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RESEARCH AND DEVELOPMENT OF MAINTENANCE FUNCTIONS

The finishing line in the board factory

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Abstract

The aim of the final thesis was to study the problems that were encountered in the Stora Enso Barcelona Packaging Board Mill's finishing line. The thesis project studied causes for the failures and looked for solutions to prevent them occurring to improve the reliability of the plant. Due to the hardening competition companies are forced to find savings from new sectors and therefore maintenance cost savings and availability performance of the machines has become additionally important.

The thesis project was carried out concentrating on the Reliability Centered Maintenance, RCM, methodologies. There were 13 different types of machines in the finishing line and 83 individual machines. In the finishing line there were no preventive or planned maintenance at all, only reactive maintenance when something failed. In the finishing line occurred many different types of failures, such as mechanical, electrical and IT ones. For each studied failure a criticality rate was given. The devices were relatively cheap and they did not have direct relation to the profit losses and maybe because of these reasons the finishing line played a minor role. The line produced approximately less pallets than it could have done or the sheeters could have cut.

There were found solutions that were thought to reduce the down time. Some of the solutions needed small modifications of the finishing line, some operational procedure changes to modernize the functions, and there came additional tasks for the operators to make the working more efficient. During the thesis project the company had already called for offers to replace two of the three bottleneck machines of the line, which was an option according to the studies. During the investigation of the finishing line there was no time to implement these findings. It would be interesting to see if the company decided to press some of the solutions into service and what would be the benefits.

Keywords
Finishing line, reliability centered maintenance, computerized maintenance management systems, operator driven reliability, 5Ss

Miscellaneous

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Tiivistelmä

Opinnäytetyön tarkoituksena oli tutkia ongelmia joita kohdattiin Stora Enson pakkauskartonkitehtaan loppukäsittelylinjastolla. Opinnäytetyö selvitti syitä havaituille toimintahäiriöille ja etsi ratkaisuja ehkäisemään ongelmien esiintymisen, jotta tehtaan luotettavuus parantuisi. Kovenevan kilpailun takia yritykset joutuvat etsimään säästökeinoja uusilta aloilta ja sen vuoksi kunnossapidon säästöt ja koneiden käyttövarmuus ovat tulleet merkittäviksi tekijöiksi.

Opinnäytetyössä seurattiin luotettavuuskeskeisen kunnossapidon periaatteita. Loppukäsittelylinjastolla oli 13 eri tyypin laitetta ja 83 itsenäistä laitetta. Loppukäsittelylinjastolla ei ollut ennakoivaa tai suunnitelmallista kunnossapitoa, vain reagoivaa kun jokin meni epäkuntoon. Loppukäsittelylinjastolla esiintyi paljon erilaisia toimintahäiriöitä, kuten mekaanisia, elektronisia ja informaatioteknisiä. Jokaiselle toimintahäiriölle tutkittiin kriittisyysarvo. Koneistot olivat suhteellisen halpoja ja niillä ei ollut suoranaista yhteyttä tulon menetyksiin ja ehkä näiden seikkojen vuoksi loppukäsittelylinjasto oli jätetty pienelle huomiolle. Linjasto tuotti keskimäärin vähemmän paletteja kuin se olisi pystynyt tuottamaan tai arkkileikkurit olisivat voineet leikata.

Ratkaisuja, joiden ajateltiin pystyvän vähentämään seisokkiaikoja, löytyi. Osa ratkaisuista tarvitsi pieniä modifikaatioita loppukäsittelylinjastolle, osa vaati toiminnallisia muutoksia toimintojen modernisoimiseksi ja uusia tehtäviä ilmeni suorittaville tahoille työn tehokkuuden parantamiseksi. Opinnäytetyön aikana yritys oli jo pyytänyt korvaamaan kaksi kolmesta linjaston pullonkaulakoneista, mikä oli myös tutkittu olevan yksi vaihtoehto. Nopeassa loppukäsittelylinjaston tutkimisessa ei ollut aikaa toteuttaa löytyneitä ratkaisuvaihtoehtoja käytännössä. Olisi mielenkiintoista nähdä, jos yritys päätti tai päättäisi ottaa joitakin ratkaisuvaihtoehtoja käytäntöön ja mikä olisi näistä saavutettu hyöty.

Avainsanat (asiasanat)
Loppukäsittelylinjasto, luotettavuuskeskeinen kunnossapito, kunnossapidon hallintaohjelmistot, käyttäjäkunnossapito, 5S

Muut tiedot

CONTENTS

FIGURES

LIST OF ABREVIATIONS

BCM	Business-centered maintenance
CD	Condition-directed
CM	Corrective maintenance
CMMS	Computerized maintenance management system
EOP	Equipment operating procedures
FF	Failure-finding
FMEA	Failure mode and effects analysis
IT	Information technology
LCC	Life cycle cost
LCP	Life cycle profit
MIS	Maintenance information system
MTBF	Meantime between failures
MTTF	Meantime to fail
MTTR	Meantime to repair
ODR	Operator driven reliability
OEE	Overall equipment effectiveness
OIM	Operator involved maintenance
OPM	Operator performed maintenance
PDA	Personal digital assistant
PdM	Predictive maintenance
PM	Preventive maintenance
RCM	Reliability centered maintenance
RTF	Run-to-failure
TD	Time-directed

1 INTRODUCTION

One of the most important assets and objectives, while planning the maintenance, is availability of the production equipment. Due to tougher competition in many industrial sectors the availability performance of the machinery has become additionally important. (Leiviskä 2009, 238.) Machine reliability is an essential part of total efficiency and thereby a logical factor of rationalization. In some cases it is necessary to invest in new technologies, but on the other hand there are other possibilities to improve the machine reliabilities. There are big differences between different mills for example the existence and size of the finishing department and the packaging line, which lead to mill-specific problems requiring mill-specific studies and solutions. In this project the problems of the finishing line machines, their root causes and solutions to prevent them occurring were studied. In this case machine reliabilities were studied with Reliability centered maintenance (RCM) methodologies starting from the conveyors of the sheet cutting machines and continuing until the end of the finishing line in the warehouse.

The literature review of the thesis includes the company introduction and the most important operational process phases of the operational environment. Afterwards it is expanded to supportive activities tightly connected to the industrial process. Different maintenance concepts are enlarged upon to understand their roles in this project and in the complex aggregate of the maintenance world. Sometimes they are really theoretical and can only be adapted in some optimized circumstances.

The experimental part of the thesis concentrates on minimizing the machine stops or the breakdowns and making the finishing line functions more efficient by planning the maintenance and examining the most obvious root causes. The used methods are well known in this field, but the solutions in this thesis are established in order to meet the needs of Stora Enso Barcelona, and do not necessarily apply to other destination areas.

2 COMPANY INTRODUCTION

2.1 Stora Enso

Stora Enso is a global company with some 27 000 employees in more than 35 countries. The products of the group consist of paper and wood products such as consumer board, book paper, industrial packaging and fine paper. In 2009 their sales totaled EUR 8.9 billion and an annual production capacity reaches 12.7 million tons of paper and board, 1.5 billion square meters of corrugated packaging and 6.9 million cubic meters of sawn wood products. (Stora Enso in brief 2010.)

Stora Enso is using and developing expertise in renewable materials to meet the needs of its customers and the challenges of today's global raw materials. Their products provide a climate friendly alternative to many products made from competing non-renewable materials and therefore have a smaller carbon footprint. Wood based solutions give for them wide-reaching business benefits as well benefits for people and the planet. Stora Enso's sustainability: economic, social and environmental responsibility, underpins their thinking and approach to every aspect of doing business. (Stora Enso in brief 2010.)

2.2 Barcelona Mill

The Barcelona mill was founded in 1964 and it started operations in 1968 with annual 20.000 tons of board capacity and in 2010 the capacity is 160.000 tons per annum. The board is made from recovered paper, collected in the Barcelona metropolitan area. The mill produces white Line Chipboard (WLC), the board is coated on both sides and some virgin fibers must be added in order to meet the high quality standards. There is a new 8.000 square meter warehouse and a 49 MW cogeneration plant fueled with natural gas. (Barcelona Mill 2010.)

The board is manufactured by one board machine, and the sheeting plant encompasses one winder and five sheeters. Most of the production is sold in sheets.

2.3 Finishing line

In a factory manufacturing production systems are often organized with machines or work centers. They are connected in series and separated by buffers, better known in the literature as a production line, or a transfer line, or a flow line. (Artiba & Riane. 2005, 22-23.)

Finishing lines are mostly individual solutions and varying a lot in different factories of the same group. There are many factors that have an influence on the layout of the finishing lines, among other things how much there is space, how much money is available for the machines and how automated the whole process is wanted to be. In the Barcelona mill the main tasks of the finishing line are to transport the carton pallets forward, recognize the right pallets, enclose the stack of cartons, and make the plastic packaging waterproof and to put the right etiquettes on their sides. There are some special pallets that need a strap around them. Primarily the finishing line of the Barcelona Mill was planned to operate with three sheet cutting machines, but as of 2010 it has to operate with five sheet cutting machines, which make it to be the bottleneck of the finishing department (Caceres 2010).

In the Barcelona mill the finishing line is running 24 hours a day and 7 days a week without planned stops and it only stops in uncontrolled conditions. There are thirteen different kinds of machines and 83 different pieces of equipment in the finishing line. The finishing packaging line is the last stage before stocking the pallets and loading them into the trucks.

3 MAINTENANCE

Maintenance: Ensuring that physical assets continue to do what their users want them to do (Moubray 1997, 7). Defining the mission of maintenance is a challenging task. There seems to be as many different answers as there are respondents (organizations). Some respondents emphasize quick reaction times in fixing breakdowns in order to service the customer more efficiently. Some organizations intent on reducing the downtime and others focus on quality or cost control, while a few focus on safety or environmental security. All the above are right, which means that each company has its own type of interests. (Levitt 2003, 4.) If only thinking maintenance as repairing, it is too narrow a viewpoint. Maintenance is maintaining and preserving the productivity of fixed assets. According to the above statement the following matters belong to the maintenance concept:

- preserving the operative condition of the equipment (not letting it to get worse or scatter)
- complying the correct operational conditions
- recovering the original condition
- fixing the designing weaknesses
- improving the operator and maintenance skills

(Järviö 2006, 11-12.)

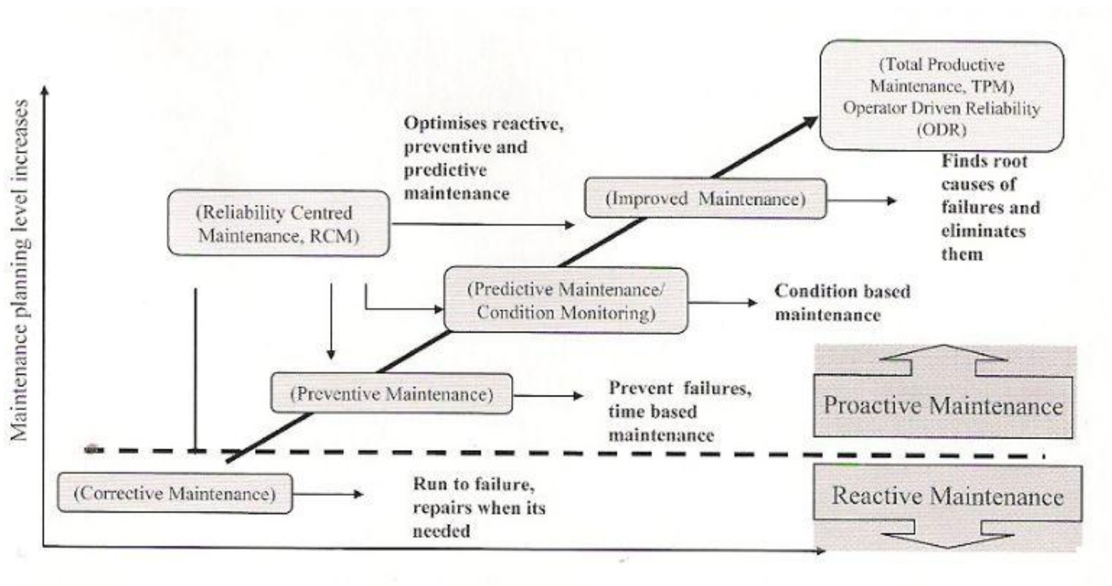

FIGURE 1. Typical maintenance concepts (Original figure from Leiviskä 2009, 308.)

Figure 1 presents different types of typical maintenance concepts. At the bottom of the picture it can be seen that there is only one concept, corrective maintenance that is purely reactive maintenance. The other concepts are above the run-to-failure dash line, which means that the others are trying to affect before something breaks down, meaning that the planning level increases; this is mostly known as proactive maintenance. Later there are more detailed discussions about different methods, which were somehow connected to this project.

Maintenance is one of the biggest expenditure of the companies and the biggest uncontrolled cost item. In well-organized enterprises efforts have been made to master the maintenance and control the costs. The influence of the maintenance is indirect on the business result of an enterprise. It is truly important to understand the influence mechanism to be able to calculate the profits produced by the maintenance. (Järviö 2006, 20-21.)

Figure 2 illustrates how the total cost varies with different kind of maintenance strategies. Figure shows clearly that there can be found an optimized maintenance level for each plant and if there is too much preventive maintenance, the cost rate arises exponentially. Similarly, if the maintenance is only reactive the production losses cost rate becomes steeper.

Typically, the most important goal of the RCM analysis, in industrial applications, is to evaluate the cost-effective maintenance tasks to minimize the total cost (Leiviskä 2009, 315-316).

> *A proactive task is worth of doing if it reduces the consequences of the associated failure mode to an extent that justifies the direct and indirect costs of doing the task* (Moubray 1997, 91).

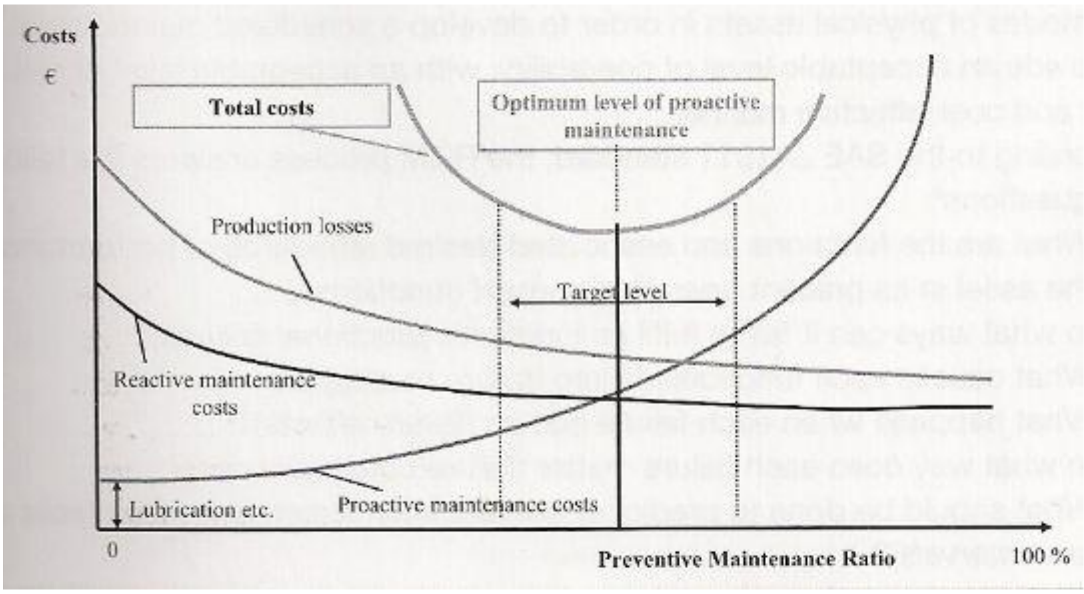

FIGURE 2. Preventive maintenance ratio- the key to minimize total costs (Original figure: Leiviskä 2009, 315.)

3.1 Different types of maintenance

3.1.1 Corrective, unplanned or reactive maintenance

> *Corrective maintenance (CM) is the performance of unplanned (i.e., unexpected) maintenance tasks to restore the functional capabilities of failed or malfunctioning equipment or systems* (Smith & Hinchcliffe 2004, 20).

If the maintenance is only made in the corrective mode, it can very seldom be productive. Reactive maintenance can be an option if the plant has a very good maintainability. Normally components are allowed run-to-failure, RTF, and no efforts are taken to maintain the equipment as the design life originally ensured. The main disadvantages of reactive maintenance are: increased costs due to unplanned downtimes, increased labour costs, especially if overtime is needed, costs related to the repair or replacement of the equipment, possible secondary equipment or process damage from equipment failure modes and inefficient use of staff resources. (Leiviskä 2009, 309.)

3.1.2 Preventive Maintenance, PM

> *Preventive maintenance is the performance of inspection and / or servicing tasks that have been preplanned (i.e., scheduled) for accomplishment of a specific points in time to retain the functional capabilities of operating equipment or systems* (Smith & Hinchcliffe 2004, 20).

Preventive maintenance, PM can be efficient only if there are enough history data about the failure rate and the distribution of failure modes, around 10-20% of the failures can be predicted. It has been found out that most of the failure modes are random, which cannot be foretold (up to 40-60%), and for those failures, time-based preventive actions are not the best solution. The advantages of preventive maintenance are: cost effectiveness, flexibility, extended component life cycle, reduced number of equipment or process failures and cost savings over the reactive maintenance program. Disadvantages of PM are: catastrophic failures could still occur, labour intensiveness can include performance of unnecessary maintenance if the failure rate is un-known and the risk of incidental damage to the equipment in conducting unnecessary maintenance (Järviö 2006, 53; Leiviskä 2009, 309-310.)

There exist four basic elements behind the decision to define and choose PM actions: to prevent (or mitigate) the failure occurrence, to detect the onset of failure, discover a hidden failure and do nothing, because of valid limitations. There are also four task categories from which a PM action may be specified. The task categories are worldwide employed in constructing a PM program, irrespective of the methodology that is used to decide what PM should be done. They are as follows: Time-directed (TD); aimed directly at failure prevention or retardation, condition-directed (CD); aimed at detecting the onset of a failure or failure symptom, failure-finding (FF); aimed to discover a hidden failure before an operational demand and run-to-failure (RTF); a deliberate decision to run to failure because the others are not possible or the economics are less favorable. (Smith & Hinchcliffe 2004, 22-28.)

3.1.3 Failure finding

In some cases failure finding is also known as detecting failures. In normal RCM study up to 40% of failure modes fall into the hidden category and furthermore up to 80% of these failures require failure-finding. When a protected function fails while a protective device is in a failed state, it is called a multiple failure. Usually there are no other feasible tasks to be done, but to check that the hidden function is still working. All the possible failure causes should be checked without disconnecting the functions, but sometimes the physical factors make it impossible to test. A failure-finding task has to be done so that it does not increase the risk of the multiple failures and the frequency must be practical. If there is no suitable failure finding task that can be found and a multiple failure could still affect the safety or the environment, redesign is compulsory. If it does not affect safety or the environment then it is acceptable to take no action. (Moubray 1997, 170-186.)

3.1.4 Other default actions

Other default actions are non-scheduled maintenance and redesign. Non-scheduled maintenance is taken into consideration when there is not a suitable scheduled task for a hidden function, and the associated multiple failure does not have any safety or environmental consequences or any cost-effective preventive tasks cannot be found for failures which have operational or non-operational consequences. If non-scheduled maintenance is an option, then the redesign might be a valid option. Redesign is changing the specification of a component, adding a new item, replacing an entire machine, or relocating a machine. It also means any other once-off change to a procedure or process, which has something to do with the operation of the plant. The redesign option might be an expensive alternative and also slow in many cases. Before choosing the redesign alternative there has to be economic trade-off studies carried out to show it can achieve expected cost savings. (Moubray 1997, 187-197.)

3.3 Operator driven reliability, ODR

SKF reliability systems have noted that the operator driven reliability, ODR, is the teamwork process of the whole company, which optimizes the functions of a production plant and widens the operator's basic sphere of responsibilities. The ODR can be divided into three smaller sub-concepts. Equipment Operating Procedures (EOP): actions related to the equipment functions, which manufacturers have specified, but normally after a certain time these actions change a bit to the best established practice. Operator Involved Maintenance (OIM): actions that are reacted by the operators and maintenance are observed daily. The operators take part e.g. in finding the causes to a problem. Operator Performed Maintenance (OPM): Operators individually perform tasks, which improves the availability. These tasks can consist of inspections, cleaning, repairs, measurements, oil / component changing and adjustments. ODR attempts to change the attitudes and the ownership scheme of the themes of the machines also to the lower operator levels. (Numminen 2005, 32-33; Operator Driven Reliability; Kunnossapidon toiminnot.)

Normally ODR is part of other maintenance systems and more likely supporting them, and more from the preventive point of view. Many times ODR is based on visual inspections, because the operators are closer to the machine and can detect symptoms earlier. In many cases using personal digital assistants, PDAs, is supported to achieve faster information change and processing. Usually the successful ODR results have improved availability, improved efficiency and improved quality of the products. The three factors above affect the plant OEE (overall equipment effectiveness=availability x performance x quality) and therefore the OEE-parameters are good indicators to show the success of the program. The hardest part to implement ODR is to train the operators properly and change the attitudes toward the way of thinking that the operators own the machines. The most important addition to the maintenance system that ODR brings along is the earlier detection of problems, improved atmosphere and cost savings from breaking the normal operator-maintenance interface. (Hykin n.d; Numminen 2005, 33-34.)

3.4 Housekeeping & 5Ss

The 5Ss stand for the five Japanese words, whose English equivalents are 5Cs: Clear out, Configure, Clean and check, Conformity, Custom and practice. The 5Ss method is practiced to achieve high quality standards in the production of goods, from a well-organized working environment. The 5Ss, as well as, other maintenance methodologies depend on the commitment from top management to total quality management and continuous improvement drives the initiative. It all goes to keep a good order in an applied field. The method motivates to give positive feedback in order to show progress and achievements and this way it gives employees a means of monitoring the effectiveness of their actions. (O'hEocha 2000, 321.)

Implementation of the 5Ss improves environmental performance, housekeeping or health and safety standards, which have been studied and found to depend on a great extent upon the company culture. Normally the top management and organizational structure determine the culture in the company. A manager's actions of the top and middle management influence the communication dynamics, which in turn determines the extent of involvement and motivation at the operative level. In theory, the 5Ss set out a clear way to achieve better results, but in practice the method is a far more complex system, because of the plethora of human actions. (O'hEocha 2000, 322-330.) Ahonen (2010) also explicated that commitment for housekeeping requires normally indication of the action from the company. If the company makes such changes in the working environment which can be easily noted by the employees, it can give the workers an idea that the company wants to take care of its property in a new different way.

4 RELIABILITY CENTERED MAINTENANCE, RCM

> *Reliability-centred Maintenance: a process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context (Moubray 1997, 7).*

RCM can be considered as a maintenance development process that has ascended from the aviation industry. RCM is a tool to improve the results and the process is also a risk evaluation, while it tries to minimize all the unplanned stops in a factory by studying equipment and components carefully and their probability to fail. The RCM process is systematic, measurable, and objective as it indicates and performs effective maintenance functions. (August 2004, 1-6.) RCM is a suggestive, simple and fast framework for enterprises to discover right manners of the maintenance and to take better care of the economy. (Järviö 2000, 16-19.)

There are seven basic questions that the RCM process brings along and these questions are asking about the assets or system under review, as follows:

1. What are the functions and associated performance standards of the asset in its present operating context (functions)?
2. In what ways does it fail to fulfill its functions (functional failures)?
3. What causes each functional failure (failure modes)?
4. What happens when each failure occurs (failure effects)?
5. In what way does each failure matter (failure consequences)?
6. What can be done to predict or prevent each failure (proactive tasks and task intervals)?
7. What should be done if a suitable proactive task cannot be found (default actions)?

(Moubray 1997, 7; Leiviskä 2009, 316.)

Normally the RCM is used as a tool to develop the proactive maintenance program for the production line or plant asset. There have to be an accurate plan, trained and motivated human resources, and effective tools (software). Usually there is a facilitator, who leads the project and the role of the facilitator is essential to achieve the goals of RCM. That person must master the RCM methodology, have good skills to handle different situations and especially have the skill to motivate people to do systematic, analytical work. It is important that a team has know-how and skills to find answers to all seven RCM questions. (Leiviskä 2009, 316-321.)

4.1 The seven questions of the RCM

Functions

A function definition- and by implicating the definition of the objectives of maintenance for the asset - is not complete unless it specifies as precisely as possible the level of performance desired by the user. A complete function statement then consists of a verb, an object and the standard of performance desired by the user. The maximum performance standard comes from the physical limitations of the machine, but the minimum performance standard is something that the user has to set, meaning that there are desired performance (what the users want the asset to do) and built-in capability (what it can do). It should be born in mind that maintenance can only restore the asset to an initial level of capability; it cannot go beyond it, otherwise it is modification. Functions should be written so clearly that everyone involved could understand what is wanted, including enough quantitative performance standards and secondary function information if possible. (Moubray 1997, 21-44.)

Functional failures

If the asset is unable to do what the user wants, for any reason, the user will consider it to have failed. Functional failure can be a complete loss of function or a situation where the asset still functions, but performs outside acceptable limits. What is considered as a failure depends highly on who is defining it, for instance the safety manager and the production manager might have two really different points of views. Functional failure can be said to be the level when proactive maintenance is needed to sustain the required level of performance. (Moubray 1997, 45-52).

Failure mode and effect analysis, FMEA

As a precise definition for a failure mode could be used the following: a failure mode is any event which causes a functional failure. It is important to identify the failure modes, which are reasonably likely to affect functional failures, ideally identified before they occur at all, or before they occur again. In an ideal situation they are analyzed to really itemized level, using detailed vocabulary for each asset. Once they are identified it is possible to consider what happens when a failure occurs, to assess its consequences and to decide what to do to anticipate, prevent, detect or correct it, or maybe re-design it. Without a descent failure mode analysis it is impossible to develop a systematic, proactive maintenance management strategy. Probability of the functional failures also affects the failure mode analysis; it is not wise to list every single failure possibility. (Moubray 1997, 53-71.)

The next step would be to list what happens when each failure mode occurs, known as failure effects. Anyhow, failure effects are not the same thing with consequences. A good description of failure effects is used to evaluate the consequences of the failure. Specially, when describing the effects of a failure, the following should be recorded: what evidence there is (if any) that the failure has occurred, in what ways (if any) it poses a threat to safety or the environment, in what ways (if any) it affects production or operations, what physical damage (if any) is caused by the failure, and what must be done to repair the failure. (Moubray 1997, 73.)

Failure consequences

Each failure somehow affects an organization, which is using the asset. Failures can affect the output, quality and customer service or maybe the safety, environment, operating costs, energy or other consumption, while a few have an impact on several above-mentioned, and still others may appear to have no effect at all if they occur on their own. The last type can still expose the organization to the risk of much more serious failures. If failures are not prevented it binds resources, which could be used more efficiently elsewhere. There is a difference between failure effect asking what happens and consequences describing how- and how much - it matters. The list of failure consequences is the ultimate stage before deciding whether proactive maintenance is worth of doing in each case and it also suggest what action should be taken if a suitable proactive task cannot be found. (Moubray 1997, 90-128.)

4.2 What RCM can achieve

Results of the RCM are mainly inspected from two points of views: (1) performance efficiency of the maintenance and (2) cost efficiency of the maintenance. Key figures of the number one aspect to measure the performance are MTBF, MTTF, failure probability and effectiveness (input/output). The key figures of the second aspect are direct maintenance costs, labour costs, spare part and material costs, and design and supervision costs. (Järviö 2000, 144.)

RCM can achieve and fulfill many expectations. RCM is contributing to greater safety and environmental integrity, higher plant availability and reliability, longer useful life of expensive items, minimizing the less sudden failures, improved product quality, greater maintenance efficiency (cost-effectiveness), and greater motivation of individuals, better teamwork, and improved maintenance database and system. The key feature of the RCM is that it provides an effective step-by-step framework for trying to tackle all of the above at once, and for involving everyone who has anything to do with the equipment in the process. (Moubray 1997, 307-317.)

5 MAINTENANCE INFORMATION SYSTEMS (MIS)

In the business-centered maintenance (BCM) some form of the documentation system for recording and conveying information, is an essential operational requirement for all the elements of the maintenance management cycle. Documentation can be defined as: any record, manual, catalog, drawing or computer file containing information that might be required to facilitate maintenance work. Moreover, MIS can be described as: the formal mechanism for collecting, analyzing, storing interrogating and reporting maintenance information. Anyhow, most of the current systems are computerized in the efficient business world of today, but their mode of operation has evolved from the classical paperwork. Figure 3 is introducing the basic model of the maintenance system. (Kelly 2006, 168-187.)

All the information should be documented just once and a backup file created. History information base needs to be a real time system, which means that all the information has to be open for everyone on the following day. All the calculations and analyses must be performed in real time, updated with the latest information. There should not be overlapping systems collecting the same information and there always has to be LCC (life cycle cost) / LCP (life cycle profit) calculations done when analyzing the history information. (Mäki 2009, 24.)

5.1 Documentation parts

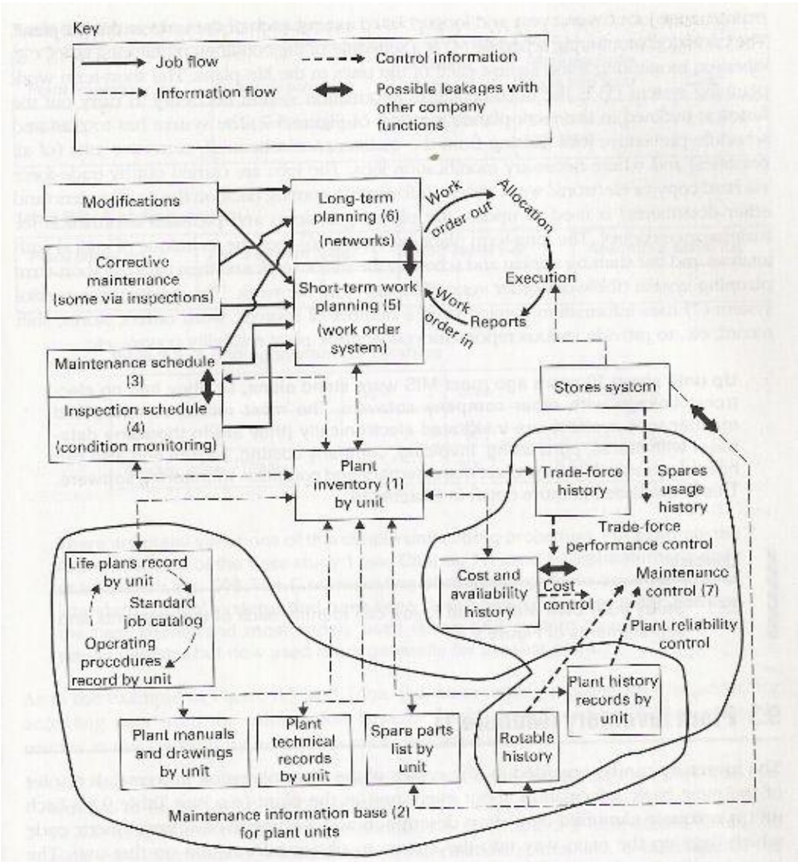

FIGURE 3. A functional model of a maintenance documentation system (Original figure: Kelly 2006, 169)

With the first glance Figure 3 might look a bit confusing, but when it is internalized it can help to understand the benefits of a maintenance documentation system. With the following introductions this Figure 3 can be opened better. The documentation system can be roughly divided into seven sections, which are made up of: (1) plant inventory, (2) maintenance information base, (3) maintenance schedule, (4) condition monitoring, (5) short-term planning, (6) shutdown work planning and (7) maintenance control. (Kelly 2006, 169-171.)

The plant inventory (1) consists of a coded list of the plant units, which are identified by a short description and all the basic information. This flags the main way into the system to obtain information on the unit. The maintenance information is a database (2) that includes information of the unit life plans, job catalogs, maintenance instruction manuals, and safety information etc for each individual unit. Suitable database is essential for the efficient planning of work. A maintenance schedule (3) stores preventive maintenance jobs, which are formulated from the recommendations of the studies and job specifications. The indexes can be updated and if necessary re-scheduled as on the return of the information. (Kelly 2006, 171-178.)

A condition monitoring (4) maintenance program might well include inspections that need to be done and hence scheduled, independently from the main maintenance jobs. There can be: condition checks, readings, inspection routines undertaken by artisans, condition monitoring routines carried out by technicians using off-line equipment. The short-term work planning (5) system has to carry out and schedule preventive jobs, corrective jobs and where necessary modifications. The system can produce a list of most important jobs that has to be carried out and adds them into the task planning system. The complete programs are formulated in terms of resources, plant availability and the opportunities known to be arising. Shutdown work planning (6); modification / preventive work and corrective tasks are jobs that the plant needs to be offline for an extended period. Ongoing maintenance originates from the shutdowns, because the overhaul of a small unit might consist of hundreds of interrelated jobs. It is important that the execution and the control of the shutdown should exploit the work order system so that the cost control and history recording may be sustained. The maintenance control (7) system collects information coming from a number of different sources, such as work orders, time cards and material purchasing records, to update the planning systems and provide various reports for different parties that need the information. (Kelly 2006, 178-187.)

When talking about spare parts they are considered as a product support items, whose availability is important when planned or unplanned maintenance is to be carried out. One of the best ways to optimize the unplanned stoppages is to forecast properly the required number of spare parts, based on technical characteristics, operating environmental conditions of a system and reliable history data. The environmental conditions should be taken more into the consideration with part manufacturers to minimize the MTBF. (Artiba & Riane. 2005, 70-82.) Delivery times depend a lot on the type of the spare parts. With a well-organized warehouse and spare part system costs can be saved, maybe less capital is tied up and maintenance is improved, when there are the right parts available. (Leiviskä 2009, 345-352.)

5.2 Computerized maintenance management systems, CMMS

With computerized maintenance management systems, CMMS, the strategies are organized and carried out and it is a managing tool for the maintenance activities, meaning that it indicates where the maintenance activities have been successful and where not. CMMS illustrates the direction of the maintenance development and gives the feedback. (Mäki 2009, 54.) In the CMMS the most important sources of information are the work orders. Many times it is also the weakest point, because too often the operators and maintenance crew do not record enough information, which makes the analysis to be too superficial. Usually most of the programs give information from MTBF, MTTR, availability, costs, timetables and TOP 10 lists of failures. (Leiviskä 2009, 313-314.)

Kelly (2006, 194-195) highlights the easy access to CMMS from different levels, it is easy to share, it has excellent storing possibilities, it is flexible and it has an ability to analyze and report large quantities of control data. Usually the main reasons why CMMS might operate below its capability is that the organizations do not have the will to educate their employees, store enough descent data, they underestimate their capabilities and benefits versus the time and money to make the process on the functional level (Kelly 2006, 195-196).

CMMS does not guarantee that planning is working automatically. Planning with CMMS is not simple and just because the company has a computer does not mean it has a planning function. It is a tool used, not only by the maintenance staff, but by the entire plant or company. The system helps with the information, but often the term "maintenance" has a bad connection to previous history where maintenance is thought merely as the repair of broken equipment. CMMS is not planning itself, but it can be a tremendous resource for planning. (Palmer 2006, 283-284.)

When deciding, which program should be taken into use, it is really important that different options are studied well, because each company has their own needs and interests and not all the program providers have the same features, although many have possibilities to do tailored versions. Another meaningful factor to think about is that how much there is support available from the program provider. The chosen option should stay for a long time in the market to avoid sometimes painful system changes and education of the staff to use them properly. There might be various databases between different departments, which could be avoided with one common system and that way the information flood is decreased. (Vekara 2003, 6-10+47.)

6 PdM TESTING TOOLS AND METHODS

Many testing techniques can be applied to a family of similar components, but the periodicity of the predictive maintenance, PdM, tasks is individual for each one depending on the environment, criticality, classification and operating conditions. It also matters if the component is operating in continuous duty mode or cyclic duty. (Bloom 2006, 172.)

The method decision involves selecting alternative designs, procedures, plans, and methods that consider time and economy restrictions in their implementation. In many cases it is needed to consider the situation from the economic point of view; what is reasonable to test or inspect and also note that common sense and experience can help to decide where to put the effort and how to set realistic expectations. (Mobley, Higgins, Lindley & Wikoff 2008, 211-212; Neuwirth 2010,10-11.) With descent inspection system (around 30-40% of the failures can be predicted by the condition) costs can be reduced, security improves, and environment load diminishes. Inspection systems can improve availability, quality, guarantee and product development questions with a manufacturer. (Kunnossapidon toiminnot; Järviö 2006, 54.)

6.1 Different PdM testing techniques

Vibration monitoring is mostly valid for rotating machinery where alignment problems, bearing wear or unbalanced conditions can be detected. Vibration sensors are used to detect loose or cracked support mountings or support pads, bent or cracked shafts, and coupling problems. Vibration measurements can be controlled by software, which monitors incipient failures as they progressively get worse. (Bloom 2006, 172-173; Kunnossapidon toiminnot.) There are also portable off-line pieces of equipment, which can be carried to non-stable locations and their data is analyzed by a specialized operator.

Acoustic monitoring can be used to detect internal and external leaks in all types of valves such as motor and air-operated valves, manual valves, and check valves. Normally it is air or water that leaks by or through different types of valve parts. Acoustic monitoring can also detect leaks through heat exchanger tubes that are cracked and it can be used to measure the general condition of the machine. (Bloom 2006, 173; Kunnossapidon toiminnot.) Figure 4 shows the rising trend toward the failure limits, which is already known and set down. With the trend it is possible to prognoses which lighten the maintenance planning and scheduling.

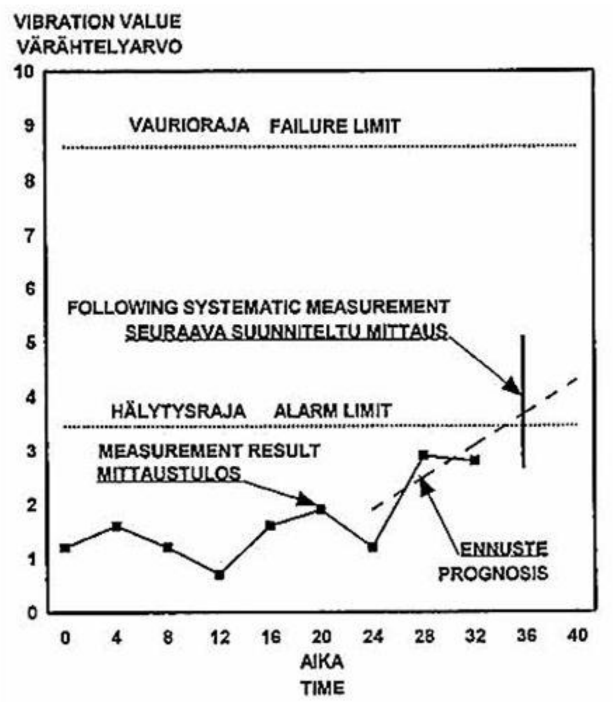

FIGURE 4. Example chart of vibration monitoring (Original figure: Kunnossapidon toiminnot.)

Normally this type of thermograph monitoring is used to find heated spots using an infrared camera. This is quite a precise technique as it can detect electrical connections that have become loose and it can be programmed to detect any parameter that might run hotter than usually expected, such as relay coils, motor windings and hydraulic / pneumatic systems. Incipient bearing or integral gear failures are commonly detected by oil sampling and analysis. This is easy to do: a small amount of oil is drained from the unit and analyzed and inspected for wear particles and other contaminants such as water intrusion into the reservoir. (Bloom 2006, 172; Kunnossapidon toiminnot.)

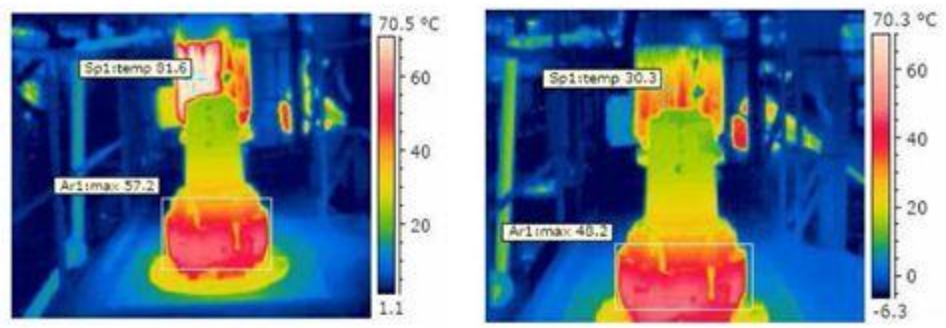

FIGURE 5: Thermograph photos of dirt (left) and a cleaned (right) motor and its rotating cogwheel gear (Original Figure: Saarenpää 2006, 69-70).

Figure 5 shows how much difference normal cleaning can make to the operating temperatures on electronic motors. The target is outside and the temperature difference between the two photos is 7 °C and it can be said that the cleaning reduced approximately 40 °C the surface temperature. If a motor has to operate too long, too hot, its insulation's lifetime shortens considerably. The lifetime of the winding insulation shortens approximately to half for every 8 ...10 °C rising of the temperature in continuous usage. A damage the heat can do is not rapid; the motor can run few years properly without any problems, but a cleaned motor can run multiple times, concerning the insulation parts. (Saarenpää 2006, 68-70.)

Radiography inspections uses x-rays to detect subsurface flaws in welds or other metallic parts such as casings or valve bodies and the same things can be also tested by ultrasonic testing. Surface cracks on metallic parts can be tested by magnetic particle inspection or by the Eddy current test. Pipe cracks can be detected with the liquid penetration technique. Motor problems such as cracked rotor bars and some motor winding, are detected by the motor current signature analysis. A boroscope can inspect visually internal part of equipment that cannot be inspected externally. (Bloom 2006, 172-175.)

7 OBJECTIVES AND STRUCTURE

Objective of this bachelor thesis is to locate problematic pieces of equipment and components, to find reasons that cause the problems and improve the finishing line reliability with suggested solutions. Physically the scope of investigation starts from the beginning of the conveyor line (after sheeters) and ends in the warehouse where pallets are transported by forklift trucks. Problems on the finishing line are investigated whether electrical, mechanical or information technology, IT. The actual board manufacturing process, the board machine or cutting machines are not covered in this thesis.

There are 13 different category machines (later each are presented) in the finishing line and some of them have a couple versions such as conveyor parts. The primary focus will be on finding new maintenance possibilities to improve the availability. Secondary focuses are to re-design the functions or pieces of equipment in a way that they can run more reliably.

Ways to improve the reliability are evolved by generating ideas from conversations with employees from different levels, using RCM methodologies, supporting materials of the company and the writer's own observations. Many theoretically ideal maintenance solutions cannot be applied due to their high costs versus the minor benefits.

While carrying out the project there were no planned maintenance in the finishing line, only reactive and corrective (except putting grease on the crawler of the oven). A big problem is that there are many different kinds of machines; each has unique problems, sometimes small ones, but they occur often. One problem is that the machines are relatively cheap and their disintegrations do not have as direct cost losses as for example the board machine breakdown.

Failures, gravities and resolutions of each machine can be seen from the appendices 1-6 and the most important solutions are presented in a separate chapter in the thesis. The implementation of the suggested solutions and obtaining is not possible in this thesis and therefore the solutions are considered on the theoretical level, not forgetting the characteristic features of the finishing line. Therefore the company has to implement the parts that they consider to be reasonable to take into use and obtain the new findings.

8 INTRODUCING THE FINISHING LINE

There are a few logics controlling the line movements. Logics get their inputs from the sensors that recognize pallets and if the pallet is free to continue on the line, the logic puts an output on. Pallets go all the time on a conveyor line or on a transfer carriage and all the machines are on the conveyor line. All the compressed air, which a couple machines are using, is compressed in one place and the finishing department is the last part of this system. All the 83 individual pieces of equipment in the finishing line are powered at least partly by electric motors. In this thesis the primer and secondary functions of the machines are not presented detailed or pieces of equipment are not listed component by component, but below there is short introduction to the machines of the finishing line. Nevertheless the components and functions of the pieces of equipment were investigated and noted during the process. The finishing line is divided into two parts. The finishing line layout can be seen in the appendix 1. The first part, M3 and the pieces of equipment on the left side, is meant for the pallets that can continue directly without interruptions. The second part, TRM15 and the pieces of equipment on the right side, is meant for the pallets that need quality control after the sheet cutters, e.g. if the carton stack is not straight.

8.1 Machine descriptions briefly

Conveyors

There are two different types of conveyors in the finishing line, chain and belt versions, which are seen in Figure 6. In the belt version the belt is in the middle of the conveyor and under the rolls contrary to the chain version where the chain transmission is in the side of the conveyor. Parts of the conveying system are a few swivels and transfer carriages. Swivels are used to turn the running direction of the pallets, normally 90 degree. The transfer carriages are used to replace swivels and conveyors where walking or truck path has to go through the line or simultaneously a few pallets have to be transferred at the same time.

FIGURE 6 Two dissimilar conveyors

Twirler

A twirler machine is located on the side of the line where only go pallets that need to be quality controlled. The twirler is meant to reform the carton sheet stack in the way they fulfill the quality needs. There might be bad cartons in the middle of the carton stack and when the machine turns it on its side and releases the press, it is easy to take the bad sheet away or straighten the stack. It has moving roll tables, which can press the pallets tight enough when it turns upside down or just in its side like it is processing in Figure 7.

FIGURE 7. Twirler turning a pallet

Pushers

In some cases rolls of the conveyors are not in the same running direction and the pallets have to be pushed to the following conveyor line, mostly the pushers are after the sheeters, while the pallets are side by side. The pushers work with hydraulic pumps and cylinders give the pushing power to the bar that touches the pallets.

Centering devices, Reike & Centrador

Pallets can arrive in a two different ways and only one is the right. Therefore pallets have to be turned into the right way as the pallet shown in Figure 8 (left). The latter part of the finishing line is above the earlier conveyor line and therefore the pallets have to be raised on the same level. The centering devices also center the pallets in the middle of the conveyor, straighten their legs to the running direction and the equipment called Reike also pushes the carton stack in the middle of the wooden pallet. Reike is considered to be one of the most problematic equipment in the finishing line, as it is one of the three bottleneck points.

FIGURE 8. The centering device (right) and Reike (Left)

Sheet counter

There is a machine that calculates the exact amount of the carton sheets and compares the result to the theoretical value, which is read by a scanner from the bar code. A flash and laser system calculator gives the information forward to a computer that forwards the data to later proceedings.

Covering and wrapping devices

Pallets are covered with plastic in two stages. First the other machine puts the plastic on top of the pallet and in the second phase the wrapper spins the plastic around the pallet. The wrapping machine, known as the Octopus, is one of the bottleneck points of the finishing line. Covering principles are seen in Figure 9 where the pallet is already covered (earlier equipment) and the plastic around the pallet is put with the circling feeding, cutting and attaching tool.

FIGURE 9. Octopus (left) and covering (right) equipment

Oven

Packaging around the pallet has to be enclosed to be waterproof. In the oven the plastic shrinks tightly next to the carton and there is not much air inside. The plastic layers attach to different layers and there is no need for further compacting. There are four gas crematories heating the oven and ventilators to circulate the air inside. There is an entrance and exit door and only one pallet can enter into the oven at a time. The oven is one of the three bottlenecks of the finishing line.

Strapping device

For every pallet after the oven the strapping device presses the packaging. Pallets that are loaded to vessels need straps around the wooden pallet and carton stack. An operator has to put carton softeners manually to the corners of the carton stack. A pneumatic system feeds the strap to a passage system and when the strap is properly around the pallet, there is an actual strapping machine that connects the two ends and releases the passage system to the waiting mode. A package can continue forward after the strap is attached to the two leg holes of the pallet.

Robot attaching the labels

A scanner recognizes a pallet and gives orders for the computer, which automatically prints the new labels. Printed labels move on tracks to the robot that clings to the label with low pressure and takes it to a glue sprayer and then it is attached to the pallet. The computer, printer, and logics are located in an air-conditioned cubby, while the robot arm and the glue sprayer are next to the conveyor.

8.2 Finishing line problems

Problems that are dealt with in this thesis can be found in appendix 2 (RCM 2 information worksheets) and here the most common problems and different kinds of possible failure modes are presented. The thesis concentrates more on the failures that occur more likely, but theoretical problems have also been thought. The gravity chart of the failures can be found in appendix 3. Appendix 4 is a model of criticality analysis of the failures to show how gravities were chosen.

In many cases on this finishing line there occur problems even if nothing has broken down and in some cases resetting by an operator can solve the problem and the maintenance staff is not needed. Mostly these problems occur, because the logic and the pieces of equipment do not communicate correctly and a manual drive for a moment can make it operate again. Figure 10 shows a problem where nothing breaks down: only an emergency rubber plate on an orange transfer carriage is dimensioned too long and it touches unwillingly to a following conveyor (green part on the right in Figure 10) and stops the automatic process.

FIGURE 10. Too long rubber emergency stop plates, which are touching the conveyor

One of the biggest problems is the scenario, when pallets arrive really indirectly to the centering equipment Reike. Indirect pallets wear down the lifting table equipment or pneumatic parts have to use more than normal amount of power to straighten the pallet. In many cases Reike cannot recognize the pallet correctly and in the worst case a pallet can depart its legs pointing to the wrong direction, which reflects later problems. Figure 11 shows three possible problems where the original reason is an indirect pallet in the beginning of the finishing line and the result can be stuck or fallen pallets.

FIGURE 11. Three example sites where the incorrect direction of the pallet legs can cause problems (Oven, CTM 44 and M17)

There can be hydraulic problems, while the pusher and its cylinders are powered by a hydraulic pump. Then the pallets cannot be pushed to the conveyor line. There are problems with the twirler, because it cannot create enough compressed air, in which case the process has to be more manual and slower. Other air problems occur with the equipment called Reike when there is not steady compressed-air available, due to the other usage of the air in the factory. There are cases when pneumatic parts fail and they need to be changed, such as valves in the machine Reike.

The oven is meant to operate approximately in 250 °C, but the temperature is not regular, it varies a bit. If the crematories fail the temperature lowers, but into a certain point pallets can stay for a longer time in the oven, which nonetheless slows down the finishing line. The ventilators failing do not give proper air circulation. The oven is one of the biggest reasons for quality problems that occur in the finishing line.

There are also failures that appear due to physical breakdowns. On Octopus there are lots of mechanical movements, high speed, torque and erosion and components are more stressed (Figure 12). There are wheel abutments on the circle, chain supports and their fasteners, a supporter of the motor and transmission belt as well as a cutting and attaching tool of the plastic. The supporter for the motor of the transmission belt that can be seen in Figure 12 (second from the right side) failed during the summer 2010. The bolts and already once welded part had slowly started to warp. Finally the belt was too low and the whole circling system had problems to operate correctly. The attaching and cutting tool seen in Figure 12 (right one) finishes the wrapping by melting the two plastic ends together by a small resistance wire. There is a pneumatic cylinder moving the cutting blade. Electric wires are connected to an electric lump, which has connection problems, because the cutting tool movements stretch the connector. The consequence is that the wrapping is not finished and the operators have to put the plastic end under other plastic layers or the plastic end can give wrong information for the sensors while hanging freely or the plastic end can unpack the plastic packaging.

FIGURE 12. Octopus' components that are stressed in mechanical movements

Rolls on the conveyors can bend or their fasteners can fail. In some cases the roll can bend so much that the pallets can jam into the gap. The chain version is thought to be more reliable than the belt version, because the belt is torn more likely. In the summer time working conditions and the temperature can raise to really high readings. These conditions expose the pieces of equipment to higher risk to fail and one good example is a servo motor for the Octopus, which is located in a closed electric closet. One reason to the failure can be overheat without a required cooling system and air circulation. One problem is that sensors do not recognize the pallets when they should. Other sensor types can break down, they can be just wrongly adjusted or they are too much covered by dirt.

Problems can also be more in the program of the logic. There is an example when the label robot is attaching (Figure 13) a label onto the front of the pallet. When laser sensors do identify the pallet it stops immediately. It is possible that the pallet moves backwards and the sensors do not recognize the pallet anymore and the process stops due to wrong information. Actually there are several possibilities to solve this problem, but in this thesis it is later investigated from the IT point of view and solved with a small program modification. The sheet counter and its scanner fail many times to operate automatically. The scanner cannot read a bar code or a computer does not accept values. The software turns to manual mode and the operator has to feed the values and this failure mode occurs often.

FIGURE 13. Label robot is attaching a label onto the front side

8.3 Failure survey

The following Figures 14 and 15 illustrate a short time review of the finishing line failures that needed repairmen to fix them during one month period. However they do not represent the 100% truth as they are taken from manual diaries of the mechanics, which caused several problems for the undersigned. Also these results do not show more information than the devices, which were maintained.

As shown in Figure 14 conveyor failures took 33 % of the work orders of the mechanics and mostly they were roll changes. As indicated earlier the bottlenecks are Octopus, Reike and the oven and they took all together 49 % of the orders. The bottleneck pieces of equipment are single machines whereas there are several conveyor units. In Figure 15 the bottleneck pieces of equipment are also at the top of the list when automation mechanics were needed, together they made 54 % of the orders. Some of these maintenance orders needed both mechanics and automation mechanics, but there were also individual tasks such as automation mechanics repairing photo sensors or conveyor repairs needed more often only mechanics.

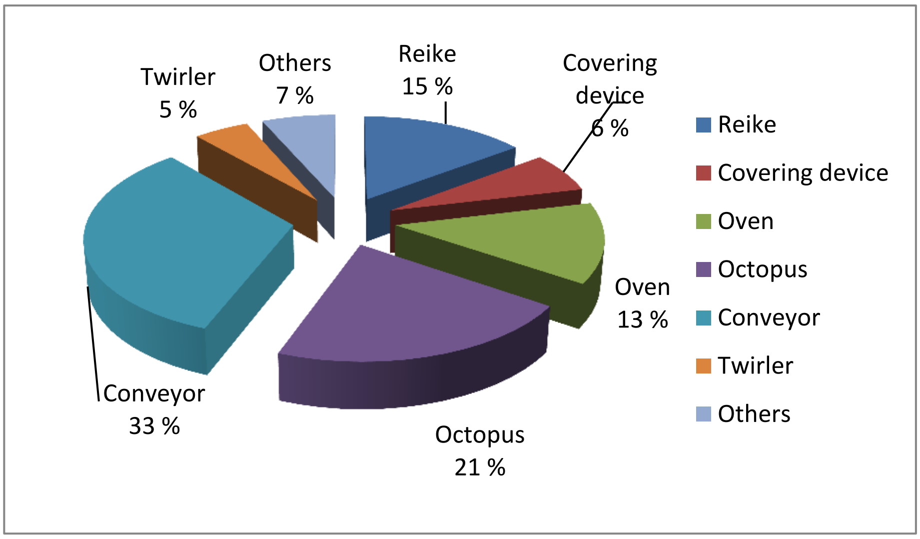

FIGURE 14. Incidents that needed mechanics 29.5-29.6.2010

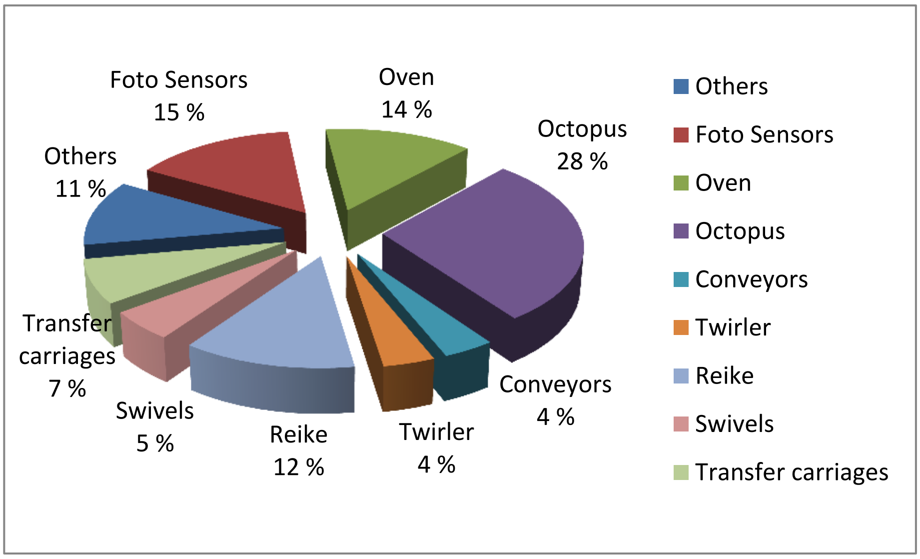

FIGURE 15. Incidents that needed automation mechanics 29.5-29.6.2010

8.4 Line efficiency

The slowest machine (strapping equipment, special packaging) takes up to 80 seconds to process one pallet when the maximum amount that the finishing line could process in an hour would be 45. The slowest machine, which every pallet has to go through, takes up to 60-70 seconds to process one pallet. With this cycle approximately 55 pallets per hour could be operated.

As of 2010 August the average the finishing line sheeters cut per hour is 31.25. In theoretical circumstances (thickness, quality, width of the roll, sheet sizes etc) the maximum the five sheeters could cut can be close to 100 pallets per hour (Caceres 2010.)

The sheeters have to operate below their capacity, because of the finishing line, which illustrates indirect influences of the finishing line on the other parts of the plant. The interviews also proved that approximately 20% of the pallets have to re-enter the finishing line after they have gone through it due to the quality problems, mostly caused by packing problems, such as holes in the plastics.

9 RESULTS AND DISCUSSION

On the finishing line there does not exist continuous systematic condition monitoring and most of the information is in the heads of the people. In this thesis the results are suggestions to improve the maintenance planning process and some more specific machine centered solutions. The conclusions that are suggested in this thesis are partly confirmed by the operators or by the maintenance staff to consider their usefulness or practicability.

On the appendix 5 (RCM decision worksheets) indicative solutions are suggested for each conceivable failure. Appendix 6 is presenting the RCM decision logic to evaluate consequence of a failure and to choose a proper solution suggestion. Technological PdM methods cannot be taken into a bigger picture, because mostly the testing equipment could be expensive and their use can be directed to more important locations. In the finishing line the benefits got from PdM tools does not mostly pay the effort. In this the focus is not that much on electronics, because electronic devices have been said to fulfill their life time expectations.

9.1 Modifications

One major finding is not that much from the maintenance point of view, but implementing a centering device (an example is introduced in Figure 8) on the conveyor M13 could reduce many failures that are caused by the indirect pallets. The implementation could reduce problems with the centering equipment Reike, sheet counter, transfer carriage and oven. The implementation of the equipment could reduce falling or jamming of the pallets, mechanical stressing of the lifting table M16 and functional disorders of the Reike and sheet counter. In addition, the program of the centering device Reike could be changed in the way it reduces mechanical stressing. As of 2010 August pallets were driven against the M17 conveyor and M16 rolls were forced to spin with the heavy pallet on it. The conveyor M16 tried to straighten the pallet this way. With the implementation of the centering equipment the earlier phase is unnecessary and the system could recognize the pallet before it hits the M17 edge.

Transfer carriages TFR-7 and TFR-10 rubber emergency stopping plates (Figure 10) could be cut from the sides in the way that they do not touch unintentionally other components. The parameters of the sheet counter software could be changed in a way that it accepts a bigger difference between the theoretic amount of layers and the real amount of layers. The scanner of the sheet counter could be re-situated in the way that it can read the barcodes even the barcodes are little indirect.

The strapping device is a really old and unique machine and therefore it is difficult to find spare parts for it. During one failure situation the machine was opened and all the components were cleaned, which showed that most of them were worn down. One option could be to invest into a new machine, which could insert two straps at the same time. Some smaller modifications could also be done. In Figure 16 there is a plate tightened by one spring, which is an essential part when locking the two strap ends together. Sometimes this plate is too loose and the locking cannot be completed. One option could be to drill holes and tighten the plate with more springs.

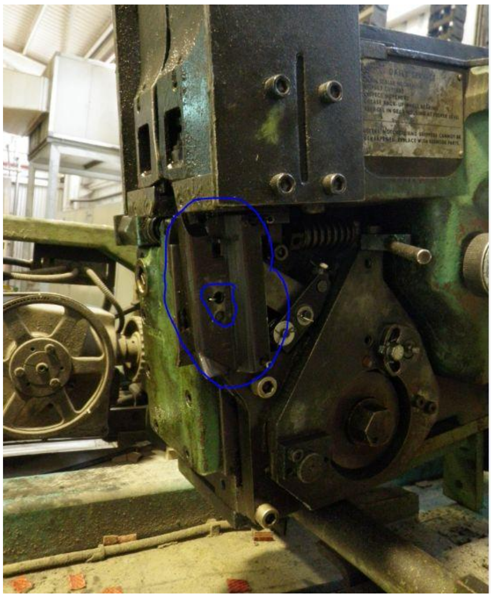

FIGURE 16. Strapping equipment and too loose plate

The servo motor of the octopus fails due to high temperatures in the closet. Normally it helps when the door of the closet is opened and the servo is let to cool for a while. There is not a proper air ventilation in the closet; there are only small holes in one side, which do not create enough air circulation. Implementing a ventilator on the other side could add more air flow that could cool enough the working conditions for the servo motor. As of 2010 August there had been called for an offer to replace the octopus with a new machine. The new machine is a different type and it is not wrapping the plastic around the stack of carton, but the pallet runs toward a big plastic that is attached when the pallet have passed by. In this type of machine there are less susceptible components to fail. The oven is also the other equipment, which the finishing section manager has called for an offer to replace it with a new machine.

The previous problem described about the label robot was solved by a small program modification. The problem was that the pallet moved away from the sensor line. The solution was to insert a small waiting time after the sensor pair has recognized the pallet. Now the pallet runs approximately 3 cm over the sensor line before the logic stops the conveyor. This way it does not matter if the pallet can move a little backwards. This is also a long time solution and the chain of the conveyor does not have to be tightened that often. Tightening the chain, not to let the rolls spin backwards, was another solution, but it would not have guaranteed as good reliability as the program change.

9.2 Condition monitoring, visual inspections and ODR

In a defined routine the operators could make visual inspections and basic maintenance tasks for the machinery. The equipment and components that really need inspections should be studied further, because there is no point to loose recourses to check everything. The operators should be fully trained to make the advantageous visual inspections, not just sent them to walk around and look over the machines. There could be a checklist indicating all the components that need revision solved in a way that pleases the enterprise.

The operators could make the basic preventive or corrective maintenance tasks such as tightening chains and fasteners, lubricating components, changing failed or probably failing parts, adding missing rivets or other elements and cleaning also the operating equipment and components, not just the environment. Figure 17 is an example of the strapping equipment where the operators could do preventive or corrective maintenance while there are symptoms available.

There are some predictive tasks that the operators could do. E.g. the laser sensors on the G2 swivel did not recognize the pallet leg and the front part of the pallet was empty and it was allowed to move too long with the result that the pallet was tightly jammed to the cage around. This can be avoided if the operators check that the sensors recognize the pallets from the correct height. TFR-7 and TFR-10 positions are recognized by a laser distance meter. Many times the system has problems to identify the transfer carriages and the system turns to off-line mode. The operators could check the parameters and make sure they are between the desired limits.

FIGURE 17. Examples of faults that the operators could maintain

There are some elements that should be taken into consideration if they need preventive maintenance such as the oven. The doors of the oven are supported firmly only above and in which case it wastes the heat. Many times there occur problems in opening and closing the doors and the mechanical failures could be prevented with the correct maintenance. The logic program is one of the causes for the opening and closing problem and this needs more studying why the problem occurs.

There have been tools for the operators to do basic maintenance tasks and there have also been a mechanic only for this section, but they have been taken away to reduce costs. This thesis is not indicating that a new mechanic should be hired, but the maintenance skills and tools for the existing operators could be improved. A further investigation has to be done to sort out the real needs.

9.3 Operation procedure changes

There were cases when the automation mechanics did not have enough useful information of the systems. All the important documents, such as circuit designs, should be up to date to ensure the sufficient aid for the maintenance staff. Only small failure descriptions exist in the manual diaries of the mechanics and each writer seems to write in a way and a different amount of information.

Taking a CMMS into use could help to improve the maintenance system in the whole factory. After a certain time there would be much more data from the machine problems such as running times, random and regular error rates, downtimes, MTTF, MTTR, MTBF, OEE etc. The information could be used to make more efficient planning of the maintenance tasks and to follow the results of the maintenance. Taking the CMMS into use can be time and resources consuming, but its paybacks have been said to be undeniable.

The company could change with small actions the way how the finishing line is maintained to give a new picture that the finishing department also matters in the bigger picture. It was seen that some operators felt the present situation hilarious in cases when down times were high. With some actions the motivation and teamwork could be improved.

10 CONCLUSIONS

None of the findings or the results was taken into action while the experimental part was carried out. Another report was delivered to the company and it is up to them if they consider that the solutions are worth of trying. Therefore there is no observational information of the results. During the project there were also carried out different layout modification suggestions. They were to ensure more intermediate storage space on the conveyor line without changing the general layout and sketches to change the whole floor plan for the future investments. Nonetheless those suggestions are not presented in this thesis, but were thought as an option to improve the availability.

This project was carried out really independently, on a tight schedule and without advanced special studies. This thesis involved a great amount of communication. All the communication was carried out in Spanish, which the writer can only speak satisfactory. These facts surely have some influence on the results and with better language skills the findings would have been undoubtedly more extensive. The other factor that is affecting to the results is the fact that some functional failures, failure modes and failure effects were undemanding to study precise enough. Therefore there can be too much vague descriptions that need further studies.

The biggest problem in the finishing line is that there are plenty of different kinds of small problems, such as hydraulic, electronic, pneumatic, mechanic and IT ones. There is something failing often, which makes the working impracticable sometimes. The machines are dissimilar devices and relatively cheap and they do not have direct relations to profit losses and maybe because of these reasons the finishing line plays a minor role in the factory. There is only reactive maintenance and when another problem is fixed it does not take a long time in general when the next failure occurs. Some of the failures are the type that it is really hard to make preventive maintenance cost effectively or it is not reasonable to do predictive maintenance tasks. For this reason many problems are allowed to run-to-failure, RTF.

The maintenance process is suggested to have some modifications in a couple of different ways. There were few functional problems caused by indirect pallets, which can be avoided with a relatively cheap investment. It is often better if there is a possibility to find solutions that do not need investments, but in this case adding the centering equipment can reduce notably the number of failures. This is also known as eliminating the root cause. Other big finding was that there is no clear documentation system in use. While having interviews each operator knew a bit about different failures and causes for them. Also the maintenance staff diaries describing tasks done vary a lot. There is no controlled system how each work order should be identified and described in the diary. Thereby it is suggested that CMMS is taken into the consideration. It was seen that the tasks were divided with the classical world of ideas; the operator mostly just run the machines and the maintenance staff repair them. One option to improve the process could be dissipating the dividing the tasks between different workers. Giving proper tools and education for the operators could in some cases hasten the maintenance or reduce the amount of the failures.

With the latest studies it is not always the age of the machine that automatically causes problems, but in this finishing line some of the machines are thought to fail due to the high age. Therefore there have been made two offers to replace the two bottleneck machines in the finishing line, because they have reached their life time expectations. If investments could be done freely, there would be several ways to improve the availability and reliability of the plant. As mentioned earlier the finishing line was planned to work with three sheeters and now there are five of them. There has also been some talk about that there would be more sheeters coming in the future. As of 2010 August, the finishing line efficiency and effectiveness are that low that in the future bigger changes might be needed.

One interesting point is; how important the better availability of the equipment is for the community spirit. The workers from the section manager to the operators emphasized the fact that the more there are problems the worse the community spirit is. It was also easy to see that the operators did not feel their work as important as it should be, because that much attention is not paid to the finishing line from the higher levels. With small inputs the company could change the operator’s appreciation of their work, not letting them feel that their tasks are of secondary importance compared to the other sections of the factory. The biggest risks why these findings would not give any real results, such as longer equipment life time and improved efficiency and effectiveness of the finishing line, are that the company has too fast expectations, lack of patience and lack of discipline of the employees towards the changing process. One major factor is that there has to be enough data from failure history and that is why the CMMS is suggested.

It is important that the enterprise examines the findings and if necessary make some modifications to them before implementing, which unfortunately was not possible during the thesis project. The whole process was that fast that from the training the writer to writing the first report took only five weeks. That is a short time of period and it can be said that there are more ways to improve the availability than anyone can present in a bachelor's thesis. Gullsten (2010) indicates that the best way to implement continuous improvement is to keep eyes and ears open. The earlier statement applied to the maintenance field means more communication between the operators, maintenance staff and technical managers to make better planning of the maintenance and achieving better results on different measurements.

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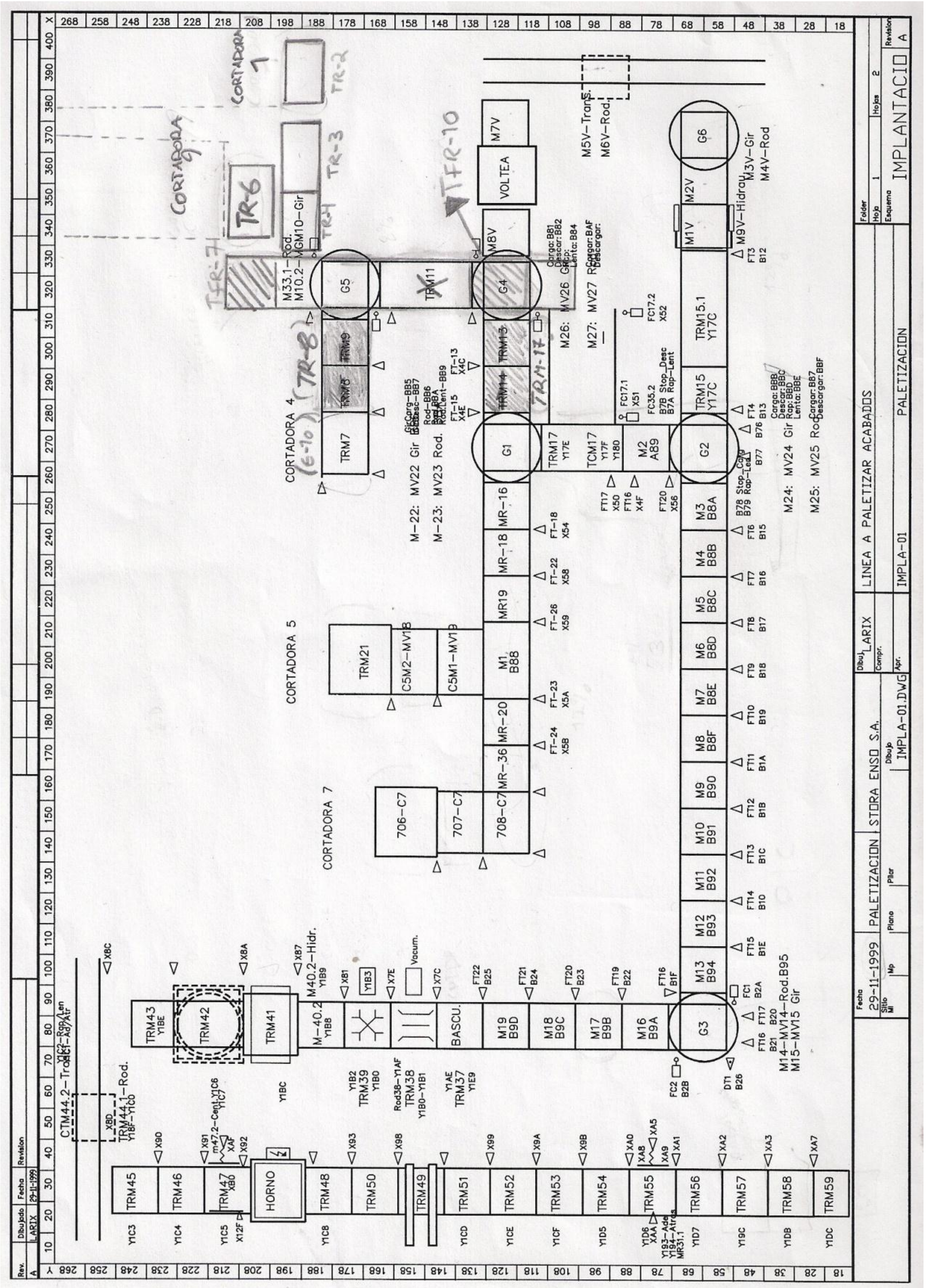
APPENDICES

Appendix 1. Floor plan of the finishing line



Appendix 2. RCM information worksheets

RCM Information worksheet			System Finishing Line		System number 1	Consult David Leal	Sheet 1
			Sub-system Conveyor		Sub-system number 1.01	Auditor Sauli Lankinen	Of 1
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Transform the pallets from A point to B point	A	Roll(s) do not spin	1	Motor Does not work	The conveyor stops and other pallets cannot pass this stage	
				2a	Transmission belt is broken	The conveyor stops and cannot move the pallet	
				2b	Transmission chain is broken	The conveyor stops and chain can jam	
				3	Gearwheels are broken	Moving chain does not pass all the energy via gearwheel to the rolls	
				4	Bearings and/or suporting devices are broken	Rolls might bend or jump up from their places, pallets might jam and cannot go over the gap	
				5	There is carton between rolls and belt	Carton jams rolls and motor does not have enough power to run the conveyor, rolls have to be opened and lifted so carton can be removed	
				6	Sensors and logic do not give the right information	Pallet is not recognized correctly and output to move pallets does not go on	
		B	Pallets fall down or jam	1	There is too big gap between two different conveyors/Transfer carriages	Pallet legs hit the edge of the transfer carriage and stack of cartons might fall down	
				2	Pallet legs are in the wrong running direction	Carton stack might fall down in different locations	

RCM Information worksheet			System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Swivels		Sub-system number 1.02	Auditor Sauli Lankinen	Of 2
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Move the pallets into the rolls running direction	A	Rolls do not spin	1	Motor Does not work	Pallets cannot enter further that previous conveyor is forcing them	
				2	Transmission belt is broken	Motor can run, but there is no transmission, rolls do not spin	
				3	Bearings are broken	Roll(s) drop down a little and need more energy to move	
				4	There is carton between rolls and the belt	Carton jams the belt tightly and motor cannot overcome this force	
				5	Sensors and logic do not give the right information	Right inputs and outputs do not go trough	
2	Turn the pallets running direction	A	swivel does not turn	1	Motor Does not work	Pallets enter to the conveyor, but swivel does not turn, cannot pass further	
				2	Gearwheel / transmission is broken	Motor is running, but transmission does not give energy to move the body	
				3	swivel is not on its rails	Motor and transmission can stil spin the wheels and it can continue until system stops	
				4	Sensors and logic do not give the right information	System is stopped or running until it gets right inputs and outputs	

RCM Information worksheet			System Finishing line		System number 1	Consult David Leal	Sheet 2
			Sub-system Swivels		Sub-system number 1.02	Auditor Sauli Lankinen	Of 2
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
		B	swivel does not recognize its position	1	Inductive sensors do not work	swivel turns too much or too little	

RCM Information worksheet

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Transfer carriage		Sub-system number 1.03	Auditor Sauli Lankinen	Of 2
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Transport the pallets from the other conveyor to the another	A	transfer carriage does not move	1	Motor has failed	Pallets cannot be transported forward and there might be gue to this point, next side line can run until it is empty	
				2	Transmission for wheels does not work	Motor can run, but the machanical energy is not transported to wheels and the transfer carriage cannot move	
				3	Sensors does not recognize its position	transfer carriage stops somewhere and does not communicate with the logic	
				4	Logic is down	transfer carriage stops somewhere and all the devices that are controlled with the same logic does not operate	
				5	Emergency stop is on	transfer carriage stops in that point where the bar has given the signal	
				6	Electric cables do not have connection	Depends, which cable, usually stops the movement	
		B	Rolls do not spin	1	Motor Does not work	Transfer carriage cannot take the pallets correctly or move them to the next conveyor, finally the conveyor stops from some misbehavior that logic recognize	
				2a	Transmission belt is broken	Rolls cannot spin and pallet can only move as far as previous conveyor can push it	
				2b	Transmission chain is broken	Broken chain can jam, rolls do not move	

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 2
			Sub-system Transfer carriage		Sub-system number 1.03	Auditor Sauli Lankinen	Of 2
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
				3	Gearwheels are broken	Rolls do not spin correctly or at all	
				4	Bearings and/or supports are broken	Rolls might bend and jump from their locations	
				6	Sensors and logic do not give the right information	Motor does not get running order from logic and pallets have to wait right output	
		C	Pallets fall down in the end of the conveyor	1	Photo sensors do not give the stop order for the logic, transfer carriage is in the wrong place	If transfer carriage is in the wrong place and conveyors last sensor does not stop the pallet it drops from the conveyor line and the fallen pallet is in the way of the transfer carriage and it cannot operate	

RCM Information worksheet

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Twirler		Sub-system number 1.04	Auditor Sauli Lankinen	Of 2
	Function		Functional Failure		Failure Mode	Failure Effect	
1	Put air between carton layers and vibrate it more straight	A	Vibrator does not work	1	Air pump is broken or other airflow device	Machine cannot fullfill its tasks, move cartons straight, and stack of cartons is straighten manually	
				2	Pneumatic cylinders or other parts are not working	Plate cannot vibrate and straighten the cartons, human hand work is needed	
2	Straighten the cartons automatically and transport them forward	A	Automatic process does not work	1	There is not enough compressed air	Machine cannot work automatically and humans have to use it, process needs hand made tasks	
				2	Sensors are not working	Machine logic does not get right commands, quality control process stops	
				3	Logic is down	Machine turns to manual mode	
3	Press the pallet so it can be turned	A	Tables do not move or press	1	Motors do not work (there are 2 (1 for each table) and just 1 is enough to press)	Multiple fail needed that this phase is not working, though with small pallets there might occur problems just with one pressing table	
				2	Transmission / chains are broken	Tables do not squeeze the pallet so it could be turned and dropped that cartons could be straighten	

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 2
			Sub-system Twirler		Sub-system number 1.04	Auditor Sauli Lankinen	Of 2
	Function		Functional Failure		Failure Mode	Failure Effect	
				3	Supports are broken	mechanical energy is not focused on right directions	
4	Take the pallet into the machine or forward it to the next conveyor	A	Rolls do not spin	1	Motor does not work	Pallet cannot enter further that previous conveyor is forcing them to and they cannot leave the machine	
				2	Transmission does not work	Motor can run, but energy is not transported to rolls	
				3	Sensors or logic are not working	Machine is not working and waits right commands	
5	Turn the pallet on its side or upside down	A	twirler does not turn around	1	Turning motor does not work	Pressed pallet cannot be turned and quality demands do not fulfil. Needs manual working	
				2	Chain, axle or other transmission particle breaks down	Motor can run, but energy is not transported to wheels that spin the twirler outer circle rail	
				3	Supporting devices are broken	Machine is not on its rails and none of its tasks can be done	
				4	Inductive sensors do not communicate with the logic	twirler does not recognize its positions and cannot finish its movements into correct position	

RCM Information worksheet

	RCM Information worksheet		**System** Finishing line		**System number** 1	**Consult** David Leal	**Sheet** 1
			Sub-system Pusher		**Sub-system number** 1.05	**Auditor** Sauli Lankinen	**Of** 1
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Push pallets from a conveyor to another	A	Device does not lift or lower the pushing tool	1	There is not enough power in the hydraulic pump (2+4)	Device is down and works just as normal roll, up it does not pass any pallets	
				2	Motor of the pump is not working	Device cannot move to any direction	
				3	Y-direction cylinders or other hydraulic devices are not working	Device is down or if it is up, new pallets cannot pass it	
				4	Pipes are leaking oil and the pressure is too low	Device can move slowly, but with heavy pallets the is not enough power for the cylinders, visible oil spills	
				5	Logic and sensors does not communicate	Pushing tool stays standby and pallets are waiting the logic to give right orders	
		B	Device does not push the pallets	1	There is not power in the hydraulic pump (2+4)	Pallets do not move or they move indirect, otherside goes ahead	
				2	Motor of the pump is not working	Device cannot move to any direction	
				3	X-direction cylinders or other hydraulic devices are not working	Device cannot push or reverse	
				4	Pipe leaks	Pushing tool stays standby or moves slowly	
				5	Sensors and logic	Pushing tool stays standby and pallets are waiting	

	RCM Information worksheet		**System** Finishing line		**System number** 1	**Consult** David Leal	**Sheet** 1
			Sub-system Reike		**Sub-system number** 1.06	**Auditor** Sauli Lankinen	**Of** 3
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Lift the pallet to same level with Reike	A	Table does not work	1	Lifting motor is not working	Pallet stands on the table, cannot continue to the next level	
				2	Transmission parts or chains are broken	Pallet stands on the table, cannot continue to the next level, motot can run	
				3	Supports are broken	Motor can run and maybe transmission can lift it, but it is unsteady	
				4	Inductive/other sensors do not recognize the pallets or table position	Pallet runs against the next wall and rolls spin until a certaint time, if sensor does not recognice process stops or it can move in a wrong time and fall down the pallet	
				5	Logic is down	All the machines stages are standby	
				6	Indirect pallets	Effecting (reason) all the previous	
		B	Rolls do not roll	1	Like earlier rolling problems	Table does not continue its task	
				2	Indirect pallets	Pallet waits the logic to be resset, have forced rolls to spin earlier	
2	Center the pallet in the middle of the conveyor + straighten it	A	Walls do not press/move the pallet	1	Pneumatic cylinders or other devices	Walls do not move or have enough power to push, stages might be able to do, but not properly	
				2	Compressed air	Walls do not move or have enough power to push it as planned	

RCM Information worksheet

	RCM Information worksheet		**System** Finishing line		**System number** 1	**Consult** David Leal	**Sheet** 2
			Sub-system Reike		**Sub-system number** 1.06	**Auditor** Sauli Lankinen	**Of** 3
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
				3	Sensors do not communicate correctly with the logic	Usually machine stops and needs human to reset it	
				4	Limit switches do not recognize cylinder movements	Walls are stopped to center or sides	
				5	Parameters are incorrect	Walls do not move correctly or at all	
				6	Indirect pallets	System cannot recognize the pallet correctly	
		B	swivel does not turn	1	Motor is not working	Pallet can be centered just from 1 direction	
				2	Gearwheel spinning transmission is broken	Table stays in the position where it has stopped and broke	
				3	Inductive sensors	Table cannot move or recognize its position	
				4	swivel is not on its rails	swivel cannot move and is lower than normally	
				5	Parameters / sensors /logic are incorrect, not working	Machine waits to be resset	
		C	Rolls do not lower	1	Motor is not working	Chains and rolls stay in the same level, cannot turn the pallet	
				2	Transmission chains are broken	motor runs but rolls do not lover	

	RCM Information worksheet		**System** Finishing line		**System number** 1	**Consult** David Leal	**Sheet** 3
			Sub-system Reike		**Sub-system number** 1.06	**Auditor** Sauli Lankinen	**Of** 3
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
		D	Rolls do not spin	1	Motor is not working	Process cannot take pallets in	
				2	Transmission is broken	Process cannot take pallets in, motor runs, but not transporting the energy	
		E	mover chains do not spin correctly	1	chains that move pallets are broken or too loose	Pallets jam to the chains and stops the process, can break the chain	
				2	Motor is not working	Chains cannot move the pallet into center	
				3	Transmission parts are broken	Chains cannot move the pallet into center	

RCM Information worksheet

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Sheet counter		Sub-system number 1.07	Auditor Sauli Lankinen	Of 1
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Count the layers of the stack of cartosn	A	Closing tower does not move	1	Motor is not working	Cylinder do not have power and the camera cannot work from far distance	
				2	Cylinder is not working	Tower cannot move, motor cannot give energy forward	
		B	Camera does not lift or lower	1	Lifting devices have failed	Camera cannot count different layers	
		C	Counting device does not work	1	Flash has failed	Laser does not recognize different layers	
				2	Laser has failed	There is no information collected without laser	
		D	Computer does not accept the information	1	Too big difference between real and theoretical informations	Computer turns to manual mode, operator feeds the information	
				2	Indirect pallets	Counter cannot recognize the layers if they are in bad position	
				3	Software, run time error	Manual information feeding, maybe restarting the program	
		E	Scanner cannot read the etiquette	1	Indirect pallets	Line stops, scanner cannot read the indirect barcode	
				2	Plastic on pallet	Scanner does not recognize values under the second time coming palet's plastics	
				3	Upper cartons have moved	Line stops, scanner cannot read the indirect barcode	

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Covering equipment		Sub-system number 1.08	Auditor Sauli Lankinen	Of 1
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Cover the pallet with plastic	A	Machine does not lower or lift	1	Motor does not work	Plastic cannot be put in the right height and attached to the pallet	
				2	Road transportation cloth transmission/support is broken	Tower drops down	
		B	covering device does not feed more plastic	1	Plastic feeding device is not working	Pallet is not covered	
		C	Plastic is not cut	1	Blade is not sharp enough	Plastic would follow the pallet until logic recognize wrong movements and stops the line	
				2	Pneumatic parts have failed	Cylinders do not hit the blade hard enough or at all and plastic is not diveded to two parts	
		D	Plastic does not stay properly on the pallet	1	Big pallets	Plastic does not attach or it might rupture and finally it is cut even it is not covering the pallet	
		A-C			Sensors and logic	Process is not working as expected if there are no right inputs and outputs, process might be stopped	

RCM Information worksheet

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Octopus		Sub-system number 1.09	Auditor Sauli Lankinen	Of 2
	Function		Functional Failure		Failure Mode	Failure Effect	
1	Cover the pallet with plastic from all sides	A	Lifting device cannot adjust its height	1	Motor does not work	Plastic cannot be spinned to different altitude layers	
				2	Chain transmission or fasteners are broken	The spinner body or circle drops down	
				3	Sensors does not communicate correctly with the logic	Octopus stops or is doing wrong tasks in a wrong phase	
		B	Plastic feeding machine is not circling around the pallet	1	Motor does not work	Plastic cannot be put around the pallet	
				2	Transmission belt is broken	Energy created by the motor cannot be transported to the spinner and plastic feeding machine	
				3	Supporting devices /wheels/bearings are broken	Circling body drops down or hang too low and there is more friction while moving if can move at all	
				4	Inductive or other sensors do not communicate properly with the logic	Octopus cannot recognize its postions or work with the right task in the right phase	
		C	Upper pressing machine is not working	1	Motor does not work	Pressing table is stopped to the postion where the motor has failed	

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 2
			Sub-system Octopus		Sub-system number 1.09	Auditor Sauli Lankinen	Of 2
	Function		Functional Failure		Failure Mode	Failure Effect	
				2	Road transportation cloth transmission is broken	Pressing table drops down which is its natural position without road transportation cloth support	
		D	Cutting tool does not cut	1	Pneumatic cylinder does not work	plastic is still attached to feeding machine	
				2	Blade / wire is too loose	two ends of the plastic are connected to each others, not cut	
				3	Electric connections have failed	Cutting tool does not work efficiently or at all	
				4	Resistor does not get warm enough	Plastic around the pallet is not attached to the other end, plastic might follow the pallet and give wrong information for the logic when blocking one sensor pair and stopping the line	
		E	Plastic attaching tool is not working	1	Pneumatic cylinder does not work	Other end of the plastic cannot be closed between two bars, loose part of the plastic might give wrong information for the logic when blocking one sensor pair and stopping the machine	
				2	Electric connections have failed	Attaching tool does not get all the information, plastic might hang out in a wrong place	
				3	There is not friction between 2 bars	Plastic does not stay/attach on its place	
		F	Machine controlling device is down	1	Heat in the electric closet	The servo or other electronics have failed and needs resetting, especially to lifting servo motor	

RCM Information worksheet

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Centrador		Sub-system number 1.10	Auditor Sauli Lankinen	Of 1
	Function		Functional Failure		Failure Mode	Failure Effect	
1	Straighten the pallet legs	A	Pushing device does not move	1	Motor is not working	Pallets cannot be straightened and there is no output to continue moving (normally after sledge has pushed and reversed)	
				2	Transmission and or chain is broken	Motor runs without transfering the energy	
				3	Threaded rod is broken	Motor and chain can run, but the pushing tool do no have power	
				4	Cylinders do not work correctly	Pushing tool can still push, but it does not have descent support and lies on the rolls and there is more friction	
				5	Limit switch/electrical devices are not working	Stages of the process cannot be informed to the logic and device does not put output on, it is not getting information which position the device is	

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Oven		Sub-system number 1.11	Auditor Sauli Lankinen	Of 2
	Function		Functional Failure		Failure Mode	Failure Effect	
1	Enclose the plastic packacking	A	Doors do not open or close	1	Motor is not working	Oven looses heat and packacking is open or pallet is too long in the oven and there might occure holes in the packacking	
				2	Transmission and or chain is not working	Entrance / exit door(s) stay open or closed	
				3	Door is not on its tracks	Oven is not energy efficient, door might drop down, lots of friction	
				4	Logic /sensors/program	Pallet might stay too long in the oven or two might try to enter at the same time and doors try to close against the pallet or pallets leave against doors	
		B	Air circulation is not working	1	Ventilator is broken	Warm heat is not pressed down and heat varies in different levels	
				2	Curtains / heat plates are in a wrong position	Air flow cannot move as normally, heat varies in different levels	
		C	Oven is not heating correctly	1	Gas crematories are broken	Some of the 4 crematories cannot heat, problems to enclose the packacking	
		D	pallets fall down / jam between 2 conveyors	1	Big gap between oven caterpillar tread and conveyor, different levels	Pallet legs stuck to the gap and doors cannot close	
				2	Pallet legs are in the wrong direction	Pallet legs stuck to the gap and doors cannot close and maybe cartons fall down	

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 2
			Sub-system Oven		Sub-system number 1.11	Auditor Sauli Lankinen	Of 2
	Function		Functional Failure		Failure Mode	Failure Effect	
		E	Oven ceterpillar tread is not moving	1	Motor has failed	Pallets cannot enter or exit the oven	
				2	Caterpillar tread /transmission is broken	Pallets cannot enter or exit the oven	
				3	Sensors / logic	Pallet might not enter or exit when it would be possible	
				4	Trash(wood) jams the caterpillar tread	Caterpillar tread slows down or stops	

RCM Information worksheet

RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
		Sub-system Strapping equipment		Sub-system number 1.12	Auditor Sauli Lankinen	Of 1
Function		Functional Failure		Failure Mode	Failure Effect	
1 Press pallets	A	Pressing table does not move	1	Motor is not working	Table cannot lift or lower and after the oven the packacking cannot be pressed	
			2	Transmission chains / supporting devices are broken	Table vibrates more, might fall down or cannot move	
2 Banding the pallets	A	Band does not go around the pallet	1	Air does not spin the band roll	Special pallets cannot be finnished and band cannot go around the pallets via tunnels	
			2	Band tunnels / are not open	Feeding machine is pushing more band, but it cannot enter to the tunnels and around the pallet	
			3	Motor for the tunnel cylinder is not working or transmission parts	Band cannot go under the pallet	
	B	Two ends are not pressed together	1	Machine is not working (old worn parts)	Band stays around the pallet, but not connects, packacking is not ready	
			2	No electricity	Locking device cannot put the two ends together	
			3	Electric motor is not working	Two end cannot be locked together	
			4	There are no locking parts	Device do try to push bands together, put cannot do it without right parts	

RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
		Sub-system Label attaching robot		Sub-system number 1.13	Auditor Sauli Lankinen	Of 2
Function		Functional Failure		Failure Mode	Failure Effect	
1 Put labels on two side of the pallet	A	There are no labels available	1	Actual printer has failed	Received information cannot be printed on the printing paper	
			2	There is no ink	Printing cannot be finished	
			3	Track from the printer is not working	Printed labels cannot enter in the robot area	
	B	There is no glue to attach	1	Glue spraying device does not work	labels cannot be attached, pallet is not ready	
			2	There is no glue	label cannot be attached only by pressing ,humans have to change glue tank	
	C	Robot cannot take the labels	1	Pneumatic low pressure device is not working	In the worst case robot moves without labels and sprays glue to attaching tool	
	D	Robot is not moving	1	Motor, mechanical or electrical parts have failed	Robot stands by, process is stopped	
	E	Scanner does not give information	1	Machine has failed	No information goes further to the robot, CP and printer	
			2	Bad barcodes / position	Needs manual information feeding	

RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 2
		Sub-system Label attaching robot		Sub-system number 1.13	Auditor Sauli Lankinen	Of 2
Function		Functional Failure		Failure Mode	Failure Effect	
2 Send pallet forward	A	Pallet does not lcontinue after attaching the labels	1	Robot pushes the pallet back and it is not on photo sensor line and it does not recognize the palet	Pallet cannot get moving order, because logic does not receive information from the sensor.	
3 Contact right label into the right pallet	A	Robot is attaching same label to different pallets	1	Logic, its program or memory is not working	Forklift driver needs to check the right details from top of the pallet, implement these to the computer, print the right labels. All the time line is stop and in worst case sheet cutters have to stop too.	

RCM Information worksheet

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Photo Sensors		Sub-system number 1.14	Auditor Sauli Lankinen	Of 1
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Recognize coming pallet, send information to logic	A	Does not recognize pallet	1	Laser does not work	Does not give information to the logic that pallet has arrived	
				2	Laser is wrongly focused / targeted	Does not stop the pallet (like the pallet that had carton only on other side and it ran too long and was jammed to the cage)	
				3	Reflector part does not reflect laser	Laser does not get reflection information and stop the pallet	
		B	Does not communicate with logic	1	Cables are not working	Logic does not get input message and cannot put output on	

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system logic and electronics		Sub-system number 1.15	Auditor Sauli Lankinen	Of 1
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Control line movements	A	System failure	1	Stressed logic crashes	That part the logic is controlling stops	
				2	Electronical parts fail (heat, humidity, dirt etc)	Logic or other equipments cannot fullfill their tasks until failed parts have been reset or changed	

	RCM Information worksheet		System Finishing line		System number 1	Consult David Leal	Sheet 1
			Sub-system Electric Motors		Sub-system number 1.16	Auditor Sauli Lankinen	Of 1
	Function		**Functional Failure**		**Failure Mode**	**Failure Effect**	
1	Create mechanical energy from electricity	A	Motor does not run	1	Electronic connectors do not have connection	Motor do not have using electricity from the wires and cannot run the device it is meant to run	
				2	Cabels do not transform electricity	Motor do not have using electricity and the fault is before the machine	
				3	Logic or wires do not send or receive information	Information from or to machine does not connect with logic	
				4	Transformer	Coming electricity cannot be transformed to correct amount of voltages	
				5	Coil is broken	Electricity field does not appear inside	
				6	Stator is broken	It is not able for Rotor to spin araund stator	
				7	Rotor is broken	Device does not spin around stator	
				8	Kommutator is broken (only DC)	Magnetic field direction cannot be changed and motor cannot run the whole rounds	
2	Run equipments	A	Motor does not transform created mechanical energy forward	1	Drive train parts have failed	Motor can run, but shaft or following part does not transfer mechanical energy forward	
3	Less friction	A	Heat arises, machine might stop	1	Bearings have overheated / failed	Motor does not operate correctly, heat and vibration	

Appendix 3. Gravity table for each failure

MACHINE	Error/Criticity	Error/Criticity	Error/Criticity	Error/Criticity	Error/Criticity	Error/Criticity	
Conveyors	1-A Important	1-B Important					
Swivels	1-A Important	2-A Important	2-B Important				
Transfer carriage	1-A Critic	1-B Important	1-C Important				
Twirler	1-A Tolerable	2-A Tolerable	3-A Important	4-A Important	5-A Important		
Pushers	1-A Important	1-B Important					
Centering device Reike	1-A Critic	1-B Critic	2-A Critic	2-B Critic	2-C Critic	2-D Critic	2-E Critic
Sheet counter	1-A Tolerable	1-B Tolerable	1-C Tolerable	1-D Tolerable	1-E Important		
Covering device	1-A Important	1-B Tolerable	1-C Tolerable	1-D Tolerable			
Octopus	1-A Critic	1-B Critic	1-C Important	1-D Critic	1-E Critic	1-F Important	
Centrador	1-A Tolerable						
Oven	1-A Critic	1-B Critic	1-C Critic	1-D Critic	1-E Critic		
Strapping equipment	1-A Tolerable	2-A Important	2-B Important				
Robot of the etiquettes	1-A Important	1-B Important	1-C Critic	1-D Important	2-E Important	2-A Important	3-A
Photo sensors	1-A Important	1-B Important					
Logic+Electronics	1-A Important						
Motors (part of others)	1-A Important	2-A Important	3-A Important				

Appendix 4. Criticality analysis of the failures

CRITICALITY ANALYSIS OF THE FAILURES			
Safety and environment	Production	Maintenance	
Serious accident, probable	Needs stopping or affects to efficiency or performance	High cost of reparation (>10.000€)	Critic
Serious accident, improbable	Affect to efficiency and/or performance, but the failure is improbable	Medium cost of reparation (1.000-10.000)	Important
Little influence in safety or environment	No affect to the prodution	Low cost of reparation (<1.000€)	Tolerable

If one of the answers for each failure were chosen to be important then the gravity was also important. If one of the answers were chosen to be critic then the gravity was chosen to be critic. If all the answers were on the tolerable line, then the gravity was tolerable. On each answer option it did not matter how many answers there were in the same class, just the highest ruled the gravity class. This is fast and easy way to study criticalities of the machinery.

Appendix 5. RCM decision worksheets

													System Finishing Line	**Consult** David Leal	**Page** 1
Reference to the cause of the error			Evaluation of the consequences							Default accion			**Subsystem** Conveyor	**Auditor** Sauli Lankinen	**of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		User
1	A	2a	s	n	n	s	n	n	s				Scheduled replacement: Make/buy stronger belts and future investments to chain versions		
1	A	2b	s	n	n	s	n	s					Preventive: lubricate chain		User
1	A	3	n				n	n	n	s			Verification: check that the gearwheels are ok		User
1	A	4	s	n	n	s	n	s					Preventive: lubrication, tightening the fasteners etc		User
1	A	5	s	n	n	s	n	s					Visual inspections: Remove all trash from the track		User
1	A	6	n				n	n	n	s			Failure search: now turn to manual mode and drive until it can run automatically		
1	B	1	s	s	n		n	n	n	n	n		Redesign: Make the gap between two lines smaller, Put one CEN (centering) machine before G3		
1	B	2	s	s	n		n	n	n	n	n		Redisign: Put one CEN (centering) machine before G3		

													System Finishing Line	**Consult** David Leal	**Page** 1
Reference to the cause of the error			Evaluation of the consequences							Default accion			**Subsystem** Swivel	**Auditor** Sauli Lankinen	**of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
1	A	2	s	n	n	s	n	n	s				Scheduled replacement: Change belt to stronger type		
1	A	3	n				n	s					Preventive: keep bearings lubricated		user
1	A	4	s	n	n	s	n	s					Visual inspections: Remove all trash from the track		user
1	A	5	n				n	n	n	s			Failure search: now turn to manual mode and drive until it can run automatically		user
2	A	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
2	A	2	n				n	s					Preventive: Make sure that transmission parts are lubricated and clean		user
2	A	3	s	n	n	s	n	n	n				Run to Failure: Very unlikely to happen, but if happen, raise back to its rails and repair		
2	A	4	n				n	n	n	s			Failure search: now: When occures, turn to manual mode and drive until it can run automatically		
2	B	1	s	n	n	s	s						On condition task: check the connection indication light.		user

RCM Decision worksheet

Reference to the cause of the error			Evaluation of the consequences							Default accion			System Finishing Line	Consult David	Page 1
													Subsystem Transfer carriage	Auditor Sauli Lankinen	of 1
F	FE	CE	H	S	E	O	H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	H4	H5	S4	Proposed task	Initial interval	Can be done by
1	A	1	n				n	s					Preventive: keep motor parts clean and lubricated		user
1	A	2	n				n	s					Preventive: lubricate transmission parts		user
1	A	3	s	n	n	s	n	n	n				When occures, turn to manual mode and drive until it can run automatically. Verifications: check the parameters		user
1	A	4	s	n	n	s	n	n	n				When occures, turn to manual mode and drive until it can run automatically, if not helping turn off-restart,check the parameters		user
1	A	5	s	n	n	s	n	n	n				Redisign: Cut (recalculate) the emergency stop bar rubber plate that is touching the other conveyor		
1	A	6	n				n	n	n	s			Visual inspections: check that the transfer carriage is working correctly		user
1	B	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
1	B	2a	s	n	n	s	n	n	s				Scheduled replacement: change belts to stronger type		
1	B	2b	s	n	n	s	n	s					Preventive: lubricate chain and transmission parts		user
1	B	3	n				n	s					Visual inspections: check gearwheels condition		user
1	B	4	s	n	n	s	n	s					Preventive: lubricate bearings, check the fasteners and down supports		user
1	B	5	s	n	n	s	n	s					Visual inspections: Remove all trash from the track		user
1	B	6	n				n	n	n	s			Failure search: now: When occures, turn to manual mode and drive until it can run automatically		user
1	C	1	n	s	n		n	s					Verification: Make sure that the laser is rightly focused		user

Reference to the cause of the error			Evaluation of the consequences							Default accion			System Finishing Line	Consult David Leal	Page 1
													Subsystem Twirler	Auditor Sauli Lankinen	of 1
F	FE	CE	H	S	E	O	H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	H4	H5	S4	Proposed task	Initial interval	Can be done by
1	A	1	s	n	n	s	n	s					Preventive: keep pump motor parts clean and lubricated		user
1	A	2	s	n	n	s	n	n	n				Visual inspections: check that the cylinders move naturally		user
2	A	1	s	n	n	s	n	n	n				Verificaciones: check there is enough air coming from the pump		user
2	A	2	n				n	n	n	s			Visual inspection, check that sensors react		user
2	A	3	n				n	n	n	n	n		Run to failure: When occures, turn to manual mode and drive until it can run automatically		
3	A	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
3	A	2	s	n	n	s	n	s					Preventive: Lubricate chain and other transmission parts		user
3	A	3	s	n	n	s	n	n	n				Visual inspections: Check that supports are in a good condition		user
4	A	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
4	A	2	s	n	n	s	n	s					Preventive: Lubricate chains and other transmission parts		user
4	A	3	n				n	n	n	n	n		Run to failure: When occures, turn to manual mode and drive until it can run automatically		
5	A	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
5	A	2	s	n	n	s	n	s					Preventive: Lubricate chains and other transmission parts		user
5	A	3	s	s	n		n	n	s				Visual inspections: Very unlikely to happen: check that supporting devices are in a good condition		user
5	A	4	n				n	s					Visual inspections: When occures, check the connection and sensor		user

RCM Decision worksheet

Reference to the cause of the error			Evaluation of the consequences							Default accion			System Finishing Line	Consult David Leal	Page 1
													Subsystem Pusher	Auditor Sauli Lankinen	of 1
F	FE	CE	H	S	E	O	H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	H4	H5	S4	Proposed task	Initial interval	Can be done by
1	A	1	s	n	n	s	n	n	n				Visual inspections: check that the tool works correctly		user
1	A	2	s	n	n	s	n	s					Preventive: keep hydraulic pump motor parts clean and lubricated		user
1	A	3	s	n	n	s	n	n	n				Visual inspections: check that cylinders work normally		user
1	A	4	s	n	n	s	n	s					Visual inspections: Check that pipes are in a good condition, connected and there are no visible oil spills, tighten fasteners		user
1	A	5	n				n	n	n	n	n		Run to failure: When occures, turn that part control devices to manual mode and drive until it can run automatically		
1	B	1	s	n	n	s	n	n	n				Visual inspections: check that the tool works correctly		user
1	B	2	s	n	n	s	n	s					Preventive: keep hydraulic pump motor parts clean and lubricated		user
1	B	3	s	n	n	s	n	n	n				Visual inspections: check that cylinders work normally		user
1	B	4	s	n	n	s	n	s					Visual inspections: Check that pipes are in a good condition, connected and there are no visible oil spills		user
1	B	5	n				n	n	n	n	n		Run to failure: When occures, turn that part control devices to manual mode and drive until it can run automatically		

Reference to the cause of the error			Evaluation of the consequences							Default accion			System FinishingLine	Consult David	Page 1
													Subsystem Centrador Reike	Auditor Sauli Lankinen	of 1
F	FE	CE	H	S	E	O	H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	H4	H5	S4	Proposed task	Initial interval	Can be done by
1	A	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
1	A	2	s	n	n	s	n	s					Preventive: lubricate chain and other transmission parts		user
1	A	3	s	n	n	s	n	n	n				Visual inspections: check that supporting devices are in a good condition or redisign it to be more stable		
1	A	4	s	n	n	s	n	n	s				Redisign: Change the logic/software program that it recognize the pallet faster and without forcing the pallets to roll against M17		
1	A	5	s	n	n	s	n	n	n				When occures, turn to manual mode and drive until it can run automatically		user
1	A	6	s	n	n	s	n	n	n				Redisign: Put one CEN (centering) machine before G3		
1	B	1											Look e.g. Conveyor part		
1	B	2	s	n	n	s	n	n	n				Redisign: Put one CEN (centering) machine before G3		
2	A	1	s	n	n	s	n	n	n				Verifications: Check that pressure is between marginals		user
2	A	2	n				n	n	s				Redisign: Second compressor or more stable usage, -fisnishing department is on the end of the line		
2	A	3	n				n	n	n				Run to failure: When occures, turn to manual mode and drive until it can run automatically		
2	A	4	s	n	n	s	n	n	n				Verification: Check that limit swithc light is active when it is in use		user

RCM Decision worksheet

2	A	5	n				n	n	n	s			Failure search: Check that parameters are between the margins		user
2	A	6	s	n	n	s	n	n	n				Redisign: Put one CEN (centering) machine before G3		user
2	B	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
2	B	2	n				n	s					Preventive: lubricate gearwheel and other transmission parts		user
2	B	3	n				n	n	n	n			Visual inspections: check the connection light and sensor		user
2	B	4	s	n	n	s	n	n	n				Run to failure: Wery unlikely to happen, if happens move back and repair		
2	B	5	n				n	n	n	s			Failure search / Verification: Check that parameters are between the margins		user
2	C	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
2	C	2	s	n	n	s	n	s					Preventive: lubricate chains and other transmission parts		user
2	D	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
2	D	2	s	n	n	s	n	s					Preventive: lubricate chains and other transmission parts		user
2	D	3	s	n	n	s	n	s					Preventive: Bearings lubrication, cheking the fasteners		user
2	E	1	s	n	n	s	n	s					Preventive: Lubricate and tighten the chains		user
2	E	2	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
2	E	3	s	n	n	s	n	s					Preventive: lubricate chains and other transmission parts		user

Reference to the cause of the error			Evaluation of the consequences							Default accion			**System** Finishing Line **Subsystem** Sheet counter	**Consult** David Leal **Auditor** Sauli Lankinen	**Page** 1 **of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
1	A	2	s	n	n	s	n	n	n				Visual inspections: check that the cylinder works correctly		user
1	B	1	s	n	n	s	n	n	n				Run to failure: When occures, feed details manually and put it to automatic mode when it is repaired		
1	C	1	s	n	n	s	n	n	n				Run to failure: When occures, feed details manually and put it to automatic mode when it is repaired		
1	C	2	s	n	n	s	n	n	n				Run to failure: When occures, feed details manually and put it to automatic mode when it is repaired		
1	D	1	s	n	n	s	n	n	n				Redisign: Accept wider range of values		
1	D	2	s	n	n	s	n	n	n				Redisign: Put one CEN (centering) machine before G3		
1	D	3	s	n	n	s	n	n	n				run to failure: restart, feed details manually and put it to automatic mode		
1	E	1	s	n	n	s	n	n	n				Redisign: Put one CEN (centering) machine before G3		
1	E	2	s	n	n	s	n	s					Preventive: cut the plastic above the bar code		user
1	E	3	s	n	n	s	n	n	n				Run to failure: straighten the carton, feed details manually and put it to automatic mode		

RCM Decision worksheet

Reference to the cause of the error			Evaluation of the consequences							Default accion			System Finishing Line	Consult David Leal	Page 1
													Subsystem Covering device	Auditor Sauli Lankinen	of 1
F	FE	CE	H	S	E	O	H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	H4	H5	S4	Proposed task	Initial interval	Can be done by
1	A	1	s	n	n	s	n	s					Preventive: keep motor parts clean and lubricated		user
1	A	2	s	n	n	s	n	n	s				Visual inspections: Check that the cloth is in a good condition, if not, change it when is good time to do it		
1	A	3	n				n	n	n	s			Visual inspection, check that sensors react		user
1	B	1	s	n	n	s	n	n	n				Visual inspections: check that it is feeding plastic normally		user
1	C	1	s	n	n	s	n	n	n				Visual inspections: Check that the blade is in a good condition, if not, change it when is good time to do it		
1	C	2	s	n	n	s	n	n	n				Visual inspections: check that cylinders are working correctly		user
1	C	3	n				n	n	n	s			Visual inspection, check that sensors react		user
1	D	1	s	n	n	s	n	n	n				Run to failure: manual rework if necesary		

Reference to the cause of the error			Evaluation of the consequences							Default accion			System Finishing Line	Consult David Leal	Page 1
													Subsystem Octopus	Auditor Sauli Lankinen	of 1
F	FE	CE	H	S	E	O	H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	H4	H5	S4	Proposed task	Initial interval	Can be done by
1	A	1	s	n	n	s	n	s					Preventive: Keep motor parts clean and lubricated		user
1	A	2	s	n	n	s	n	s					Preventive: Lubricate chains and other transmission parts, tighten fasteners		user
1	A	3	s	n	n	s	n	n	n				Run to failure: When occures, turn to manual mode and drive until it can run automatically		
1	B	1	s	n	n	s	n	n	s				Redisign: put cooler in the motor controlling unit closet		
1	B	2	s	n	n	s	n	n	n				Visual inspections: Check that belt has no ruptures		
1	B	3	s	n	n	s	n	n	n				Visual inspections: Check that supporting devices are in a good shape and lubricate rolling parts if needed		user
1	B	4	n				n	n	n	s			Failure search: When occures, try with manual mode, check that there is no pulling on the cables/connections and sensors are ok.		
1	C	1	s	n	n	s	n	s					Preventive: Keep motor parts clean and lubricated		user
1	C	2	s	n	n	s	n	n	n				Visual inspections: Check that cloths / body are in a good condition		user
1	D	1	s	n	n	s	n	n	n				Visual inspections: check that pneumatic parts and cylinder are working properly		user
1	D	2	s	n	n	s	n	n	s				Redisign: Instal new cutting tool, which does not loose in use		
1	D	3	s	n	n	s	n	n	s				Redisign: Instal new cutting tool, which electric connections are protected		
1	D	4	s	n	n	s	n	n	s				Redisign: Instal new connecting tool that heats and cool properly and has more reliability		
1	E	1	s	n	n	s	n	n	s				Redisign: invest into new attaching tool		
1	E	2	s	n	n	s	n	n	s				Redisign: Instal new attaching tool, which electric connections are protected		
1	E	3	s	n	n	s	n	n	s				Redisign: Instal new attaching tool that has better friction and does not need tape modifications		
1	F	1	s	n	n	s	n	n	s				Redisign: Insert cooling ventilator / fan into the closet where electric parts are located		

RCM Decision worksheet

Reference to the cause of the error			Evaluation of the consequences							Default accion			**System** Finishing Line	**Consult** David	**Page** 1
													Subsystem CENtrador -47. -55	**Auditor** Sauli Lankinen	**of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	s	n	n	s	n	s					Preventive: Keep motor parts clean and lubricated		user
1	A	2	s	n	n	s	n	s					Preventive: Lubricate transmission parts		user
1	A	3	s	n	n	s	n	s					Visual inspections: Check that rod does not bend and it works correctly and keep it lubricated		user
1	A	4	s	n	n	n	n	n	n				Visual inspections: Check that cylinders work correctly and keep lubricated		user
1	A	5	n				n	n	n	n	n		Visual inspections: Make sure that the sensors recognize its movements		user

Reference to the cause of the error			Evaluation of the consequences							Default accion			**System** Finishing Line	**Consult** David	**Page** 1
													Subsystem Oven	**Auditor** Sauli Lankinen	**of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	s	n	n	s	n	s					Preventive: Keep motor parts clean and lubricated		user
1	A	2	s	n	n	s	n	s					Preventive: Keep motor parts clean and lubricated		user
1	A	3	s	n	n	s	n	n	s				Redisign: Instal new doors or supports that do not loose as much heat as these ones and that are better suported		
1	A	4	n				n	n	n	s			Failure search: find, which part cause the problem		
1	B	1	s	n	n	s	n	n	n				Run to failure: When occur, add more time that pallets spend in the owen		
1	B	2	s	n	n	s	n	n	n				Visual inspections: Check that curtains or heat plates have not ruptured or moved		user
1	C	1	s	n	n	s	n	n	s				Redisign system: Invest new oven, make sure that the process can work with less crematories while one is replaced or repaired		
1	D	1	s	s	n		n	n	n			n	Redisign: Insert tracks to same level with the caterpillar track and smaller the gaps (CEN machine, M13)		
1	D	2	s	s	n		n	n	n			n	Redisign: Instal CEN centrador before Centrador Reike		
1	E	1	s	n	n	s	n	n	s				Preventive: Keep motor parts clean and lubricated		user
1	E	2	s	n	n	s	n	s					Preventive: Check that caterpillar track and transmission are enough clean and greased	Every week	user
1	E	3	n				n	n	n	n	n		Visual inspections: Check that sensors react		user
1	E	4	s	s			n	s					Visual inspections: Remove all the trash from the track		user

RCM Decision worksheet

Reference to the cause of the error			Evaluation of the consequences							Default accion			**System** Finishing Line	**Consult** David	**Page** 1
													Subsystem Strapping device	**Auditor** Sauli Lankinen	**of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	s	n	n	s	n	s					Preventive: Keep motor parts clean and lubricated		user
		2	s	n	n	s	n	s					Preventive: Keep transmission parts and chain lubricated, check the fasteners		user
2	A	1	s	n	n	s	n	n	n				Visual inspection: check that there exist descent air flow		user
2	A	2	s	n	n	s	n	s					Visual inspections: Check the plate fasteners and strap tunnels		user
2	A	3	s	n	n	s	n	s					Preventive: Keep motor/transmission parts clean and lubricated		user
2	B	1	s	n	n	s	n	n	n				Redisign: Invest into a new machine		
1	B	2	s	n	n	s	n	n	n				Redisign: Invest into a new machine and also to manual device in case the machine does not work		
1	B	3	s	n	n	s	s						Visual inspections: check that there are always locking parts in the machine		user

Reference to the cause of the error			Evaluation of the consequences							Default accion			**System** Finishing Line	**Consult** David Leal	**Page** 1
													Subsystem Label attaching robot	**Auditor** Sauli Lankinen	**of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	n				s						Visual inspection: computer communicates wih the printer, see error messages		system/user
1	A	2	s	n	n	s	s						Visual inspections: computer gives alarm messages when ink is running out		system
1	A	3	s	n	n	s	n	n	n				Visual inspections: check that the tracks are in a good condition and system works correctly		user
1	B	1	s	n	n	s	n	n	n				Visual inspections: Check that spraying device is working properly		user
1	B	2	n				n	n	n	n	n		Visual inspections: Check that there is glue		user
1	C	1	s	n	n	s	n	n	n				Visual inspections: Check that there is low pressure created and attaching tool is working		user
1	D	1	s	n	n	s	n	s					Preventive: Keep motor and transmission clean and if needed lubricated		user
1	E	1	s	n	n	s	s						When occur, feed details manually		user
1	E	2	s	n	n	s	n	n	n				Visual inspections: Check that CEN -55 straightens the pallets		user
2	A	1	s	n	n	s	n	n	s				Re-design 1:Reduse pushing power. 2*: When pallet arrives let the track run X seconds and then stop it 3: Tighten the chains and do not let the rolls move back	2* Done 25.8.2010	
3	A	1	n				n	n	n	s			Failure search: Find out, which is causing the problem		

RCM Decision worksheet

Reference to the cause of the error			Evaluation of the consequences							Default accion			**System** Finishing Line **Subsystem** Photo Sensors	**Consult** David **Auditor** Sauli Lankinen	**Page** 1 **of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	s	n	n	s	n	n	n				Visual inspection: Check that signal light works		user
1	A	2	s	s			n	s					Verifications: Check that laser recognize pallets from the right height		user
1	A	3	s	n	n	s	n	n	n				Visual inspection: check that reflector and laser are clean and ok		user
1	B	1	n				n	s					Verifications: check that connections are ok and it sends information		user

Reference to the cause of the error			Evaluation of the consequences							Default accion			**System** Finishing Line **Subsystem** Logic / other electronics	**Consult** David **Auditor** Sauli Lankinen	**Page** 1 **of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	n				n	n	n	n	n		Redisign: Change system flow so it affects as small part of the line as possible and line can work if somwhere else is problem		
1	A	2	n				n	n	n	n	n		Verifications: Check that conditions are ok where logics and electronics are located		user

Reference to the cause of the error			Evaluation of the consequences							Default accion			**System** Finishing Line **Subsystem** Electronic motors	**Consult** David **Auditor** Sauli Lankinen	**Page** 1 **of** 1
F	**FE**	**CE**	**H**	**S**	**E**	**O**	**H1 S1 O1 N1**	**H2 S2 O2 N2**	**H3 S3 O3 N3**	**H4**	**H5**	**S4**	**Proposed task**	**Initial interval**	**Can be done by**
1	A	1	s	n	n	s	n	n	n				Visual inspections: Check that connections are ok		user
1	A	2	n				n	n	n	s			Verifications: check where is the problem located		user
1	A	3	n				n	n	n	s			Verifications: check where is the problem located		user
1	A	4	n				n	s					When occur: change the motor or part		
1	A	5	n				n	s					When occur: change the motor or part		
1	A	6	n				n	s					When occur: change the motor or part		
1	A	7	n				n	s					When occur: change the motor or part		
1	A	8	n				n	s					When occur: change the motor or part		
2	A	1	s	n	n	s	n	s					Preventive: Keep rolling parts clean and lubricated		user

Appendix 6. RCM decision logic to evaluate consequence of a failure