sweden, Thailand, United Kingdom, United States.

Vasteras is a business center of Luvata Sweden AB. Luvata in Finspang produces copper strips for automotive and electrical applications. Luvata’s range of heat exchangers and coolers is produced in Soderkoping. Here air to liquid heat exchangers have been developed and manufactured. In addition to heating, cooling and heat recovery in ventilation systems, heat exchangers are used for the indirect cooling of industrial equipment.
4.2 Luvata Finspang

4.2.1 Organizational chart
In the head of the organizational chart of the Luvata Finspang stands the head chief of the foundry who is responsible for the production process and results. The personnel administration (PA) manager is in charge of human resource management questions, employees’ maintenance, organizational activities and employees union’s issues.

The heads of three production departments: casting, rolling and slitting are directly accountable to the foundry chief and belong to the management decision board together with the rest leaders of the departments. The foundry chief is a head of maintenance department as well, while the rolling chief is a leader for the Luvata Production System (LPS). The last two departments, Logistic and Quality & Environment are run to support the rest of the business.

![Figure 4.2.1 Luvata Finspang organizational chart (Luvata Finspang 2009)]

The organizational chart is not broad and there are very few people working in the entire department. That is because the resources are shared among the Luvata production Finspang and Vasteras centers.

4.2.2 Production
The pick performance of the Luvata Finspang in 2004 generally is the evidence of the world economic growth. At that time the production was extremely costly, but the customer demand was overwhelming. The latter reason caused the blind effect on the real situation in the company, creating the incorrect perceptive of the Luvata
achievements and weakened the resistance against economic crisis, when the rapid production decline took place.

In 2004 the number of employees in the casting department reached 350, however after the recession only 160 were left.

Since the main Luvata Finspang customers were automobile producers the copper coils’ demand has reduced more than twice in 2007. The motive for that was the launch of aluminum substitute in the car spare parts, previously produced from copper. By that action the car producers intended to reduce their production costs. Nevertheless the big truck companies still require the copper coils due to the high temperature resistance of that material.

![Figure 4.2.2a Production in Luvata Finspang (Luvata Finspang 2010)](image)

An electrical application company is another big customer of Luvata Finspang. The production potential here is very high and tends to increase. The demand on the specific alloy has increased providing Luvata Finspang with a challenge to boost production and improve the quality.
4.2.3 Casting department

The Luvata Finspang production facility consists of three main departments: Casting, Rolling and Slitting. Testing, developing new and improving current alloys is an on-going routine in the product development department.

Since the research work was done only in the Casting Department, it will be the center point of this report and consequently the description and analysis of the other production departments will not be included in this thesis. The production process in the casting foundry is organized according to the continuous flow principle and is repeatedly interrupted by the montage stops for different alloys. The characteristics of the alloys are governed by the customers; therefore close cooperation with them is necessary.
The organizational chart (see Figure 4.2.3b) is designed according to the process and follows the production flow in Casting Department. The casting chief is in charge of the production process in the casting department. Therefore he has a direct responsibility for the results in three operational centers: melting, casting and rolling as well as keeping close relations with the shift team leaders. The team leader is the main support for the operators, the information sharing and exchange point between the operators and the chief. However since there are only 5 people working on the shift the casting chief has an easy contact with each one of them. During the evening or night shift the team leader takes the role of the casting chief. As a support there are 6 more day-time employees in the casting department and the rest resources are shared among the whole foundry.
It is necessary to add that the operators switch the work centers once in a while in order to keep everyone aware of the work specific in each work center and the whole process in general. However, there are only few operators who are flexible enough to work in all three work centers and the rest of the team usually switch between two work centers.

4.3 Luvata Production System (LPS)

4.3.1 The Luvata Way
The Luvata Way is the “way” and the “why” and the “where” and the “when” of all the things Luvata does. Luvata is eager to succeed with the strength of the people that carry out its strategies. Those people are driven by the culture of the company— the knowledge, emotion, ambitions and values. Luvata way is about people and common culture, shared goals, aspirations and goals. The Luvata Way involves people in achieving common target, where, when and why. It explains how plans, plants and projects fit together into one picture, and how the acts and attitude of every person in every plant contribute to our progress.

The Luvata Way is all about communication and motivation. Since the period of drastic changes is almost over today Luvata Finspang transforms its production according to lean manufacturing principles.
4.3.2 The vision of LPS

The LPS vision is stated as:

- Empowering capable people to operate high performing businesses by continually reducing waste in all daily activities;
- Continuous Improvement;
- Waste Elimination;
- “Right from me”;
- Respect for the individual.

LPS is not fixated on labor productivity. It is about understanding what is important to the customers, and the value adding activities that they are willing to pay for. LPS is about eliminating waste in the processes, reducing inventories and shortening cycle times between order and ship dates. This production system aims to reduce costs, expand capacity via more efficient production and business processes. LPS is about working together to improve businesses so to be a number one in class.

4.3.3 LPS house

![Figure 4.3.3 LPS house (Luvata Sweden AB 2007)](image)
The Luvata Production System House embodies the principles that guide in decision making. As with all houses, a strong foundation is vital. The founding principles “Respect for the Individual” and “Waste Elimination” are equally important.

- LPS strives to continuously eliminate waste in all daily activities.
- Everyone should be treated with Respect regardless of gender, race, religion, age. All decisions and actions should not harm any employee.

The first floor comprises standardization, visual management, leveling production and feedback.

- The work should be standardized as much as possible to reduce variability in the production facilities. This is the base for continuous improvement.
- Working environment needs to be visual. This would allow deviations to be easily seen.
- To ensure that equipment and resources operate smoothly it is vital to level the load.
- Configuring working environment to allow quick feedback enables quick reaction to deviations.

The walls in the LPS house are mutually dependent.

- The foundations for all achievements are people. Luvata builds skills to develop people who are passionate and capable in their roles.
- Performance management is central to all Luvata activities. Systems are put in place to manage performance and drive.
- Luvata tries to configure its assets to enable material and information to flow through its plants: reducing and controlling inventory and lead times.
- Luvata operates capital-intensive processes and has already invested in expensive equipment. To be competitive Luvata aims to improve the overall equipment effectiveness.

The principles contained in the roof serve as overall decision making principles. All decisions should take Safety, Quality, Lead-time and Cost aspects into consideration.

4.3.4 LPS transformation

Luvata has adopted the lean production system; however, the transformation into a Lean company was not smooth. The barrier was an established practice to manage a foundry in a traditional way, creating useless operations and providing the insufficient management. Besides that, Luvata production facilities have mainly very big, very expensive, and often immovable machines. Therefore LPS focuses on four critical components that serve as the basis for direction of continual improvement:
1. Overall Equipment Effectiveness (OEE): LPS utilizes a standard international definition of OEE that helps to measure and quantify machine output and efficiency. Since the machinery is so capital intense, it is essential to maintain and operate equipment to the best of its capacity.

2. Flow: Flow is another very important and essential component of the Luvata Production System. Everyone is aware of the high price of copper these days. In order to manage the efficient use of machines and solve the problem with high inventory levels it is important to focus on improvements of the scheduling and operating practices. This in turn reduces inventory, improves delivery performance, and overall profitability.

3. Performance Management: The term performance management implies that everyone is responsible for managing their own performance. LPS takes this concept step further by helping to install procedures and tools to ensure everyone knows how their performance affects the performance of the business.

4. People: In order to be the best it is needed to be motivated. LPS therefore recognizes the need to develop training plans, improve working environments and create positive culture.

LPS transformation is focused on one value stream within a plant. Luvata initiated LPS pilot transformations at different facilities and achieved significant improvements. On average OEE on critical machines has improved by 10 points. Inventory reductions have averaged to 41%, and returns have decreased by 50%. Although most of the work in the pilot transformations occurred on the shop floor, everyone in the company was involved. It is important to get involved for everyone to understand and support the new way of doing business.

Implementing a production system is a complex task. The Luvata Production System uses a structured approach that implements production system elements and starts each facility on a journey to transform its culture. The LPS Transformation Approach is a rigorous 16-week project plan that implements key changes in the way a factory makes its products, solves its problems, and manages its performance. The approach consists of 4 work streams over 4 phases of the pilot project. The end of this 16-week period only marks the beginning of building a successful production system. While the LPS approach is the same from plant to plant, the details of the transformation work streams are specifically designed for each plant's business needs.
4.3.5 Finspang Pilot Update

After 16 weeks the LPS pilot in Finspang has been successfully completed. The 6 men team implemented changes in the areas of Flow, OEE and Performance Management.

1. Flow:
   - Casting cycle established in the Foundry. The casting cycle was reduced from 2-3 weeks to 1 week. Previously the casting department produced coils 2-3 weeks in advance before the rolling department actually needed them; all that time the finished coils were waiting for the rolling and slitting machines;
   - Supermarket implemented between the foundry and the rolling hall. This decouples the 2 departments reducing the effects of variability. Orders can be started based on delivery dates and not on the casting cycle which results in reduced lead time;
   - FIFO lanes were introduced in front of all pilot machines.

2. OEE only in the rolling department:
   - Set-up reduction using the SMED method was implemented;
   - Standard speeds were implemented in the rolling mills and slitters;
   - S implemented in 2 rolling mills.

3. Performance Management:
   - A new report structure was implemented using machine boards where machine’s performance is tracked every 2 hours;
   - End of shift meeting implemented;
   - Morning meeting redesigned to capture problems during previous day (LPS room and morning meeting at the casting department is a forum to keep the information shared between the whole factory within different managerial and operational level.
5 RESULTS AND ANALYSIS

5.1 Foundry map

The foundry map illustrates three work centers: melting (M.), casting (C.) and rolling (R.). The first two are located on the first floor (marked with the bold line) and the rolling mill is located at the ground floor. The work centers’ offices are situated next to the working centers’ machinery in order to keep walking distance to the specific tools, machines and equipment.

This is the top-down view on the casting foundry map. The production flow is easy to grasp, since it starts with the top left corner to down-right and process to the next department. Orange arrows show the direction of raw material (orange box) of the both outside and inside scrap as well as cathodes.

First the raw material is driven to the lift that delivers it further to the wagon. During the charging operation the wagon brings raw material directly to the melting furnace (M. furnace) approximately 5-6 times, where it is melted to the right consistency and temperature. These tasks are performed by the operators in the melting work center, which is the first in the casting foundry. As soon the right alloy conditions have been reached and the holding furnace (H. furnace) signals to be ready for melting over, the
alloy is transferred to the second work center - casting. Here non-stop strip casting procedures are mainly controlled by machines until the planned/unplanned stop occurs. During the stop the casting and melting operators perform the necessary montage that lasts minimum 3 hours.

Nevertheless when the process is not being interrupted by the stops the casting machine casts 27 mm copper strips, that process is directed further down to the ground floor to the rolling mill. At the casting work center mainly the qualitative issues of the coil are stressed, therefore the casting operator is responsible for checking the casting process and take adequate actions in order to prevent bad quality and unplanned stops.

The last work center – rolling – makes the coil 1,2 mm thickness and divides the single 36 tons coil into 9 coils as well as separate the scrap. The scrap is being reused directly in the casting foundry and the finished small coils are marked with the colored code (green, yellow and blue) depending on the quality of the coil and transported to the next Rolling department just behind the door.

5.2 Final product - Copper coils

An assortment of copper coils produced in Luvata Finspang reaches 7 types. Each of the coils has specific quality requirements for different metal component. The color coding system is applied to identify the defects – holes in a coil. Each coil is marked with the appropriate colored circle (green, green-white, yellow, yellow-white, blue and blue-white). The green color means that the coil is of the best quality, yellow stands for the limited number of holes in the coil permitted and the blue color means the worst quality. When the number of holes is higher than the lowest customer expectation boundary the coil is directed to scrap.

In order to monitor the holes while casting the coils the casting operator's office has a display that shows the flow of alloy and the dots of different color: from the grey to red one representing holes in the coils. The grey dot means a very small hole that does not affect the quality. The red, blue and the rest colored dots mean a poor quality. Therefore this coil will be used as a raw material again. During the thesis work several possible sources of holes were noticed:

- Oxygen (goes in through the bad protection, sews in montage of graphite, gable, etc.);
- Air in water cooling system;
- Exceed of the necessary amount of P (phosphorus), rarely Te (tellurium), Sn (tin);
- Cleaning the tan-dish holes increases speed instantly (shocks the system);
- Speed of transaction of alloy from the melting to the holding furnace;
- Leftovers of soot after casting two specific alloys;
- Waiting too long to make necessary action;
- Chill mold temperature reduction dramatically increases alloy temperature.
5.3  Production process

5.3.1  Melting work center

The Appendix 3 shows the detailed steps that operator performs in melting work center. The cumulative average time is 96 min. While two melting operators execute their duties in parallel they still alternate each 48-55 min to melt over/move the alloy to the holding furnace. That makes the melting process follow continuous flow production principle, since the holding furnace is never empty. The inventory occurs in the melting furnace instead when the casting machine breaks down. That causes the unplanned stop to be initiated during which a lot of inventory is waiting to be transferred to the casting work center.

The melting work center is the first place to create system problem, starting with the wrong raw material selection and incorrect alloy consistency creation and finally choosing too high speed of melting over to the next process step. The study of melting process showed the evidence of big problems in process handling and the standard task performance. Based on practical evidence lean theoretical studies were applied to develop the ideas for improvements in melting work center, as well as the rest two in casting foundry.
5.3.2 Casting work center

The most frequent problem for the casting work center is a breakdown, since this unplanned stop builds up inventory in-process and creates waste, both lead time and workforce. Often the machine breaks down because of the shortage of proactive actions or too late reaction to the deviation from the normal machine parameters. The exact cause for breakdown is rather hard to define. One reason for that is the complicated setting of the foundry machines, their technical issues, and the level of operators’ intervention. The other reason is lack of prior study and any statistical data on those issues. It is more the exception than standard to have a prepared stop if it is obvious that the machine breakdown is unavoidable. Even when the foundry runs planned stops to change the massive machine parts, adjust some tools and clean furnaces they are hardly ever transparent and are not according to schedule. All these production delays and undeveloped solutions to eliminate breakdowns create the wrong perception of the foundry processes stipulating operators to stay in these conditions for more than 20 years.

It is important to say that the daily improvements are developed and implemented in the casting foundry; however it seems to be not sufficient and too small comparing with the problem of the unplanned stop. As a reference to compare how much is being wasted during the unplanned stops it is useful to admit that the typical time spend to change and improve machine tools and settings starts from 3 h. to 7 h., and even up to 12 h., and if the production is going fine 7 tons per hour are produced. At the end the coils is finished in 5 hours and the weight of that coils is 36 tons.

It was observed the takt time for a casting operator. The time between each melting over to the holding furnace, is 56 min. (see Appendix 4). Generally saying the takt time is the time to produce 7 tons of copper coils. The casting process is run all the time until the unplanned stop occurs, following the same principle as melting process. The breakdown
of casting machine disturbs not only the melting, but the rolling and even the casting work center. During the stop the casting operators perform a highly intensive montage, which involves a lot of carrying, moving, setting of heavy tools and items.

It is rational to stress that the casting machine as a bottleneck, which decides the production capacity not only for the casting foundry, but for the whole factory in general. First of all it is important to concentrate on the process in casting work center and the montage during the stop time in particular.

Even if this bottleneck was obvious without initiating this research study no additional inventory was kept or created after the casting machine. The production of the copper coils is continuous 24 h per day, 7 days per week. The planned stops are scheduled in order to avoid overproduction. However these plans are usually interrupted by the unplanned stops due to the machines’ breakdowns. Apart from the casting machine breakdowns the rolling machine also fails to operate from time to time. After being casted the coils have to be moved to the rolling mill and since there is only one rolling mill the casting work center is forced to slow down casting in order to keep the process without unnecessary stops due to the rolling mill breakdowns. If the problem elimination is too complicated and requires more time the production has to stop.

5.3.3 Rolling work center

The production flow in casting department is not leveled in respect to the rolling work center. First of all 5 hours are spent while casting a 36 tons coil and then only 3 hours are needed to roll and split this coil in 9 small coils (see Appendix 5). In 8 hour working day a rolling operator wastes at least 2 hours that could be utilized in an efficient production process. The solution may be implemented after reducing the batch size of casted coil. More precise study and tests are required to determine the optimal production batch.
5.4 Value stream map
The current state VSM for Casting Department is shown in a figure 5.4.

5.4.1 Inventory reduction
Streaming of the production process in casting foundry covers the three work centers and their services. The orders to the suppliers are set in collaboration with planning department and depend on the sort of raw material and the specific supplier. However the ordering system is not flexible enough, since it is not possible to postpone or speed up the delivery of raw material when required. Due to the safety reasons the raw material is stored at the company at least 1 week before utilization. As a result of the complexity of ordering, transportation, communication systems and a big number of actors it is rather difficult to eliminate the inventory before Melting work center. Therefore this inventory could be considered as safety inventory, however further investigation for the boosted supply chain could be applied. The internal scrap significantly increases the amount of inventory, so should be either reduced by the improved quality in the long-run or used in melting work center as soon as it has been delivered, creating no queues and occupying no extra space in the foundry floor.

Figure 5.4 Current state VSM
5.4.2 Continuous flow
Melting work center receives the information regarding the quantity and type of alloy to be casted on the daily base as well as on the weekly scheduling of the production. This planning does not really follow the pull system and does not fully represent what the customer asks. However, since the casting parameters of different alloys vary the production follows the most appropriate ordering from the qualitative point of view. The melting process is adjusted by the casting and therefore the continuous flow principle is applied. Casting operator tracks the speed of casting copper and checks other parameters; however that step is rather machine ruled. The continuous flow here is also most suitable.

5.4.3 Leveled production
It takes from 5 to 6 hours (6 hours is only for the first coil after montage has been executed) to cast one copper coil and slightly more than 3 hours to roll the coil and split into small coils at the next work center. This situation creates a lost link condition, when the rolling process is separated from the other and is inadequate, therefore the whole casting production fails to progress in a smooth flow. In order to create a guideline to tie up the processes a casting takt time should be considered. Synchronizing both casting and rolling cycle times could be the first step towards continuous flow and leveled production.

5.4.4 Batch size reduction
Reduction of the casting cycle – reduction of the batch size is a great potential for casting foundry, however a great challenge as well. If the casting time is reduced the coil size will be reduced consequently; that small batch size will help to level the production and enable the feedback mechanism. At the same time the delivering speed to the next department could be increased and the better respond from the customers would be received. Moreover the reduced batch size can create a positive shift towards faster problem identification and solving, changeover time reduction and less inventory keeping.
5.5 Waste management
During the thesis work the following wastes have been identified and organized in a table below.

Table 5.5 Waste in Casting Department

<table>
<thead>
<tr>
<th>Identified waste</th>
<th>Melting</th>
<th>Casting</th>
<th>Casting montage</th>
<th>Rolling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Waiting</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Conveyance/Transporting</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Correction/Rework</td>
<td>✓ ✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overprocessing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Overproduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.5.1 Motion waste

- **Melting work center current state:** The motion issue is critical at the melting work center due to the large human involvement in line with machine operations. The workplace ergonomics follows the production requirement and imply a lot of walking, equipment carrying and some lifting. The melting work center is located on the second factory floor, therefore operators have to walk down to drive in the raw material and charge the lifts. Although that is not a motion problem, the only motion issue here is the excessive walking due to an inefficient work organization. The operators usually create chaos when walking up and down to perform different tasks at different times. Grouping activities according to the location is a good example how to avoid useless motion.

- **Improvement idea:** The rational grouping could also standardize the time for operation, reduce chaos and keep a safety time that could direct the process towards improvements. The procedure selected to teach operators to reduce motion is to film the process of pre-set groups of activities that follow the sequential melting work center tasks: charging, driving, analysis, melting over.

- **Casting montage current state:** The montage usually takes around 3 hours, where there is about 1 hour of walking and moving inventory and 1 hour fixing the
right size of the material, adjusting the distance between instruments, gluing, sticking, cleaning and other non-useful activities that could be done in advance.

- **IMPROVEMENT IDEA:** The video filming of what actually happens will be done to generate the most convenient way to do the montage.

### 5.5.2 Waiting waste

- **ROLLING WORK CENTER CURRENT STATE:** Waiting time for the next coil to be rolled and split sometimes reaches 5 hours and more.

- **IMPROVEMENT IDEA:** The general casting batch size reduction could level the casting and rolling cycles and improve that situation in casting foundry.

### 5.5.3 Conveyance/Transporting waste

- **CASTING MONTAGE CURRENT STATE:** Moreover the movement of the heavy items is done by operators, rather than machines. The transportation issue is critical here as well, since many heavy items could be transported to the area of montage in advance and much closer. That transportation – movement of spare parts takes too much time and too much energy.

- **IMPROVEMENT IDEA:** To define the right location of the inventory and material Spaghetti diagram is created.

### 5.5.4 Correction/Rework

- **MELTING WORK CENTER CURRENT STATE:** The waste of rework is well-known to all operators in the casting foundry. The defected coils are sent back to the melting work center to be re-melted. Those activities are very harmful since they require time, resources, materials, energy and create tremendous costs to organization. A poor protection of the melted alloy is a reason number one to create a rework, because it does not protect alloy from oxygen and directly affects the casting quality.

- **IMPROVEMENT IDEA:** In order to deal with this issue pictures of bad and good protections were taken and placed directly in the melting work centers.

- **MELTING WORK CENTER CURRENT STATE:** Another rework issue is the consistency of additives. The wrong alloy consistency is the biggest problem. When insufficient it creates additional stresses in the casting. When in excess it is a waste which spoils the whole batch.
- **IMPROVEMENT IDEA:** As a mean to train operators about the importance of the correct quantity of additives the consistency data charts were extracted from the instruction files and edited. Then they were fixed directly on the machines outside the work office and at the working table.

- **MELTING WORK CENTER CURRENT STATE:** The next rework causing factor is the speed of melting over. The operators do not pay enough attention to it because the result of melting over is not visible in melting center. The result of over speeding is discovered in the next work center by causing holes in the coils.

- **IMPROVEMENT IDEA:** So the procedure to avoid that kind of rework is to mark the level of the alloy in the furnace, so that operators would know what speed is appropriate. Another step is to display the data screen with the casting speed on the melting machine, so the operator would fill the responsibility for the performed action.

- Casting work center current state: Starting with the next work center the one of the rework reasons is caused by the operators when cleaning the tan-dish. That is an unavoidable process, however the result could be reduced by cleaning the holes more often that just after each melting over and tracking the speeds. The next reason causing bad quality and additional rework is the delay in operators’ actions. If operators would check the analysis of the alloy in some circumstances the alloy consistency could be improved.

- **IMPROVEMENT IDEA:** The solution is creating, with a help of programmers, specific signal in the computers that would attract operators’ attention and encourage them to take necessary actions. Another solution to the rework problems is to train operators to think proactively and be prepared for the sudden stops in advance: prepare equipment, new parts, preheat instruments, check their availability in the store, etc.

- **CASTING MONTAGE CURRENT STATE:** The rework waste is created by the inadequate montage performance by the operators. At times the montage is done in an inappropriate way, when the wrong parameters and insufficient instruments are used. Sometimes operators skip important check-ups or adjustments of parameters.

- **IMPROVEMENT IDEA:** As a procedure to create a strong motivation to perform the right montage DPCA cycle principle will be presented to the operators:

1. Plan your task in advance: Prepare material, item, machines in the right size and at the right place & time;
2. Do perform your tasks in the right way, follow the standardized work set cards;
3. Check if the montage item works, how well it performs;
4. Act in order to improve the machine/item performance, fix errors, adjust to the standards and run the process.
5. In general, SMED analysis is used to study the changeover process in Luvata AB Finspang.

5.5.5 Inventory waste

- **Melting work center Current state**: The level of inventory increases dramatically when the production is stopped due to the unplanned stop. At that time there is no production in melting work center. Since the raw material delivery is scheduled much earlier than production stop is initiated, a big number of delivered raw material is stored inside the foundry floor.

- **Improvement idea**: Today the raw material order is placed on the most appropriate date; therefore it is possible to follow the real need for a raw material. That was achieved due to a better cooperation with suppliers. In a short time a positive trend is expected.

- **Rolling work center Current state**: The inventory is created when the rolling mill does not work properly and some spare parts have to be changed.

- **Improvement idea**: Create a planned weekly spare parts changeover schedule and a simple check list. Assign responsible person, preferably team leader to control that.

5.6 **SMED**

The stop/montage changeover time has the highest potential to improve. Therefore SMED analysis is considered to be a rather proper tool to reduce the long montage campaigns that can sometimes consume up to 7 hours. The benefits of boosted montage process are expected to considerably reduce the montage time (from 3h. to 1h. in the beginning with the potential to decrease even more), decrease the work-in-progress inventory, stabilize the final good production and the delivery time to the customer. This would also provide a basis for creating the standardized work sheets for operators to perform the montage task in standardized way that is most appropriate for achieving the best copper coil quality.

Since the motion waste in casting montage is easy to avoid by better machinery, equipment, tools and material location this problem was the first issue that this thesis work has solved. The video recording and drawing of spaghetti diagram was applied to
study the actual roots of long montage operation. It has been discovered that 1 out of 3 hours is spent on walking back and forth in order to bring specific tool, use specific equipment or apply specific material.

There was developed a “montage box” – the box for all necessary materials to be changed during the casting montage – but it is too heavy and non-flexible to be used by operators (see figure 5.6.1).

The operators’ participation in developing the ergonomically better location in the casting foundry was vital. So first of all the explanation of the spaghetti diagram with the prototype of existing montage was presented to the operators (see figure 5.6.2). In order to improve the montage operation all equipment, materials, and tools were pictured and grouped according to their location on the spaghetti diagram. Then the two colors were used to define each item out of two categories: equipment-tools (the same almost for each montage) and material (every or almost every time new for each montage). Since there is a free space in the casting floor it is possible to implement the solution of moving montage equipment and tools closer to the casting machine. Moreover, the small elevator can easily reach all necessary items and transport them to the specific montage location.
Figure 5.6.2 Spaghetti diagram: current state montage

Later each shift was delivered an example of empty spaghetti diagram of the casting montage floor with the aim to create their own best possible locations using the principle “right from me”. After four weeks of discussion the results from all 5 shifts were collected and compared. It was obvious that operators do really understand the problem of distinct montage tools location and the threat this long montage changeover creates to the whole organization. There were several different opinions about what is the best location; however the general trend was easy to find and follow (see figure 5.6.3).
After the layout has been reorganized to minimize operator travel the first step of SMED analysis took place. The external tasks to be performed were identified in advance by casting operator, while he was waiting – watching the casting parameters. Among the external operations there is: cutting, fixing, adjusting, calibrating the optimal parameters for all the necessary materials and filling in a new mobile montage box, regularly checking the amount of the necessary materials and transporting them to the new montage place (in a short future there will be one operator assigned to fill in the montage box to follow the standardized work issue). These tasks were moved outside changeover time and reduced it by more than 0.5 hour.

Figure 5.6.3 Spaghetti diagram: future state montage
Moreover, due to the new place the actual unavoidable montage parts transportation has dramatically reduced. Lighter and flexible montage box on the wheels was developed. Moreover a new table with all montage equipment and test tools was added directly to the montage location. All that dramatically simplified the montage task. The standardized work sheets were developed to direct operators to perform all important operations in the right sequence during the montage changeover. Moreover, the PDCA cycle was introduced to operators to motivate them not only do the montage but also think proactively: plan each single action in advance, check if all equipment is ready, in its place and of the right size, then test if the montage item has been placed and fixed properly and improve or correct if it does not work.

Another SMED idea is about performing the tasks in parallel. This is a big issue in Luvata Finspang as well. Since it is not clear who is doing what during the montage the casting operator is always in charge of the montage. The casting operator mainly performs all the tasks with the help of melting operators; however their contribution to the montage is weak. That is not fair, since during the changeovers the production stops; therefore melting operators have a lot of free time and could be used as a montage resource.

The idea of organizing the montage was inspired by hospital operations where one key doctor executes the main tasks and the assistants bring the right tools and help with the rest of the procedures before and after the actual operation process. The same principle could be applied to the Luvata Finspang AB casting foundry. Due to the SMED improvement the total changeover time can be reduced significantly.

### 5.7 Visual management

In order to facilitate the benefits of the standardized work some visual management means were created. The deficit of the information at the shop floor was discovered during the thesis work. The data about the original plan (hourly) and the deviations from that plan was absent. After the interview with operators it was considered as a big issue. The need for clear and sufficient information becomes more obvious after interviews with operators. A rather practical way to visualize information is to use Gant Chart displaying it directly in the casting department lunch/fika room. The prototype of the designed Gant Chart is described below.
RESULTS AND ANALYSIS

Figure 5.7.1 Gant Chart for alloys

The Gant Chart is rather traditional and consists of a list of alloys to be casted and their sequence number. The planning is available for a week and divided into four hours per day as a reference time for a casting operation. The big yellow box is intended to write down the comments on the troubles and the delays in production: the reason of the delay, how it is solved, and other comments. The blue box is an original plan with a number of casted coils in each box.

A more advanced solution that requires much more time and specialist work is the decision to program the alarm signal into the computer software for both melting and casting offices. That is expected to motivate operators to take necessary actions. The primary idea is to attract operators’ attention during the analysis step and encourage them to perform as much analysis as necessary before the right consistency of the alloy is reached. The alarm sound and lights will provoke operator to do necessary actions. In order to help operators to reach the right consistency of the alloy the tables with the quantity of additive elements are extracted from the instruction folders, placed directly on the office tables and marked with yellow color.

The other visual management tool is a check list for changing shift operators. This was initiated by the casting chief and operators during the thesis work. The check list helps a melting operator to examine the conditions of melting process and the melting parameters used by the operator in the previous shift. If all points in a check list are satisfied a new melting operator takes full responsibility for the processes in a melting office. This visual aid is used as a reminder to check the parameters of the melting process and the melting office area in general even during the ordinary work.
In general, during the research a lot of different visual aids displayed in the foundry were discovered: The LPS room is used as a place to collect all managers/operators in order to stress important production issues on the daily base. The inside and outside walls contain updated information about specific issues, problems, responsible persons and deadlines.

Moreover, over the whole foundry the boards with the different products, items, materials, and tools are placed to define their name and location and used as a kanban cards to pull the delivery.

![Figure 5.7.2 LPS room (outside and inside)](image)

5.8 Standardized work sheets

“**We did a lot of things without thinking, because we had been taught in a certain way by our predecessors, and it seemed to work, so we just did it**”

( Fujio Cho, the Chairman of Toyota 2006)

**Why did this Thesis work is initiated?** - There was no common way to execute the production operations in a casting foundry. A high variation in operators’ work became an obstacle for continuous improvements. Incapable to figure out the major production problems one stopped thinking of improvements. That is a picture of casting foundry in the beginning of the thesis work.

**Why was the thesis student asked to solve the Standardized Work issue?** – External resource may have a different view on the old problem. Luvata production system is under development and need a University reference.
WHICH METHODS WERE USED TO DEVELOP THE STANDARDIZED WORK OPERATIONS? – To learn the production process the operators’ observations, interviews, process filming and picturing have been performed. The data collected in the casting department became a basis for VSM. So, by developing a current state VSM the overall picture of a production flow with both value added and non-value added activities was created. VSM led to the production waste identification.

It is extremely necessary to “clean” the process from the wastes in order to create a base for standard operations and continuous improvements. Waste Management technique helped to categorize wastes and to develop specific solutions to minimize them. There are few advanced solutions that require more resources and more time. However the majority of the wastes could be eliminated if operators follow the standardized work procedures.

SMED analysis was applied to reduce changeover time and improve the montage procedures. A better layout for montage items and equipment reduced the changeover time and created a foundation for new montage procedures. An improved set of montage operations was developed and illustrated in the standardized work sheets.

The visual management techniques were applied in order to make the standardized work more transparent. Gant Chart and checklist for all shifts intend to solve the lack of the information problem. The alarm signal for alloy analysis should motivate operators to follow standard procedures. Operators will be reminded to check the casted alloy characteristics and take necessary actions.

When the process is “clean” and transparent the standardized work sheets could be developed. Operators’ suggestions gained during the interviews and direct observations provided a basis for these sheets. They provide the visual information on the standardized task performance and contain little writing. To keep standardized work sheets as simple as possible only critical to operation quality procedures are displayed in the appropriate work sequence. It is clearly stated there which way to proceed is right and which is wrong. In order to attract more attention to the standardized sheets the information is displayed under the title “Important for melting!!” in the melting office.

The location of the standardized work sheets is a very important issue in casting foundry. The decision suggested in the thesis is a short-term and requires process execution and some feedback from the operators. As the best place to keep the standardized work sheets was selected the shop floor office information desk on the walls. Nevertheless, the location could be changed if necessary. Probably another good action is to place the same sheets directly on the machines.
In a figure 5.8.1 the first page out of four designed for melting work center is shown. The picture represents an important message and yellow arrows or circles on it emphasize the significance of the point. The red cross symbolizes the forbidden or incorrect conditions. The “YES" and “NO" words are also used to show the bad and good execution of the tasks. This is very simple representation of very important steps in the casting foundry. Every point in the sheets was considered and rechecked several times in order to avoid useless or wrong information. The colors of the operator’s glows, the position of melting instrument and even the location of operator were considered to be appropriate for standardized task performance as well as safety regulations.

The standardized sheets for melting, casting, rolling and montage operations were developed and placed in the offices (see Appendix 3-6). The standardized work sheets have been changed several times and finally approved by the quality department in Luvata Finspang. The variation in performance is expected to reduce if all operators will follow the standardized work sheets. One single rule how to handle the operation should direct operators to perform their job in the same way.

To train operators to work according the agreed standards is a difficult task. It was challenging to develop and locate the standardized work sheets in the shop floor, however it should be even more difficult to change operators mind and persuade them to use these sheets. Therefore it is so important to engage operators in improvement and development processes. Toyota claims that coaching standardized work is the lengthiest step in a conversion to TPS. Standardization is nearly impossible unless workers learn to describe jobs well enough to instruct others to do them. When a work organization can convert problem solutions to Standard Work and hold it, they can begin the next round of improvement from the existing Standard Work (Huntzinger 2006).
**Viktigt vid smältning!!**

Skiftbyte sker vid smältugnen!

1. Säkerheten först!!
   Använd personlig skyddsutrustning.

2. Inte för hög temperatur i ugn!
   NEJ
   JA

*Figure 5.8.1* Standardized work sheet for melting work center
5.9 Other development opportunities

Along with the thesis research topic some additional development ideas were generated. They are slightly related to the research area; however, do not follow the research questions and thesis aim. These development opportunities are represented in an Ishikawa diagram and divided in 4 M's: machine, method, material, and men power.

![Ishikawa diagram showing the 4 M's: machine, method, material, and men power.]

Figure 5.9 4 M's used in manufacturing

5.9.1 Machine

The Casting foundry utilizes old machines where an operator performs a big amount of heavy work manually. Due to the low level of automation employees have to take a responsibility for the process. The usual breakdown is very good evidence of insufficient automation in the foundry. Therefore, the decision to invest in new, modern equipment and machines should be considered in the future. The partial update of the machines is also necessary in a short-term. The lighter but safer working instruments are another option to improve the working conditions. The rest of the issues regarding the standard items are questionable, and require detailed study, however, it is obvious that Casting foundry needs standard items, standard place, and even remove all useless items from the foundry floor.

The modernization and automation of pressing machine is rather important decision as well, as this action would improve the scrap re-melting process, reduce the time for charging the furnaces and save money on man power.
5.9.2 Method

During the thesis work it was obvious that the method of casting different alloys has a defined standard pattern. Nevertheless, the result of alloy quality and quantity varies between 5 shifts. Along with the different experience and team work organization the reason for that could be a shortage of automated process inspection. Usually the decision to act in one or another way is based on operators’ personal feeling, their experience and their opinion. The situation would change dramatically if Luvata would invest in advanced computerized solution to track the production process and product quality. In addition, the recent production is organized within the functional division (melting, casting, rolling work centers) according to machines (functions), but the overall process view of the production is missing. This distinct production view is supported by low level of cooperation and communication between operators in a casting foundry, therefore, no continuity of casting operations is created.

The developed VSM and other visual management tools will partly solve this issue; however, Luvata should pay more attention to that question. In addition, thesis also proposed to examine the possibility to level out the flow, because it was noticed that the melting operators have time to work on both furnaces and the casting operators have time to prepare the items for the montage.

5.9.3 Material

The need for standard inventory and material is significant. The time spent on charging the scrap of different shape (pressed scrap box or copper sheets/cathodes) differs two-three times. This means that use of standard material would help to level out the flow and define the takt time. The shortest time is achieved when using copper cathodes. During the saved time the melting operator could work simultaneously on both furnaces, consequently, the time for transportation of the inventory would be reduced. The standard raw material solves another storage problem, since the need for the huge metal scrap boxes would diminish.

5.9.4 Man power

The training and educational activities are common in Luvata. However, there is still low level of operator interest in improvement initiatives. The majority of casting foundry operators has more than 20 years work experience. The involvement of such valuable resources in the decision making process could help Luvata to improve its production. However, during the interview one operator said: “…after working 20 years in the same company one stops thinking about any improvements and just performs his job”. The idea meeting could be initiated to motivate operators to express their opinion and start thinking about the improvements. This meeting should support informal communication between operators. Furthermore, operators could be asked to provide at least three improvement ideas per year.
The education and training should be a usual activity. The flexibility of the operators depends on the number of work centers they are able to work. Basically all operators work in melting office, and then they can decide: casting or rolling. However, the thesis suggests training all operators to work in all work centers and increase operators’ flexibility.

The communication improvement is the one of the most important questions in Luvata. The communication has to be improved between each work center. The insufficient knowledge of the process history is partly solved by the Gant Chart and check list, however, more initiative from the operators and the team leader is required.


6 **Reflection on the Thesis Conducted**

In order to keep the visualization initiative along with the thesis work, both practical and written, the reflection on the thesis is structured in a SWOT (strengths, weaknesses, opportunities, threats) analysis:

**Table 6.1 SWOT analysis of the thesis conducted**

<table>
<thead>
<tr>
<th><strong>STRENGTHS</strong></th>
<th><strong>WEAKNESSES</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Thesis result has satisfied the both sides: the project company and project student</td>
<td>• AviX or other advanced production management programs were not used</td>
</tr>
<tr>
<td>• Thesis result was achieved on time according to the scheduled project plan</td>
<td>• Operators contribution was limited</td>
</tr>
<tr>
<td>• After the thesis result has been achieved a big potential to improve the production quality</td>
<td>• Long time span between decision taken and its implementation due to a complexity of interdependent</td>
</tr>
<tr>
<td>has been discovered</td>
<td>systems in the project company</td>
</tr>
<tr>
<td>• A very good cooperation between the university, company supervisors and a project student</td>
<td></td>
</tr>
<tr>
<td>has been maintained</td>
<td>• Low company's culture of dealing with operators' resistance to changes may create a barrier to</td>
</tr>
<tr>
<td>• Good working conditions at the company (easy access to all important resources: people,</td>
<td>implement the result of the thesis work</td>
</tr>
<tr>
<td>materials, equipments, internal database) have been provided</td>
<td></td>
</tr>
<tr>
<td>• Help from both supervisors, technical workers, project managers, opponent, friends has</td>
<td></td>
</tr>
<tr>
<td>been provided</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>OPPORTUNITIES</strong></th>
<th><strong>THREATS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• A potential to improve the overall production process should be investigated further</td>
<td>• Low company's culture of dealing with operators' resistance to changes may create a barrier to</td>
</tr>
<tr>
<td>• The same project model could be applied in other Luvata departments and in other companies</td>
<td>implement the result of the thesis work</td>
</tr>
</tbody>
</table>
7 CONCLUSIONS

During the thesis work the standardized work has been developed in a casting department in Luvata Sweden AB Finspang. The standardized work sheets for each work center have been designed and placed in a casting foundry.

The thesis objectives were fulfilled by the means of VSM, Waste management, SMED and Visual management techniques. That means that the thesis has been completed in three pre-determined steps. Below the lean improvement solutions in relation to the research questions are provided:

RESEARCH QUESTION 1: HOW TO IDENTIFY THE POSSIBLE SOURCES OF WASTE AND REDUCE/ELIMINATE THEM BY USING VSM?

Through VSM the following solutions were developed:

- Inventory reduction: Improve the internal scrap management system: immediate re-melting of scrap, the scrap storage place elimination;
- Leveled production: Synchronize the casting and rolling work center takt times - reduce the casting time. Further instigation is necessary.
- Batch size reduction: that small batch size will help to level the production and enable the rapid feedback from operators as well as customers. Moreover the reduced batch size can create a positive shift towards faster problem identification and solving, changeover time reduction and less inventory keeping.

After VSM 5 out of 7 Wastes have been investigated and the improvement ideas presented. These wastes are motion, waiting, conveyance, correction and inventory. Some of the wastes elimination techniques require advanced programming and production rescheduling however the major could be eliminated applying simple tools like video and standardized work sheets for training and educational purposes.
**Research Question 2: How to standardize stop/changeover procedures by using SMED?**

The new set of stop/changeover procedures was standardized and documented in the standardized work sheets for montage. SMED analysis was performed in order to achieve that result. SMED developed rather simple rules for operators to follow the changeover process in a standard way. The standardized work sheets designed as a complimentary visual tool for operators became a key referenced during the montage.

Moreover, by June 2010 due to only a new layout in the shop floor the changeover time has reduced by 1 h. Additionally the tasks moved outside changeover time reduced it by 0,5 h. A new montage work performance taken from hospital practice normalized the working conditions for all operators performing the montage. Now there are clear roles and everyone knows what to do during the changeover. However the detailed montage schedule is not developed yet.

**Research Question 3: How the standardized work operations can be developed?**

The standardized work operations can be easily developed through the standardized work sheets, where all critical process steps are represented. In order to design these sheets it is useful to create VSM, where both value-added and non-value added activities are represented. With a help of VSM and Waste management techniques the production process is “cleaned” from wastes. SMED analysis is applied to improve and standardize the montage operations. Visual management tools were used in order to make the production process more transparent.

All these steps led to the standardized work sheets development. The best way to perform operation and the best tasks sequence are especially stressed when developing these sheets. The pictures of “bad” and “good” task execution shown and are expected to motivate operators to do their job following standard practice. Simple pictures and little writings on them encourage operators to use standardized work sheets as a reference during the production process. Training operators to work according to these standards is a task number one after the thesis work is done.
8 REFERENCES


Rother, M., Shook, J. (2003). Learning to see: Value Stream Mapping to Create Value and Eliminate Muda, The Lean Enterprise Institute, Brookline, Massachusetts, USA.


Yin, R. K. (2009). Case study Research: Design and Methods, Sage, USA.
INTERNET SOURCES:


APPENDIX 1
The current state value stream map (M. Rother, J. Shook 2003)
APPENDIX 2

Value stream mapping symbols:

Value stream mapping process symbols (M. Rother, J. Shook 2003)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Customer/Supplier Icon" /></td>
<td>Customer/Supplier Icon: represents the Supplier when in the upper left, customer when in the upper right, the usual end point for material</td>
</tr>
<tr>
<td><img src="image2" alt="Dedicated Process flow Icon" /></td>
<td>Dedicated Process flow Icon: a process, operation, machine or department, through which material flows. It represents one department with a continuous, internal fixed flow.</td>
</tr>
<tr>
<td><img src="image3" alt="Shared Process Icon" /></td>
<td>Shared Process Icon: a process, operation, department or workcenter that other value stream families share.</td>
</tr>
<tr>
<td><img src="image4" alt="Data Box Icon" /></td>
<td>Data Box Icon: It goes under other icons that have significant information/data required for analyzing and observing the system.</td>
</tr>
<tr>
<td><img src="image5" alt="Workcell Icon" /></td>
<td>Workcell Icon: indicates that multiple processes are integrated in a manufacturing workcell.</td>
</tr>
</tbody>
</table>

Value stream mapping material symbols (M. Rother, J. Shook 2003)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image6" alt="Inventory Icons" /></td>
<td>Inventory Icons: show inventory between two processes</td>
</tr>
<tr>
<td><img src="image7" alt="Shipments Icon" /></td>
<td>Shipments Icon: represents movement of raw materials from suppliers to the Receiving dock/s of the factory. Or, the movement of finished goods from the Shipping dock/s of the factory to the customers</td>
</tr>
<tr>
<td><img src="image8" alt="Push Arrow Icon" /></td>
<td>Push Arrow Icon: represents the “pushing” of material from one process to the next process.</td>
</tr>
<tr>
<td><img src="image9" alt="Supermarket Icon" /></td>
<td>Supermarket Icon: an inventory “supermarket” (kanban stockpoint).</td>
</tr>
<tr>
<td><img src="image10" alt="Material Pull Icon" /></td>
<td>Material Pull Icon: supermarkets connect to downstream processes with this &quot;Pull&quot; icon that indicates physical removal.</td>
</tr>
</tbody>
</table>
### Value stream mapping information symbols

(M. Rother, J. Shook 2003)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="symbol1" alt="Production Control Icon" /></td>
<td>Production Control Icon: This box represents a central production scheduling or control department, person or operation.</td>
</tr>
<tr>
<td><img src="symbol2" alt="Manual Info Icon" /></td>
<td>Manual Info Icon: A straight, thin arrow shows general flow of information from memos, reports, or conversation. Frequency and other notes may be relevant.</td>
</tr>
<tr>
<td><img src="symbol3" alt="Electronic Info Icon" /></td>
<td>Electronic Info Icon: This wiggle arrow represents electronic flow such as electronic data interchange (EDI), the Internet, Intranets, LANs (local area network), WANs (wide area network). You may indicate the frequency of information/data interchange, the type of media used ex. fax, phone, etc. and the type of data exchanged.</td>
</tr>
<tr>
<td><img src="symbol4" alt="Production Kanban Icon" /></td>
<td>Production Kanban Icon: This icon triggers production of a predefined number of parts. It signals a supplying process to provide parts to a downstream process.</td>
</tr>
<tr>
<td><img src="symbol5" alt="Withdrawal Kanban Icon" /></td>
<td>Withdrawal Kanban Icon: This icon represents a card or device that instructs a material handler to transfer parts from a supermarket to the receiving process. The material handler (or operator) goes to the supermarket and withdraws the necessary items.</td>
</tr>
</tbody>
</table>
### Value stream mapping general symbols (M. Rother, J. Shook 2003)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="signal-kanban-icon.png" alt="Signal Kanban Icon" /></td>
<td>Signal Kanban Icon: used whenever the on-hand inventory levels in the supermarket between two processes drops to a trigger or minimum point. It is also referred as “one-per-batch” kanban.</td>
</tr>
<tr>
<td><img src="kanban-post-icon.png" alt="Kanban Post Icon" /></td>
<td>Kanban Post Icon: a location where kanban signals reside for pickup. Often used with two-card systems to exchange withdrawal and production kanban.</td>
</tr>
<tr>
<td><img src="sequenced-pull-icon.png" alt="Sequenced Pull Icon" /></td>
<td>Sequenced Pull Icon: represents a pull system that gives instruction to subassembly processes to produce a predetermined type and quantity of product, typically one unit, without using a supermarket.</td>
</tr>
<tr>
<td><img src="load-leveling-icon.png" alt="Load Leveling Icon" /></td>
<td>Load Leveling Icon: a tool to batch kanbans in order to level the production volume and mix over a period of time.</td>
</tr>
<tr>
<td><img src="mrp-erp-icon.png" alt="MRP/ERP Icon" /></td>
<td>MRP/ERP Icon: scheduling using MRP/ERP or other centralized systems.</td>
</tr>
<tr>
<td><img src="kaizen-burst-icon.png" alt="Kaizen Burst Icon" /></td>
<td>Kaizen Burst Icon: used to highlight improvement needs and plan kaizen workshops at specific processes that are critical to achieving the Future State Map of the value stream.</td>
</tr>
<tr>
<td><img src="operator-icon.png" alt="Operator Icon" /></td>
<td>Operator Icon: represents an operator. It shows the number of operators required to process the VSM family at a particular workstation.</td>
</tr>
<tr>
<td><img src="other-icon.png" alt="Other Icon" /></td>
<td>Other Icon: other useful or potentially useful information.</td>
</tr>
<tr>
<td><img src="timeline-icon.png" alt="Timeline Icon" /></td>
<td>Timeline Icon: shows value added times (Cycle Times) and non-value added (wait) times. Use this to calculate Lead Time and Total Cycle Time.</td>
</tr>
<tr>
<td><img src="go-see-icon.png" alt="Go See Icon" /></td>
<td>Go See Icon: gathering of information through visual means.</td>
</tr>
<tr>
<td><img src="verbal-information-icon.png" alt="Verbal Information Icon" /></td>
<td>Verbal Information Icon: represents verbal or personal information flow.</td>
</tr>
</tbody>
</table>
## APPENDIX 3

### Melting takt time

<table>
<thead>
<tr>
<th>Group</th>
<th>Nr.</th>
<th>Operation</th>
<th>Operation lead time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: Charging</td>
<td>1.1</td>
<td>Filling the furnace with raw material</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>Adding the wood coal on the surface</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>Filling the elevator with raw material</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cumulative value of step 1</td>
<td>15</td>
</tr>
<tr>
<td>Step 2: Driving</td>
<td>2.1</td>
<td>Walking down the stairs</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Move the raw material from the storage to the melting elevator</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>2.2</td>
<td>Move the raw material from the storage to the melting elevator</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>Remove the pressed scrap from the pipe</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2.4</td>
<td>Change the scrap box</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>Drive away the empty box</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>2.6</td>
<td>Walking up the stairs</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>2.7</td>
<td>Waiting for alloy to melt completely</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cumulative value of step 2</td>
<td>49</td>
</tr>
<tr>
<td>Step 3: Analysis</td>
<td>3.1</td>
<td>Spread the melting raw material over the surface, check protection and the edge</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3.2</td>
<td>Take alloy sample</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check the consistency of metal (add if necessary and take a new analysis)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3.3</td>
<td>Waiting for the right temperature</td>
<td>20</td>
</tr>
</tbody>
</table>
### Developing Standardized Work in Casting Department

#### Appendix 3

<table>
<thead>
<tr>
<th>Step 4: Transfer</th>
<th>Description</th>
<th>Cumulative Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Remove the burned coal from the surface</td>
<td>1</td>
</tr>
<tr>
<td>4.2</td>
<td>Transfer the alloy to the holding furnace</td>
<td>5</td>
</tr>
<tr>
<td>4.3</td>
<td>Stop transferring and clean the pipe</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cumulative value of step 3</th>
<th>25</th>
</tr>
</thead>
</table>

| Total value | 96 |

### Notes about the Melting Process

<table>
<thead>
<tr>
<th>Step 1: Charging:</th>
<th>1.1</th>
<th>Difficult to notice the right quantity if the raw material is not pressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td></td>
<td>If there is a better place for coal in the furnace? (see Appendix figure 3.1)</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>Unnecessary usage of elevator, when charging not pressed raw material</td>
</tr>
</tbody>
</table>

| Walking          |     |

<table>
<thead>
<tr>
<th>Step 2: Driving:</th>
<th>2.1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Walking |     |

<p>| 70 |</p>
<table>
<thead>
<tr>
<th>Waiting</th>
<th>Step 3: Analysis: 3.1</th>
<th>The edge of the melted alloy differs a lot (no relevant to instructions) (see Appendix figure 3.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.2</td>
<td>The temperature of alloy vary between 1130-1170 when the sample is being taken If there is a better place to take sample? One example: the opposite corner than the casting pipe (in order to be sure the alloy is mixed well enough) (see Appendix figure 3.3)</td>
</tr>
<tr>
<td></td>
<td>3.3</td>
<td>Check consistency of elements for different alloys in a table &amp; keep in mind special conditions (transition to the new alloy, cleaning furnace, etc) Add necessary elements directly to the furnace (check the table on the wall) Report to the casting operator to add necessary elements directly to the casting furnace</td>
</tr>
<tr>
<td>Waiting</td>
<td>Step 4: Transfer: 4.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.2</td>
<td>The alloy temperature varies around 1172-1182 (not relevant with the instructions 1185) What is the most appropriate speed to transfer alloy to the holding furnace?</td>
</tr>
<tr>
<td></td>
<td>4.3</td>
<td>The holding furnace 18-20 degree level and then goes to 17 itself</td>
</tr>
</tbody>
</table>
Appendix figure 3.1 Coal location in a furnace

Appendix figure 3.2 Different edges of a melted alloy in a furnace

Appendix figure 3.3 Analysis area in a furnace
### Casting takt time

<table>
<thead>
<tr>
<th>Group</th>
<th>Nr.</th>
<th>Operation</th>
<th>Operation lead time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1: Analysis</strong></td>
<td>1.1</td>
<td>Take analysis for the clients (optional - depends on alloy) checking oxygen</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>Take analysis for the alloy consistency</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>Spread coal (take care of the cover protection) / add if necessary</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>Clean the holes in the mouth-dish</td>
<td>1</td>
</tr>
<tr>
<td><strong>Cumulative value of step 1</strong></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td><strong>Step 2: Observing</strong></td>
<td>3.1</td>
<td>Check the alloy sample for consistency (add if necessary)</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>3.2</td>
<td>Take necessary actions to adjust process parameters</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>3.3</td>
<td>Observe the screen, process flow chart parameters, etc.</td>
<td>50</td>
</tr>
<tr>
<td><strong>Cumulative value of step 2</strong></td>
<td></td>
<td></td>
<td>51</td>
</tr>
<tr>
<td><strong>Total value</strong></td>
<td></td>
<td></td>
<td>56</td>
</tr>
</tbody>
</table>
### Notes about casting process

<table>
<thead>
<tr>
<th>Step 1: Analysis:</th>
<th>1.1</th>
<th>Take analysis for the clients (optional - depends on alloy)</th>
<th>Different time to take analysis observed (just before transition, 10 m after transition)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.2</td>
<td>Take analysis for the alloy consistency</td>
<td>After the alloy has been transferred and the holding furnace is full</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>Spread coal (take care of the cover protection) / add if necessary</td>
<td></td>
</tr>
<tr>
<td>Step 2: Cleaning:</td>
<td>2.1</td>
<td>Clean the holes in the nozzle</td>
<td>This action affects holes on coil: too fast – cause holes, sometimes operator does not clean holes after transition of alloy, but each half hour or other time - too much proactive actions So slow and often is better, than fast and rare. Another advice – use vibration.</td>
</tr>
<tr>
<td>Step 3: Observing:</td>
<td>3.1</td>
<td>Check the alloy sample for consistency (add if necessary)</td>
<td>Too late check – too late actions. Alloy consistency table should be shown all the time. Red message about the alloy analysis disappear fast</td>
</tr>
<tr>
<td></td>
<td>3.2</td>
<td>Take necessary actions to adjust process parameters</td>
<td>Passive observing dominates, rather than proactive actions</td>
</tr>
<tr>
<td>Waiting</td>
<td>3.3</td>
<td>Observe the screen, process flow chart parameters, etc.</td>
<td>This is a wasting time, since during that time the proactive actions could be taken and preparation for the unplanned stops could be done</td>
</tr>
</tbody>
</table>
# APPENDIX 5

## Rolling takt time

<table>
<thead>
<tr>
<th>Group</th>
<th>Nr.</th>
<th>Operation</th>
<th>Operation lead time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: Run coil</td>
<td>1.</td>
<td>Put coil on the slitting machine</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>Take rapport for the coil quality</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td>Run slitting &amp; observe process</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Cumulative value of step 1</strong></td>
<td><strong>147</strong></td>
</tr>
<tr>
<td>Step 2: Cutting</td>
<td>2.</td>
<td>Check the rapport to decide how much to cut out</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.</td>
<td>bad coils</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>Run cutting machine and observe &amp; adjust process</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>Mark the coils according to the color of the</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td>quality rapport</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.</td>
<td>Locate the cut out bad coil for re-melting</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Cumulative value of step 2</strong></td>
<td><strong>46</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total value</strong></td>
<td><strong>193</strong></td>
</tr>
</tbody>
</table>
APPENDIX 6

Montage takt time

00:00 - Montage gables

00:40 - Fix the graphite blocks

00:50 - Measure the distance between graphite blocks

00:55 – Drag wooden steak to fix the construction to right place and not too tough on the graphite

01:05 – Insert the construction to lead the alloy through the process

01:07 - Put protection material

01:10 - Fix the holes in the tan-dish before montage
01:10 - fix all sews with cement and water in construction to protect from copper overfilling

01:15 Place thin copper strips on the construction and glue the rest of the pieces

01:25 Assemble nozzle and the in-between material from both sides of it

01:30 - Prepare nozzle for start, fix the rest of the sews and leave gas for heating – 30-50 min

Average takt time varies around 190 min: 50 min. decision time + 90 min. real work time + 30 - 50 min. heating up time.

Notes about the montage
- 50 min – decision time (from the production stop to the start of the montage: analysis of the error, waiting for the technician/chief decision, discussion about the problem and necessary actions);
- There are only 2 operators working on montage (casting and melting operators), however the whole shift should participate;
- Poor self organization, small interest in cooperation, useless walking, no scheduling and no sharing of responsibility
APPENDIX 7
Standardized work sheet for melting work center

**Viktigt vid smältning!!**

Skiftbyte sker vid smältugnen!

---

1. **Säkerheten först!!**
   Använd personlig skyddsutrustning.

2. **Inte för hög temperatur i ugn!**
   NEJ
   JA
3. Inte för hög nivå i ugn!

4. Läs på tavlan vilken råvara eller skrot som ska användas!

5. Chargeringstvagn: Fyll vagnen innan överföring
6. Smältugn: Täckning
  NEJ  JA

7. Analysprov: Efter eventuell justering tas alltid ett nytt analysprov på smältan

8. Skumning innan överföring
9. Kvävgas ska användas vid legering 0011/0013

10. Överföringshastighet: Ta det lugnt vid överföring!

**KONTROLLERÄ**

**PÅVERKAR NIVÅN**
APPENDIX 8
Standardized work sheet for casting work center

Viktigt vid gjutning!!

1. Säkerheten först!!
   Använd personlig skyddsutrustning.

2. Munstycke rengörning:
   Använd fräscha borr!
3. Mumstycke rensning: Ta det lugnt vid rensning!

4. Analysprov: Glöm inte att kontrollera analysen!

5. Justera vid behov!
   Efter justering tas alltid ett nytt analysprov!
6. Viktiga parametrar för gjutningen:

Klämning

Skyddsgasinställningar
7. Håll lugn: Täckning!

8. Kontrollera fräsprofil

9. Band rapport: Glöm inte att notera avvikelser och skrot
APPENDIX 9
Standardized work sheet for rolling work center

**Viktigt vid valsverk och delning av band!!**

Skiftbyte sker vid valsverket!

1. Läs Bandrapporten

2. Check om valsbyte behövs
3. Håll koll på bandet

4. Justera med skevning vid behov!

5. Upptäck tjockleksfel med hjälp av utskriften
6. Checka av provklassningen (RFS-LS, vikter, skrot mm) kolla även bandrapporten

7. Titta på bandsidor, bedöm kanterna.

8. Märk banden