Preface

This report is one of the results of a master thesis work conducted during the period June 2009 - December 2009. This work is the final element in the Master of Science programme in Industrial Engineering and Management at the faculty of Engineering at Lund University. The master thesis work has been conducted at the Department of Industrial Management and Logistics together with SWEP International. We would especially like to thank our tutor from LTH, Bertil I Nilsson together with David Persson and Staffan Selander at SWEP International for providing us with inputs, for helping us with our questions and for giving us the possibility to work with an exciting problem in an interesting company.

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Abstract

During this master thesis work that was conducted as a case study together with SWEP International, we have investigated marking standards and marking technologies that support handling of varying customer demands and increased information density. We also studied SWEP's internal information handling and traceability. We were asked to specifically look at the usefulness of RFID for SWEP, and came to the conclusion that this technology presently does not solve any of SWEP's problems in an economically realistic way. In SWEP's production RFID is not applicable due to cost and the fact that the brazing process, that all products passes, result in that the same marking cannot be used throughout the entire production. We have not found any customers that currently request this technology and likely only a limited group of customers will in the near future be able to read information stored in this way.

To be able to increase the amount of information in markings SWEP can use more modern symbologies for coding barcodes, for example Code 128 and the two-dimensional symbology Data Matrix, both of which has been requested by customers. The American car industry organization AIAG has developed a standard for transportation marking that can be used to cover the majority of customer demands regarding this type of marking. This standard can be used with both the Code 39 symbology currently used by SWEP as well as Code 128 that is requested by some customers. Other methods for information transfer, such as EDI, can be made more adapted to customer demands than labels but will not replace the need for some physical information carrier for the address and identification of the shipment.

Sammanfattning

Under detta examensarbete som genomfördes som en fallstudie i samarbete med SWEP International, har vi undersökt märkningsstandarder och -tekniker för att hantera varierande kundkrav och ökad informationsmängd i märkningen. Vi har även studerat SWEPs interna informationshantering och spårbarhet. Vi blev ombedda att speciellt undersöka hur användbart RFID är för SWEP, och konstaterade att denna teknik i dagsläget inte löser några av företagets problem på ett ekonomiskt försvarbart sätt. I SWEPs produktion är RFID inte tillämpbar på grund av kostnaden samt att lödningsprocessen, som alla produkter måste passera, gör att samma märkning inte kan användas genom hela produktionen. Vi har inte funnit några kunder som i dagsläget efterfrågat tekniken och sannolikt är det endast ett fåtal som i den närmaste framtiden kommer kunna läsa av denna typ av märkning.

För att kunna öka informationsmängden i märkningen kan SWEP använda sig av nyare symbologier för kodningen av streckkoder, till exempel Code 128 och den tvådimensionella symbologin Data Matrix, som båda två har efterfrågats av kunder. Den amerikanska bilindustri föreningen AIAG har utvecklat en standard för transportmärkning som går att använda för merparten av kundkraven och standarden kan användas både med symbologin Code 39 som SWEP använder i dagsläget, och den tätare symbologin Code 128 som efterfrågas av en del kunder. Andra metoder för informationsöverföring, såsom EDI, kan göras mer kundanpassade än etiketter, men ersätter inte behovet av fysisk märkning för bland annat adress och identifikation av försändelsen.

Contents

Symbols and expressions

AI – Application Identifiers, a standard for prefix

AIAG - Automotive Industry Action Group

ANSI – American National Standards Institute

Brazed - metal joining process at high temperature

BPHE – Brazed Plate Heat Exchanger

CEW – Central European Warehouse

Code 39 – symbology used for creating linear barcodes

Code 128 – a more compact symbology than Code 39

DI – Data Identifier, a standard for prefix

EDC – European Distribution Centre

GS1 – An organization that develops and introduces standards for barcodes

ISO – International Standards Organization

Odette – An organization that develops and introduces standards related to marking and communication within the automotive sector

Prefix – A string of characters that is used to distinguish different data segments, such as quantity and serial number

1 Introduction

This chapter starts with a background and an introduction to SWEP and their products and continues with information about the problem that this thesis addresses.

1.1 Background

SWEP has been receiving an increased number of customer requirements regarding part identification and marking of their products and pallets. The requests includes both the contents of the markings as well as how to represent data in an auto readable way. This has created a need to find a standard approach of marking items while still remaining customer oriented. Recent years has provided new technologies such as RFID that needs to be investigated to understand what extra value can be provided. SWEP also wants to stay ahead of customer demands regarding traceability. Traceability concerns the ability to uniquely identify all components and transformations of a product through the entire value chain from raw materials to finished product. This includes the ability to identify tools and machines used to transform the product and its components, as well as the operators and the components themselves.

1.2 SWEP

1.2.1 History

SWEP, founded in 1983, is today one of the world's leading producers of Brazed Plate Heat Exchangers (BPHEs). At present SWEP has more than 700 employees and are represented in more than 50 countries with sales force in 20 countries. Manufacturing takes place in Sweden, Slovakia, Switzerland, USA, Malaysia and China, were the Swedish production site situated in Landskrona is the largest. In 1992 SWEP was acquired by Dover Corporation, a diversified manufacturer of industrial products consisting of more than 50 independent companies. Since the acquisition by Dover Corporation, SWEP has grown at a rapid pace, see Figure 1, and with annual sales near USD 250 million SWEP has about 30 % market share of the BPHE market. Most of SWEP's sales (75 %) are generated in the European market with the Asian market (17 %) at second place. Frost & Sullivan estimates the annual European market for all heat exchanger types to approximately USD 3.7 billion and the annual global market to approximately USD 10 billion.

The BPHE product is estimated to be in the growth phase in the product life cycle and the BPHE market is estimated to grow at a rate of 12-15% annually in the period 2009-2012. All SWEP sales are conducted on a business to business (B2B) basis. Due to the design, a BPHE in general cannot be repaired and SWEP therefore has no aftermarket, if a BPHE fails it is replaced altogether.

SWEP's research and development (R&D), along with the head office, is situated in Landskrona but SWEP's goal is to have R&D on every production site in order to take advantage of local knowledge.

SWEP's mission: *"Lead the global development, production and marketing of brazed plate heat exchangers while facilitating conversion to sustainable products and processes."*

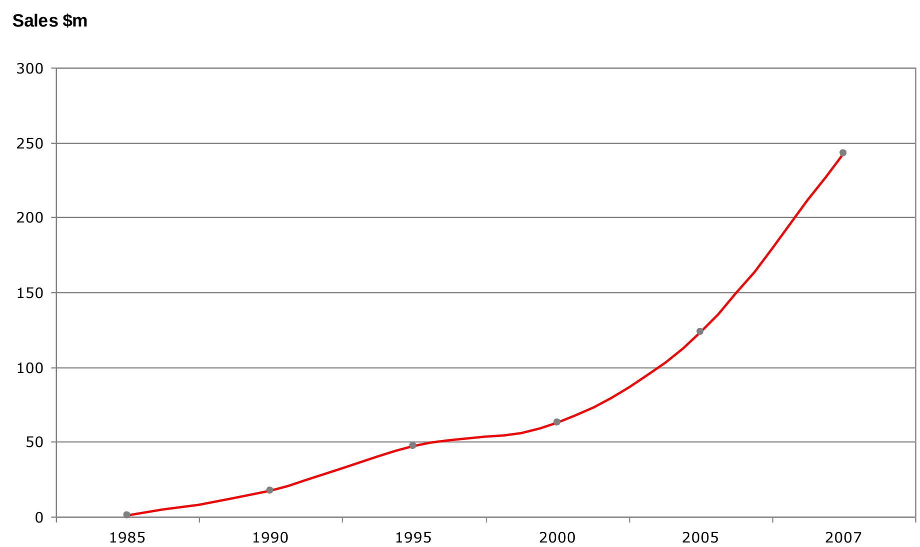

Figure 1 SWEP's sales 1985-2007

1.2.2 Organization

As Figure 2 shows SWEP's organization is function orientated and consists of the following five functions, each with a Vice President.

- **Sales & Marketing (S&M)**
  S&M deals with technical sales and support for SWEP's customers, the creation of new customer contacts and strategic planning and marketing. This function is the main connection between SWEP and its customers.
- **Research & Development (R&D)**
  R&D develops new products and tools, but also supporting tools such as software applications.
- **Finance & Administration (F&A)**
  F&A assists other functions with financial expertise and initiates actions towards better capital management.
- **Human Resources (HR)**
  HR manages employee questions such as training, education and job opportunities.
- **Operations**
  Operations is responsible for the BPHE supply chain, from components to manufacturing and delivery to customers. The function also works with improving production equipment, processes and competences.

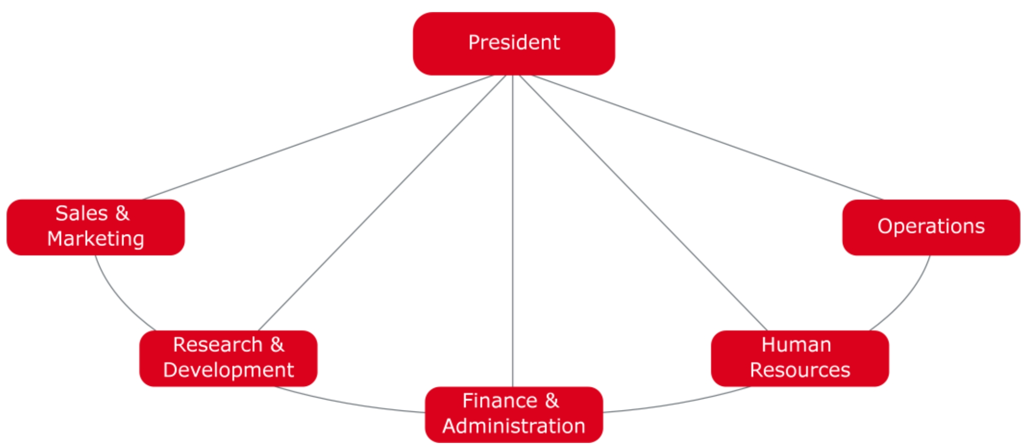

Figure 2 SWEP's organization

1.2.3 Product technology

A heat exchanger is a device that is used in order to transfer heat energy from one medium to another without having them mix. This need arises in various applications such as district heating systems where heat is transferred from the distribution system to the closed system inside a building without mixing the water. Other examples are for instance the common refrigerator and the cooling system in a car.

There exist several technologies for accomplishing the heat exchanging task and one of them is the BPHE technology. The basic idea of a BPHE is to use a package of plates that are brazed together to create channels through which a hot medium and a cold medium can be distributed. The hot and cold mediums are only separated by a thin wall consisting of material with high heat conductivity, which facilitates the heath energy to transfer.

The size, material and number of the channel plates differ between different types of BPHEs depending on what capacity is required. The channel plates are sealed with sealing plates and the whole package is covered by front and rear cover plates. Various connections can be attached in order to meet customer demand. The basic design, see Figure 3, makes the BPHEs scalable and flexible when it comes to meeting different customer demands and since many connections are available the number of combinations is great.

The design of the BPHE is efficient in the way that almost all material is used for heat transfer, making it possible to create compact heat exchangers, which is a competitive advantage since many BPHEs are used in environments with limited space. Since the plates in the BPHEs are brazed together no rubber sealing is needed between the plates, making the BPHE suitable for high demanding medium and environments. The fact that the plates are brazed makes the BPHE hard to repair and this means that SWEP has no aftermarket; a failing product is replaced all together and since the BPHE often is used in critical processes the quality conformance is critical.

Figure 3 Basic design of a BPHE

1.3 Problem description

SWEP currently receives an increasing number of customer requests for customer specific machine-readable marking of products, transportation units and transport documents. The requests concern both the information contents and how this information should be represented. To reduce cost associated with waste and claims, as well as to improve customer perceived quality, there is also a need to improve the efficiency of material tracing throughout SWEP´s processes. Consequently, SWEP needs a thorough review of how marking of material, products and transport units can be improved throughout the supply chain to improve customer service and be more efficient.

The problem we will be trying to solve can be divided into two major parts, the first part is related to the visible information on the packages and products that the customers receive, and the second part is related to minimizing errors in the internal production process.

The first problem originates from the more and more diverging customer demands on the visible information contents and the graphical organization of such information. This problem is further complicated by the fact that the rather old business system, Avanté, was not made for handling registration of this type of customer demands. To handle some of the more common demands, fixes has been added to the business system.

SWEP has a philosophy of adaptability to customer demands but the recent years of rapid growth has led to many product configurations and also several different labels for the products. Today, when a new set of information is required on the label this can often be accommodated by the business system, but sometimes this system needs to be rewritten by hard coding new routines and flags. This in turn has led to something of a patchwork system, which is why label standardization is requested.

The second problem has so far attracted no major attention from customers but may reduce cost and increase SWEP's reliability. In order for SWEP to act proactive it is also important to evaluate future needs and trends in areas where the current requirements seem to be met. New types of markings or checkups can reduce the risk of producing heat exchangers that does not match with the customer order. An example is that SWEP has started to use different kinds of steel in their channel plates, type 304 and type 316 stainless steel, which cannot be distinguished just by look. To reduce the risk of using the wrong type of material throughout the production process additional marking or use of modern technology might be useful.

1.4 Purpose and Objectives

This thesis work shall investigate marking opportunities from information, technical and economical points of view that are relevant to SWEP. The goal is to create a (set of) standard offering(s) for product and pallet marking to SWEP's customers, thus avoiding the need for customer specific markings. In order to accomplish this four main questions have been identified:

- What are real customer needs for product and transportation unit marking, and what marking options would be regarded as added value?
- How can SWEP improve material tracing with the use of modern identification technologies?
- What do SWEP's suppliers offer in terms of marking of incoming goods?
- Are there standards for marking available that could help SWEP improve its marking offerings and cover the majority of customer requests?

1.5 Delimitations

When it comes to standard transportation marking we have chosen to focus our investigation efforts on the Odette standard and the AIAG standard. The Odette standard was chosen since an investigation of this standard was an explicit request by SWEP. The only standard mentioned in the customer requirements that we have taken part of is the AIAG standard, so it was therefore natural to investigate this standard as well. Another aspect that has been considered is the time and effort required for investigating and understanding several other standards. Since the standards relies on further standards such as those defined by ANSI and ISO the time required has been quite extensive. It has also been hard to acquire information regarding certain standards that have been found.

Due to geographical reasons and time limitations we have focused our work on the factory in Landskrona. During the dialogues and interviews carried out at the head quarter in Landskrona, we have also discussed the other factories, especially the one located in Slovakia. We have discussed how the distribution centres in Europe affect supply chain management of the production sites in this region. Since the majority of the production sites as well as the customers are located in this region it is likely that the major effects are covered by this selection.

1.6 Target Audience

The target audience for this thesis is management and employees at SWEP International along with students with interest in marking technologies and traceability.

1.7 Thesis outline

This thesis follows the outline found below.

Chapter 1 Introduction
This chapter starts with a background and an introduction to SWEP and their products and continues with information about the problem that this thesis addresses.

Chapter 2 Methodology
In this chapter we discuss suitable methods for how a thesis can be conducted in general terms. We will also discuss the methods chosen in this thesis in more detail, as well as the pros and cons of the chosen methods motivating the choice.

Chapter 3 Desk study
In this chapter we describe theories, technologies and standards relevant to either understand or to analyse the problems of this thesis.

Chapter 4 Interviews and dialogues
This chapter summarizes our data gathering performed as interviews and dialogues, made in person, via e-mail or over the phone. The sources are mainly representatives from SWEP, but where suitable and possible, other sources were used as well.

Chapter 5 Data analysis
In this chapter we analyse traceability and quality in the production, as well as possible ways of meeting customer requirements on both item level and transportation level marking.

Chapter 6 Results and Discussion
Here we present the results of this work by relating back to the four main questions from the problem description. We also discuss the work in general, thoughts that arose during the work and the result.

Chapter 7 References
In this chapter the references for the thesis work is outlined.

Chapter 8 Appendix
Here we list the interview guides used in corresponding interviews, actual questions deviated as we adapted the questions to the answers of previous questions

2 Methodology

In this chapter we discuss suitable methods for how a thesis can be conducted in general terms. We will also discuss the methods chosen in this thesis in more detail, as well as the pros and cons of the chosen methods motivating the choice.

Depending on the purpose of a study it can be classified into four main types. These types are:[1]

- A descriptive study focuses on finding out and describing how something works or is done. An example of this type of study could be a description of a market in terms of its size and structure. The purpose of the study is only to describe, not to explain.
- Exploratory studies focus on understanding in depth how something works or is done. This study is often used if little information about the phenomenon studied is available and the relevant questions at issue are unknown. In such a situation it is needed to understand the problem in order to be able to conduct further studies.
- Explanatory studies try to find causal relations in the object of study. In other words, the study is trying to find not only correlations between variables but also what factors affect other factors. One example of such a study can be to map the relation between income and consumption.
- Problem solving studies try to solve specific problems.

A thesis can have more than one purpose, and each purpose may be achieved by one chosen method or a combination of methods. General methods for defining target groups of data gathering can be:

- Surveys, which are a compilation and description of the current status of a number of chosen objects or phenomena under study. When a survey is carried out, the reality is observed as it is, without interference from the researchers conducting the study.

[1] (Lekvall & Wahlbin, 2001)

- Case studies, which are a deeper study of one or a few cases where the researcher, as in surveys, tries to interfere with the object under study as little as possible.
- Experiments, which compare a set of variables by isolating all factors and manipulating one variable at a time.
- Action research, which is a closely monitored and documented study of an activity, with the aim of solving a problem.

The methodology can be fix or flexible, with a fix methodology the researchers cannot change the study during its course usually because that would make it impossible to compare data gathered in the study, while in a flexible study the researchers are free to adapt the methodology when new information is acquired.[2]

In practice, a combination of different methods is often used, such as when a study tries to describe a phenomenon both in depth and with a wide perspective in mind[3].

2.1 Case study and clinic research

Studies of single objects with the purpose of gaining a deep understanding are referred to as case studies. A case study can be appropriate if a new problem is to be studied where limited information exists. The strength with case studies is that new phenomenon can be studied in its natural environment where understanding and experiences can be created due to the researcher's involvement[4]. Clinic research can be described as research in action, rather than research about action and is used if the problem description is created by the company studied[5]. Since our purpose in this thesis is to both solve a specific problem for SWEP International, and to create a deeper understanding of the customer demand regarding marking and traceability this approach was chosen.

One concern regarding this approach it the ability to draw general conclusions from this thesis. Since we have studied a part of one company in detail the conclusions may only be valid for this company (or part of this company), but there might be

[2] (Höst, Regnell, & Runeson, 2006)
[3] (Lekvall & Wahlbin, 2001)
[4] (Sköld)
[5] Ibid.

similarities between different companies throughout the industry making this work useful for another audience.

2.2 Quantitative and qualitative methods

Studies can be either quantitative or qualitative, and such studies are generally distinguished by two factors[6]; how gathered data and information is presented and how data is analyzed. In a quantitative study data can be presented, coded, in numerical form and analyzed by mathematical and statistical methods. In a qualitative study data is often presented in words and expressions and analyzed as verbal reasoning and relations. These two are examples were both the data gathering and the data analysis is of quantitative or qualitative form, but in practice combinations are common[7].

In this thesis the focus will be more on capturing varying customer requirements rather than the exact rates of occurrence of each requirement. This means we will not be using random samples and conduct interviews in a fix manner to support statistical analysis of the data; instead we will select interview persons that reflect as much variety, as in for example gender, age or time of employment, as possible. We will analyze the data using reasoning and existing theories.

2.3 Primary and secondary sources

Material created for a study other than the current is referred to as secondary sources, information and analysis gathered and conducted specifically for the current task on the other hand is referred to as primary sources[8]. For example compare two ways of gathering information about raw material used in production; interviewing a member of the purchasing department is using a primary source, while using statistics of futures exchanges is using secondary information if this information was not produced for the study. Primary sources are not necessary better than secondary ones, what kind of sources to use depends on what information is asked for. The type of information can vary widely; the person from the purchasing department might give information about specific types of steel used for his or her company's

[6] (Lekvall & Wahlbin, 2001)
[7] Ibid.
[8] Ibid.

production whereas the exchange statistics might give information concerning iron ore prices.

Interviews are mostly considered primary sources due to the fact that generally the information comes from personal knowledge or experience by the interview object. However interviews can on occasion be a secondary source, if for example the interview object is only forwarding an opinion of a co-worker. In this thesis interviews will be regarded as primary sources. If some information is found to be secondary the authors will try to confirm this information with a primary source. If this is not possible, this will be specially noted in the report.

2.4 Procedures for analysing and drawing conclusions

When solving specific problems and in R&D, the ambition is not to produce knowledge in the form of theories, thus such work is neither inductive nor deductive in a scientific context. The researcher uses a theory that is suitable in the current context without expressing oneself in a theoretical manner or committing to a specific thought pattern.[9]

2.4.1 Induction

Studies that focuses on interpretation and building theories around gathered data is said to have an inductive approach since these studies uses empiric data to create a theoretical understanding[10]. The researcher can, however, still bias the research as some individuals are more likely to take note of specific information, or come up with certain ideas.

2.4.2 Deduction

When using a deductive approach the focus is mainly on the problem definition and the theory testing. The theory is tested with regards to the problem, which is often designed as a hypothesis, in order to evaluate the theory[11]. The fact that the approach is grounded in existing theories is usually assumed to strengthen the objectivity of the research[12].

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[9] (Patel & Davidsson, 2003)
[10] (Grönmo, Metoder i samhällsvetenskap, 2006)
[11] Ibid.
[12] (Patel & Davidsson, 2003)

2.4.3 Abduction

A third approach is called abduction and can be considered a combination of induction and deduction, see Figure 4. The research starts with a specific case from witch a hypothesis is formulated, after testing the hypothesis it can be refined and tested again. Theories derived from such a method are in some cases generalized.[13]

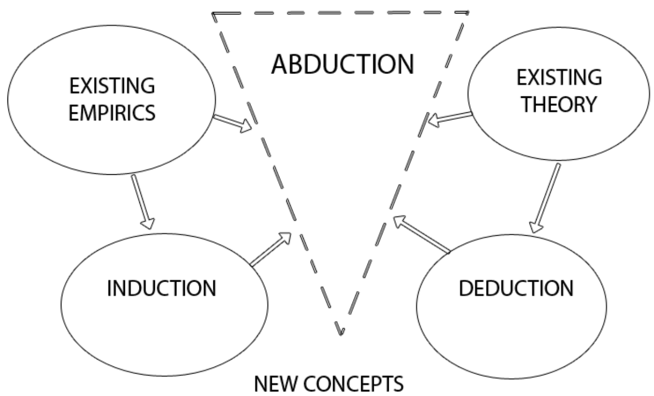

Figure 4 Relation between abduction, induction and deduction (Roos, 1999)

2.5 Thesis value

Below the value of this thesis in form of validity, reliability and objectivity is discussed.

2.5.1 Validity

A study's validity is how well the method measures what is intended. The researchers may believe that they are measuring one variable, but the correspondents may answer according to some other variable, making the validity of measurement method low. One example of this could be a company trying to estimate how well they communicate with their customers using a survey regarding their advertisement, but the correspondent answers regarding to if they think the advert is looking nice or not[14].

[13] (Patel & Davidsson, 2003)
[14] (Lekvall & Wahlbin, 2001)

Throughout our work we have tried to interview persons holding different positions at different departments in order to get second opinions on questions that were raised. We have also had continuous updates regarding the direction of our work, especially in the beginning when we were trying to specify the problem description of the thesis, to ensure that we were investigating the right areas.

2.5.2 Reliability

Reliability is a measurement of how consistent the measurement method is. If the measurement is repeated, are the conclusions still the same? If the conclusions are the same then the measurement is said to have high reliability and if they are not the same the measurement is said to have low reliability. As an example of a course of action that can lead to low reliability is when different interviewers are used that asks the questions differently from one another[15]. The answers can then differ depending on how the question was understood by the person interviewed. Another example could be if the respondent lacks interest and therefore answers the questions randomly.

Both authors have been present at the interviews taking separate notes in order to minimize the risk of misunderstandings. To further minimize the risk of misunderstandings and errors the notes from the interviews conducted have been sent back to the persons interviewed for approval and correction. Most of our analysis has been discussed with employees at SWEP and some of the analysis has also to some extent been discussed with third parties when we needed deeper knowledge and experience in certain areas. This was done to ensure that we had reasoned, and also explained our thoughts and ideas in a logical and consistent manner.

2.5.3 Objectivity

During this thesis work we have kept in mind the importance of being open minded and we have developed solutions without personal prestige. We believe that this has been made easier since we are not employees at the company and that we therefore have been able to see the problem in another perspective.

[15] (Lekvall & Wahlbin, 2001)

2.6 Approach

2.6.1 Interviews and surveys

Our first objective was to fully understand the problem as it was perceived by SWEP, so the first line of interviews were conducted with a reference group of people working in different departments at SWEP. These interviews not only created an insight to the underlying problem, also other information, such as information about SWEP's processes where revealed.

After the interviews with the reference group we conducted an email survey with representatives of the sales force, trying to map the types of customer demands and the work related to complying with these demands. The sales force was chosen since these are the persons working close to the customers. This survey was conducted prior to the attempt of interviewing customers since we wanted to find out what customer demands were already internally known by SWEP.

We then conducted an interview with a consultant in supply chain management to get an external view of our proposed solutions. We also conducted an interview with the manager at Odette Sweden in order to collect information about the Odette system.

We have also conducted surveys with companies providing transportation services with the goal to understand future technology trends and extended service offers, as well as SWEP's steel coils suppliers to understand what their marking offers are.

We have tried to get customers to answer our survey regarding their needs and demands related to marking and supply chain management. However we have not received any responses to this survey. Therefore the customer demands in this work consist of the ones that have been sent from the customer to SWEP along with the ones discussed in the interviews with the reference group at SWEP.

2.6.2 Literature study

A literature study was conducted in order to find out what relevant information already existed regarding our problem definition. Theory from supply chain management and different marking technologies was compiled so that an analysis could be conducted. The study is based on secondary sources which primarily are books along with articles found on Electronic Library Information Navigator (ELIN), a service supplied by Lund University Libraries. We have also studied documents defining specific standards, regarding marking and traceability and we have used information published by suppliers of technology that, could to a large extent, be validated by other sources.

3 Desk study

In this chapter we describe theories, technologies and standards relevant to either understand or to analyse the problems of this thesis.

3.1 Traceability

The goal of traceability, in the context of this thesis, is to be able to fully trace all components both internally within the company and also externally through all suppliers and customers. In some industries such as food or drugs, laws require even more, for instance in the drug industry not just information on what tools were used must be available, also the entire history of those tools, in regard to both manufacturing and maintenance, must be possible to retrieve[16][17][18].

In some contexts traceability can have different meanings, for instance in software development the information connects requirements and the implementation, testing and sub-sequent use of the software[19]. In supply chain management it is sometimes mixed with the term tracking, the purpose of which is to know where a product is and what is being done with that product at a given moment.

There are different ways of managing traceability however the important part is to have access to the history of the product. Some different ways of managing traceability are; attaching a paper form to the product where information on the work being done is added as it is done, this paper is extended with the corresponding document of each component, a perfectly valid however also inefficient way of tracing the history of the product. Another way is using unique serial numbers on the components and storing all information regarding transformation or assembly in a database, in a more or less automated manner[20].

Obviously companies want to minimize the total cost of this system in regard to both the acquisition and storage as well as retrieval of the information. This is a balance between the cost of manual labour and the investment cost of a large information

[16] (CFR - Code of Federal Regulations)
[17] (Food and drug administration departtment of health, education and welfare)
[18] (Ruiz-Garcia, Steinberger, & Rothmund, 2008)
[19] (Lago, Muccini, & van Vliet, 2008)
[20] (Ruiz-Garcia, Steinberger, & Rothmund, 2008)

technology system. These costs also set the limits of what is in reality feasible while still remaining competitive. In other words, it is important to trace what is regarded as necessary and in a way that is creating value however tracing beyond that only introduces costs.

One reason to implement traceability is to improve quality conformance and the first step to rectify a problem is to identify its origins. Poor quality can cause costs in the forms of badwill and in extension loss of orders, not to mention the cost of reworking or replacing the failing product. Another reason to implement a traceability system is to minimize the risk of injury (of either consumer or labourer), often this reason is expressed through laws and union demands, and then it is generally a high level of traceability that is demanded. If the underlying cause is profit oriented, the degree of traceability is dictated by the marginal cost of higher traceability. Yet another reason to implement traceability is to facilitate recycling of the product at the end of its life time. At this point it can be hard to acquire information regarding the material of the components of the product.

3.2 Processes

One major task in this thesis work is to map relevant processes at SWEP in order to understand physical product and information flows. One definition of a process, translated from Swedish, reads "A process is a repetitive used network of in-order linked activities that uses information and resources in order to transform object in to object out, from identification to satisfying a customer need."[21] This definition implies that a process is more than a transformation of an object to another object and therefore defines a process in a wider context. Mainly we will be focusing on internal processes at SWEP, although not in total isolation, since processes according to the definition is a part of a wider network. To be able to map processes some key components needs to be defined.

[21] (Ljungberg & Larsson, 2001)

There are according to the used definition five key components that can be referred to as process components[22].

- **Object in** is the object that starts the process or an activity
- **Activity** is a sequence of actions
- **Resources** is needed to transform the object
- **Information** supports and controls the process
- **Object out** is the result of the transformation in the process

There exist several standards that can be applied when mapping processes. It is important to be consistent when mapping processes and the number of figures should be kept on a minimum so that the understanding of the map is made easier[23]. In this thesis square symbols are used, see Figure 5, to represent objects and arrow shaped figures, see Figure 5, to represent activities that are transforming an object. The map starts with an object in on the left hand side and is finished with an object out on the right hand side.

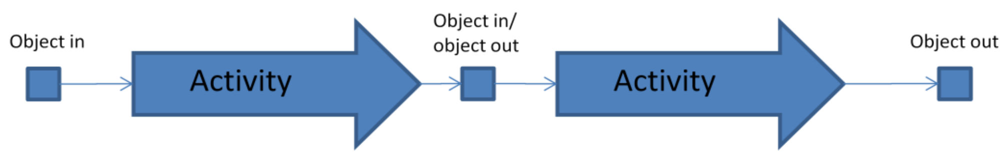

Figure 5 **Objects and activities**

Note that and object out according to one activity can also be an object in according to the next activity and vice versa. See Figure 5 for an illustration of this case.

The logic expression AND is represented by Figure 6 and the logic expression OR is represented by Figure 7.

[22](Ljungberg & Larsson, 2001)
[23] Ibid.

Figure 6 The AND expression

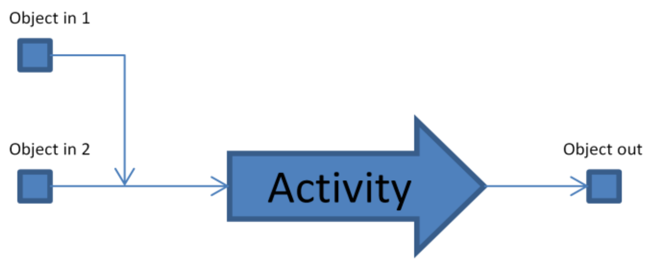

Figure 7 The OR expression

3.3 Marking technologies

There are many ways to transfer information such as in plaintext, in an electronically readable printed format and many more. In this part we describe technologies related to barcodes or RFID tags that are transferred with a physical bearer, sometimes the product itself.

3.3.1 Barcodes

There are two fundamental ways of encoding information to a one dimensional barcode (Figure 8), using delta codes or binary codes[24]. In the delta code approach a colour is used to represent a bit, the coloured bar could represent one and the space could represent zero. In the binary approach the ones and zeros are distinguished by using different widths so that a wide bar or space represents one and a narrow bar or space represents zero, see Figure 9 . One of the most popular binary code symbologies is the Code 39 where the barcode consists of nine elements, five bars and four spaces. Out of these three can be wide, hence the name Code 39. This

[24] (Pavlidis, Swartz, & Wang, 1990)

means that the barcode can hold 84 symbols (the number of ways three items can be chosen out of 9) and 44 of these are used for representing the 10 digits, 26 letters and 8 special characters[25]. In 1981 Code 128 was introduced which uses 106 symbols and can hold more information relative a physical size.

Figure 8 One dimensional barcode (http://www.gs1.com, 2009-11-24)

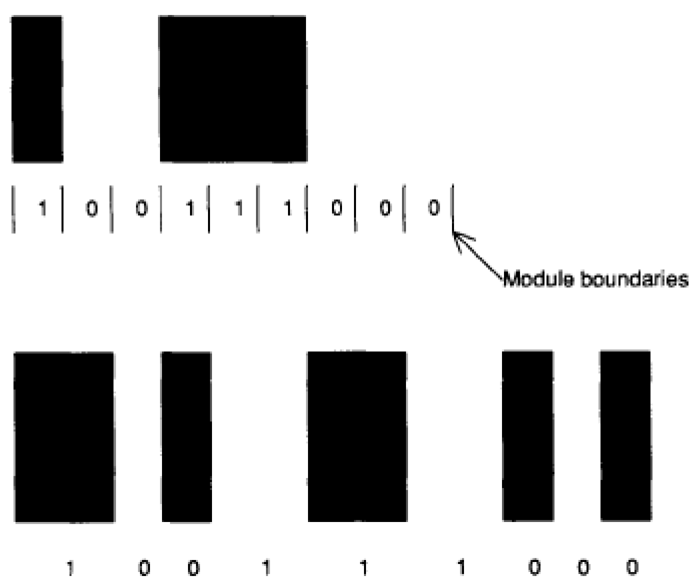

Figure 9 The delta code approach (above) and the binary code approach (below) (Pavlidis, Swartz, & Wang, 1990)

[25] (Pavlidis, Swartz, & Wang, 1990)

When printing a barcode one should strive to create as high contrast as possible, making the combination black and white preferable. Often the reader uses red light when scanning the barcode, making for example the colour red appear as white to the reader[26]. The barcode needs to have a left and a right so called quiet zone, a blank zone where no pattern is allowed, in order to be read properly[27].

3.3.1.1 The GS1 system

There exist different standards for how to use the information that can be represented by a barcode, and one of these is the GS1 system. The process that led to this system was initiated by the Uniform Product Code Council (UCC) in USA in 1973. UCC developed a 12-digit identification number that could be represented with a barcode symbol. Following this success, the European Article Numbering Association (EAN) was formed in 1977 to create a standard that could be used outside North America. The EAN system used a 13-digit identification number. In 2005, the non-profit GS1 organization was formed as the successor to these two organizations, and the identifications numbers were called Global Trade Item Identification Number (GTIN). As the need for more information in the GTINs grew, different types of GTINs have been developed. They are generally named GTIN followed by the amount of numbers they are composed of, for instance GTIN-12, GTIN-13 and GTIN-128[28].

When a company joins the GS1 system, a company prefix normally consisting of nine numbers is allocated. One number is used for error detection so when using GTIN-13 the company then gets three numbers that they can use for their products, leading to a maximum of 1000 product types per company[29].

One should distinguish between the carrier (for example the barcode) and the identification number (for example GTIN)[30]. This means that a GTIN number can be represented with other carrier technologies besides barcodes. The GTIN standard is widely used in the retail trade where a common standard is important because of the high amount of suppliers and retailers. Barcodes are however also widely used to

[26] (GS1)
[27] (GS1, Jan-2009)
[28] Ibid.
[29] (GS1)
[30] Ibid.

carry less standardised information, such as serial numbers, within different industries.

3.3.2 Two dimensional barcodes

The two dimensional (2D) barcode technology was developed in cooperation with NASA in order to minimize the amount of documentation on paper that arose within the space shuttle program[31]. NASA needed an auto readable technology where the marking could be carried out in a way that made the symbols more heat resistant. They were also looking for a technology that would minimize the problems that were introduced due to unreadable one dimensional barcodes and due to labels that fell off[32].

A two dimensional barcode can be described as a matrix that is constructed by high contrast squares or dots. The size of these squares or dots is called the X-dimension[33]. One difference between 1D barcode technology and the 2D barcode technology is that in the latter, both the height and width of the symbol is used to represent data. This means that more information can be stored using a symbol taking up less physical space. The 2D barcode consists of a section that contains the actual data and this section is surrounded by a finder pattern. The finder pattern is used in order to identify that the symbol is a 2D barcode and to recognize the X-dimension[34].

A 2D barcode with its finder pattern can be seen in Figure 10, where the left and lower side consists of solid black squares and the right and upper sides consists of squares alternating between black and white. The solid black sides are used to indicate the correct orientation and the boundaries of the 2D barcode[35]. The sides with alternating colours are used for identifying the X-dimension, the density of the 2D barcode, as well as the boundaries. As with 1D barcode technology, 2D barcodes must be surrounded by a quiet zone. The quiet zone is a blank area that may not

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[31] (Cunningham, 2006)
[32] (The Engineer, 2004)
[33] (GS1, Mar-2009)
[34] Ibid.
[35] (IEEE Computing & Control Engineering, 2006)

contain any pattern with the minimum size corresponding to 1 or 1.5 times the X-dimension[36][37].

Figure 10 Square shaped 2D barcode (http://www.gs1.com, 2009-11-24)

A 2D barcode consists of a various number of rows and columns, and one can use different shapes when creating the symbols. These can be either of square formats, see Figure 10, or rectangular formats, see Figure 11, and depending on what data size and physical size is required, the best format can be chosen. If there are high printing speed requirements, such as when using a printer in combination with a conveyor belt, a rectangular shape might be preferable. Prints can be made with high printing speeds when the height of the symbol is limited. A square shaped symbol can on the other hand hold a larger amount of data[38].

Figure 11 Two rectangular shaped 2D barcodes (http://www.gs1.com, 2009-11-24)

The GS1 standard for 2D barcodes is called GS1 Data Matrix and with this standard a square 2D barcode consists of 10 to 144 rows and columns. This variation makes 24 different symbol sizes available to choose from. When a rectangular shape is used, the rows and columns can vary from 18 to 48 and six different sizes can be created.

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[36] (GS1, Mar-2009)
[37] (IEEE Computing & Control Engineering, 2006)
[38] (GS1, Mar-2009)

The maximum amount of data a square shaped matrix can hold is 2 335 alphanumeric characters or 3 116 numbers. The corresponding amount of data for a rectangular shaped matrix is 72 alphanumeric characters or 98 numbers[39]. These amounts of data can be compared to a 1D barcode usually holding around 14 numbers.

Another common standard is the Portable Data File (PDF) 417 standard. When using the PDF417 standard a 2D barcode can hold up to 1848 letters or 2792 number characters[40].

As with 1D barcode technology, 2D barcode technology needs visual contact between the reader and the symbol. A difference though, is that the 2D barcode is not orientation sensitive, which means that the symbol, or the reader, does not need to be rotated in order to read the symbol correctly[41]. The reader must be able to read 2D barcodes, which is done with a camera and an image processor. Many of the more modern printers are compatible or can after a software update be used to write 2D barcodes. This means that often a company does not have to replace all its current equipment to be able to use 2D barcodes.

Since a 2D barcode can hold significant more data than a 1D barcode, it is possible to keep the communication with the database at a lower frequency[42]. It is common that the identification number that the 1D barcode corresponds to is used to communicate with a database to collect more information about the corresponding product. When using a 2D barcode some or all of this information can be directly held by the symbol. This means that more information can be shared throughout the supply chain in a more efficient way. The ability to hold an increased amount of data makes it possible to use 2D barcodes for holding information that can be decoded to sounds or images[43].

Generally, as with the lines in 1D barcodes, one should strive to achieve a high contrast between the different squares that constitute the 2D barcode. A black and white configuration is therefore the preferable colour configuration also when using

[39] (GS1, Mar-2009)
[40] (Zhang, Dai, & Mu, 2008)
[41] (IEEE Computing & Control Engineering, 2006)
[42] (Zhu, Wu, & Yu)
[43] (Zhang, Dai, & Mu, 2008)

2D barcodes, but other colour configurations that creates high contrast may also show satisfying results[44].

Unlike a 1D barcode, a 2D barcode can still be read even though it has been damaged. This is due to the inbuilt error correction that usually works as long as 70-80 % or more of the symbol is intact. Another difference compared to a 1D barcode is that a 2D barcode cannot be partially read, either 100 % of the data is read or no data at all is read[45].

There are four main technologies that are suitable for 2D barcode marking[46].

- Thermal transfer
- Inkjet
- Laser etch
- Direct part marking (engraving)

Thermal transfer may be the most common technology to create on demand labels. With this technology a special ink is heated in order to transfer the symbol to a label. This technology enables the creation of high quality symbols.

Inkjet is a technology where material and the printer do not need to be in contact. The technology uses drops of ink to create the symbol.

Laser etch, see Figure 12, is a technology where a laser beam is used to burn the symbol into the material. This technology only functions with materials that are suitable for laser operations.

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[44] (GS1, Mar-2009)
[45] (The Engineer, 2004)
[46] (GS1, Mar-2009)

Figure 12 Laser etched data matrix (http://www.emeraldinsight.com/, 2009-11-24)

Direct part marking uses a needle of some hard material such as tungsten to engrave the symbol on the material. This type of technology can be effective in use with solid materials, such as metal or glass, see Figure 13. The technology is suitable for hard materials and creates a durable marking[47].

Figure 13 Direct part marked data matrix (http://www.emeraldinsight.com/, 2009-11-24)

3.3.3 Radio Frequency Identification

Radio Frequency Identification (RFID) is a technology where radio waves are used for transferring information from a transponder to a reader. Using radio waves makes it possible to read a tag without visual contact and the orientation of the tag is not important[48]. RFID technology can be found in a variety of applications, for example in smart cards used for authentication purposes or for pet identification purposes where a RFID chip can be planted inside the pet. The price of RFID equipment, and especially the price of tags has, due to technology development, fallen and this makes the technology interesting for use in the supply chain. Using RFID throughout the supply chain often makes it possible to reduce manual labour since identification can be

[47] (GS1, Mar-2009)
[48] (Symonds & Parry, 2008)

carried out in a more automated way than for example when barcode technology is used[49]. An example could be the reading of items placed on a transport pallet, when using barcodes one might be forced to unpack the items placed on the pallet in order to scan the items individually. With RFID technology, the items may be identified automatically in a matter of seconds, without having to unpack the individual items. This automatic identification can also be used to minimize the risk of human errors, such as scanning the wrong product or scanning the data into the wrong field in the software[50]. There are also other possibilities to address this problem that are discussed in 3.5.

The transponder, often referred to as a tag, consists of a chip, an antenna, and in some types a battery. The physical size and price of the tag varies depending on its storage capacity and maximal reading distance. Though the storage capacity varies among different tags, a tag can hold significantly more information than a traditional barcode, making it possible to trace a product in a more detailed and efficient way. With this extra information, processes such as inventory control and the placing of new orders can generally be automated to a higher extent. The real advantages are introduced when a standard RFID solution is used throughout the supply chain, from the supplier to the final customer, but the introduction of such a solution imposes great challenges and might require a closer relation between actors in the supply chain[51].

The tag has a unique identification number that is used to identify a single tag and can hold several kilobytes of data[52]. Depending on the requirements, a tag can be made relatively thin so that it can be placed inside or on the back of a standard label. When conventional labels are fitted with a RFID tag, as shown in Figure 14, they are often referred to as smart labels.

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[49] (Singer, 2003)
[50] Ibid.
[51] Ibid.
[52] (Gandino & Rebaudengo, 2009)

Figure 14 Example of RFID tag attached to a label (http://www.kennedygrp.com/, 2009-11-24)

3.3.3.1 Passive tags

A passive tag is a tag that does not have its own power supply. It uses the electromagnetic waves sent by the reader to charge a current in order to send its data[53]. When the tag is not near a reader it is referred to as being asleep and when the tag is within reading distance the reader will cause the tag to wake up. Since this type of tags does not require a battery they can be made compact and to a lower cost. The downside is that the required distance between the tag and the reader is much shorter than when using a tag with a battery and the tag needs extra time to wake up since it takes some time for the current to reach required level.

3.3.3.2 Active tags

The tags that have their own power supply in form of a battery are called active tags[54]. These tags are always awake, hence the name, and therefore always ready to send and receive data. The distance between the tag and the reader can be significantly larger for this type of tag than the distance when using passive tags since the active tag´s signal can be made stronger due to the battery. The physical size of an active tag is generally larger than that of a passive tag and the cost is significantly higher, making the use of this type of tag relevant only for high value products or in applications where the tag can be reused[55]. One of the more common active tag applications is the use for car identification in road toll systems. When the battery is discharged, the tag cannot longer be used[56].

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[53] (Angeles, 2005)
[54] Ibid.
[55] Ibid.
[56] (Kim, Choi, & Lee, 2007)

There exists a compromise between passive and active tags called semi active tags. These tags use a battery, but are only woken up when they are within the reach of a reader[57]. The semi active tags have a significantly stronger signal and shorter wake up time than passive tags, to a cost lower than that of active ones.

3.3.3.3 Read and write possibilities

In addition to being of active or passive type, the tag has different read and write abilities.[58]

- **A read-only tag** is a tag where the information is written at the time of production of the tag. The information can only be read, not changed, once the tag has been produced.
- **A write-once/read-many (WORM) tag** is a tag where the information can be written once, at an arbitrary time. After it has been written once, it can only be read.
- **A write-many/read-many (WMRM) tag** is a tag that can be read and written numerous times throughout its lifetime.

3.3.3.4 Security aspects

Since RFID technology uses radio frequency for communication there is a risk that unauthorized readings and writings may occur which might lead to information leakage. This risk grows along with cheaper mobile readers entering the market. One way of limiting information leakage can be to kill the tag before it reaches the consumer, the term kill here meaning deactivating the tag's reading and writing capability. However, this technique might limit the advantage of using RFID[59]. Normally, RFID tags have no cryptographic capabilities; however, solutions to avoid security and privacy threats are under study[60].

3.3.3.5 Readers

At present, there are a variety of readers available on the market which are suitable for different applications. Readers with an internal antenna are a simpler and cheaper

[57] (Angeles, 2005)
[58] (GS1 Sweden)
[59] (Kim, Choi, & Lee, 2007)
[60] (Gandino & Rebaudengo, 2009)

alternative suitable for applications where tags are read one at a time. Such an application can for instance be found when conveyor belts are used, with single items passing the reader. Readers with an external antenna generally have higher capacity and are suitable for applications demanding reading of several tags within a short period of time, as is the case when reading individual items placed on a pallet. Due to their higher capacity, readers with external antennas may also prove more efficient when there is a need for communication between separated antennas[61].

There are also readers that are built in modules, making it easier to replace a malfunctioning part at the productions site. In addition one reader may support several different protocols and frequencies.

Placement of the readers[62]

- Integrated or near the label printer, in order to verify that the tag is functioning properly before attaching it to the item.
- At the attachment location to verify that the tag is functioning properly after attaching it to the item.
- At the doors of transport vehicles in order to track which item or pallet is transported with a certain vehicle.
- Near doors or between different warehouse sections in order to track which items are carried in and out of the warehouse section.
- In and out of a production site or warehouse in order to track inventory level.

3.3.3.6 Cost implications

Generally semi active tags have a significant higher price than passive tags but have a significant lower price than active ones. The price of different types of tags has fallen during the recent years and the price is expected to fall as RFID technology matures. Tags still have a significant higher price than traditional barcodes[63].

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[61] (GS1 Sweden)
[62] Ibid.
[63] (Baudin & Rao, 2005)

3.3.3.7 Impact on environment

The introduction of RFID in supply chain basically means introducing electronic parts that are integrated with items and packages. This imposes challenges for recycling since the electronics and metal parts needs to be separated in the recycling process. Research has shown that this will be a major issue if RFID enters the retail trade, with tags attached on item level (cans, bottles, packages etc.). In this sector, there is a great quantity of items with short lifetime[64].

It is estimated that the quantity of RFID tags can be a factor 450 times higher in 2016 compared to 2006[65]. Along with tags becoming cheaper and algorithms for reading several tags virtually at once becomes more stable, marking with RFID will be carried out on lower and lower item level, due to the advantages involved.

Tags may also introduce environmental possibilities, such as easier sorting of materials and better tracking of recycled items which can lead to more insight in the recycling process[66]. In a wider meaning, tags can reduce a company's environmental impact if production processes can be made more efficient.

3.3.4 Electronic product code

Electronic Product Code (EPC) is the GS1 standard for RFID. While a GTIN number can be used to identify a certain product group the EPC number can be used to uniquely identify a certain product. This means that for instance a single can of soda could be uniquely identified with the use of an EPC number. The EPC number is stored in an RFID chip and since the number is unique, it can be used to fetch relevant data from a database in a highly automated way.

3.3.5 The EPCGlobal Network

The EPCGlobal Network is a secure means to connect servers containing information related to items identified by EPC numbers[67]. This means that the EPCGlobal Network is GS1's approach to integrate information handling and information spreading throughout the supply chain using RFID. There is a need for companies to exchange

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[64] (Thomas, 2008)
[65] (Defraigne, 2007)
[66] (Thoroe, Melski, & Schumann, 2009)
[67] (GS1, 2004)

electronic product information in a standardized way and this is what the EPCGlobal Network is offering.

The EPCGlobal Network consists of three main elements, the Object Naming Service (ONS), the EPC information Service (EPICS) and the EPC Discovery Service[68]. When a product is marked with an ECP tag the manufacturer registers its Manager ID in the ONS server in order to tie the tag to the manufacturer. Every member company of the network has an EPICS server[69] that is used for storing relevant product information relating to their EPC numbers. As the product moves along the supply chain, information of certain events such as arrival and dispatch events is registered in EPICS servers.

When another member company in the supply change needs information about a certain EPC marked product they send a query via the Internet to the ONS server, which function somewhat similar to a Domain Name Service server, giving information about what EPICS server to contact. The EPICS server then executes the identification and authentication processes needed before granting access to the information stored[70]. The EPC Discovery Service is a service that lets a member of the network fetch information about which other members had possession of the product at a certain time. It can also be used to share information about reading and writing events[71].

3.4 Electronic Data Interchange

Electronic Data Interchange (EDI) is defined as "electronic data exchange of structured and standardized business data between computers"[72]. The technology makes it possible to transfer data electronically in order to avoid traditional paper documents and to minimize human labour. EDI is commonly used for routine tasks such as placing purchase orders and sending invoices. The basic idea is to let different ERP systems communicate through the use of a middleware that handles the translation of standard EDI messages so that these can be used within the partners

[68] (verySign, 2008)
[69] (GS1, 2004)
[70] (GS1, 2006)
[71] (Beier, Grandison, Kailing, & Rantzau, 2006)
[72] (Becker, 1990)

ERP systems[73] without human intervention. The interface can also be web based, so that a partner can use a web browser to create messages.

In order to make EDI useful throughout the supply chain four main technical standards for EDI has been developed. These standards publish definitions for the documents transferred. The standards are[74]:

- UN/EDIFACT – as the name implies this is the standard supported by the United Nations(UN)
- ANSI X12 – this standard is primarily used in USA, Canada and Australia
- TRADACOMS – used in the United Kingdom
- ODETTE – based on the UN/EDIFACT standard and primarily used in the automotive industry

EDIFACT is an acronym for EDI For Administration, Commerce and Transport[75] and is the result of trying to bring the standards used in Europe and the US together to one, see Figure 15.

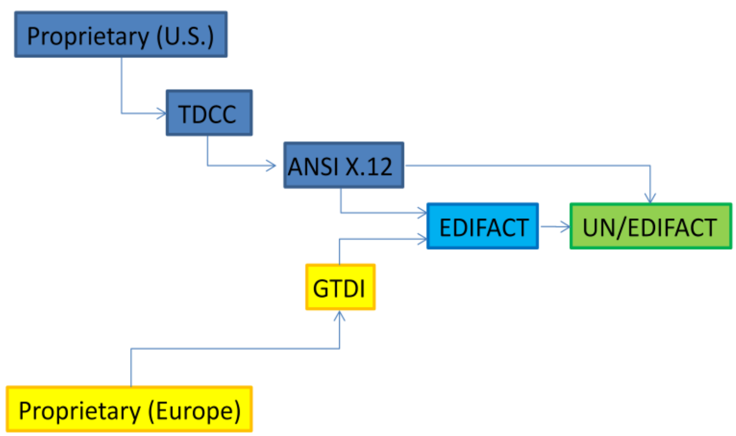

Figure 15 Overview EDI standards (EDIFACT Standards Overview Tutorial)

[73] (Fredholm, 2006)
[74] (EDI Guide)
[75] (EDIFACT Standards Overview Tutorial)

3.5 The use of prefixes

Many companies have at some point had an employee who read the wrong barcode on a label with many fields, for example by reading the barcode for the serial number into a field that was supposed to hold a value for quantity. If the information system is designed to automatically update inventory status and calculate data such as cost of inventory a number of errors quickly manifest themselves and time and effort is required to find and fix the root cause of the problem. One solution for this problem is to preamble the barcode with a prefix identifying the type of information encoded. Adding an S in front of the value for the serial number defined by the customer, and Q in front of the quantity the previous problem would be avoided as the information system warns the user that there is a discrepancy in the read barcode.

We have during our work on this thesis found two major standards defining prefixes; ANSI MH10.8.2 where the prefixes are known as Data Identifiers (DIs) and GS1 where the prefixes are named Application Identifiers (AIs). A DI consists of zero to three numbers followed by a letter and an AI by two to four numbers in length. The DI prefixes is not printed in the plaintext information part of the barcode, the AI prefixes are encapsulated by parentheses. Many of these prefixes can be directly translated between the two standards but some prefixes are unique to each standard.

4 Interviews and dialogues

This chapter summarizes our data gathering performed as interviews and dialogues, made in person, via e-mail or over the phone. The sources are mainly representatives from SWEP, but where suitable and possible, other sources were used as well.

Interviews were conducted with part of the reference group that was formed during the start of the project. In the end some members of this group were not interviewed, mostly due to unforeseen reasons that made them unavailable. We also interviewed one person that was not originally a member of the reference group to extend our understanding of the production processes. To help understanding the following subchapters Figure 16 can be kept in mind.

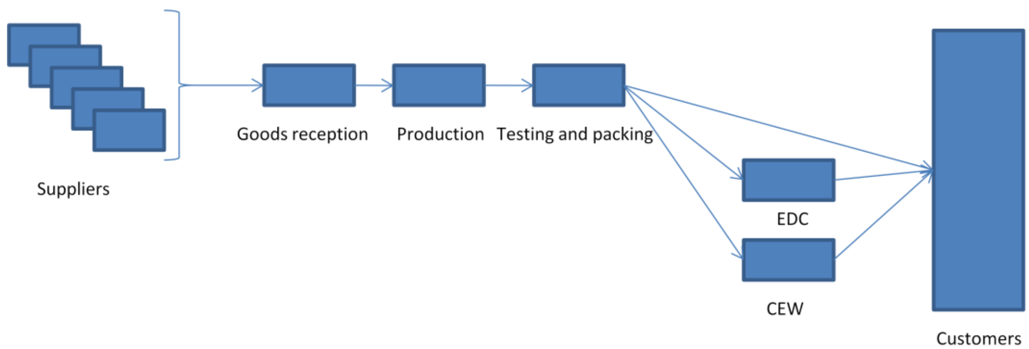

Figure 16 Illustration of the flow of products

4.1 Customer types

SWEP divides its customers into three groups, SKA, HUB and e-business. SKA stands for Strategic Key Account and these customers amount to about 50% of SWEP's annual revenue. This group consists of about 30 organizations with 150-200 customer accounts. A majority of the production for these customers are made to order. The reason that 30 organizations can result in so many accounts is that generally each production site and sometimes also different departments from the same customer has their own customer account.

The HUB business represents about 40% of SWEP's annual revenue, the common denominator for this group is the geographical location, and orders from this group are placed to, and handled by regional sales offices. There are seven hubs in Europe, one in Japan, one for the rest of Asia and one in North America. The sizes of orders varies greatly but are mainly delivered from stock.

The final group represents the remaining 10% of annual revenue; these customers order their products via SWEP's e-business system and generally buy standard solutions, though requests for individual adaptations are becoming more and more frequent.

4.2 E-type and B-type heat exchangers

SWEP has several types of heat exchangers and the two most common SWEP calls E-type and B-type. The E-types heat exchangers are relatively small and cheap, SWEP produce around 3 million of these each year. The heat exchangers of type B are larger than those of type E however the size can vary widely. SWEP produces around 750 thousand B-type heat exchangers yearly.

4.3 Labels

The labelling of individual heat exchangers depend on what type it is, the E-type is marked with a batch number by printing it on the side of the exchanger with ink. All other heat exchanger types have individual serial numbers that can be found on a label on one of the cover plates of the exchanger. Before the exchanger has been tested it is labelled for internal purposes with a white label as seen in Figure 17. After the exchanger has been approved in the test process it is labelled with a silver label, shown in Figure 18. The contents of the silver label may vary depending on customer demands. The silver label replaces the internal white label and sometimes covers it as space on the cover plates is sometimes limited.

Figure 17 Internal white label

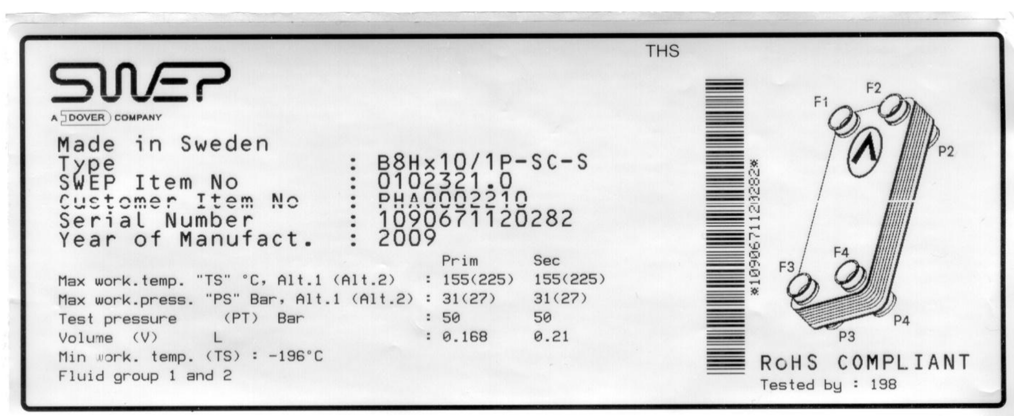

Figure 18 Silver label

As heat exchangers are pressure vessels it is often expected that the products are tested in accordance with some third party standards organization, usually depending on the geographical region in which the final product will be sold. The most common third party approvals for SWEP's products are from PED/CE in Europe, ULC in North

America and KHK in Japan; however a great number of other third party organizations are required with varying frequency. SWEP has for the most occurring approvals a license to perform the tests themselves, but for the other organizations an external inspector must come to the production plant and inspect the test.

4.4 CEW and EDC

CEW stands for Central European Warehouse, and acts as a distribution centre mainly for products from the European production sites. At times the European plants are busy with producing to orders, and the warehouse is kept stocked with heat exchangers from the production sites in Malaysia or China. From time to time a customer requires, for tax and customs related reasons, that the products have been produced in Europe. This is noted in the business system for each individual exchanger, a task that requires time consuming manual labour and the risk of human error is large. Most deliveries from CEW go to customers in the e-business segment.

EDC stands for European Distribution Center, and is a customer specific warehouse for registered customers that buy entire batches, in other words fully packed pallets with pre-determined quantities.

4.5 Internal processes

Below the SWEP's production and methods for purchasing, goods reception and claims handling are described.

4.5.1 Production

The first step in production is to press the channel plates that will contain the mediums in the heat exchangers. These plates are made from stainless steel type 304 or 316 or from titanium, between each of these plates copper or nickel plates are placed that will later be used in the brazing process. All exchangers except those of E-type have two cover plates, one at the front and one at the back. These plates normally do not come in direct contact with the mediums in the exchanger, therefore they do not need to be as resistant to corrosion as the channel plates and are therefore generally made from steel 304 to reduce costs. Channel plates can be either symmetrical or asymmetrical, for symmetrical plates the rotation of the plate is unimportant, however for the asymmetrical plates rotating the plate so that the hole for connection F1 aligns to connection F4 (see Figure 19) would result in a complete failure of the exchanger.

Figure 19 Connections on BPHE

After the plates have been pressed the whole heat exchanger is assembled. At this point it is important both that the plates are oriented correctly (if the plates are asymmetrical), and that the correct number of plates are used. Contrary to the rest of the heat exchanger the connections are produced in batches to stock or purchased premade, and these too are assembled with the exchanger.

A label on the box containing the connections exists, but a mix up between connections can be introduced if the operator accidently places a connection in the wrong box. It is common that one type of connection is difficult to distinguish from another type just by looking at it.

Figure 20 Pallet of BPHEs in furnace

The assembled heat exchangers are put in columns on a heat resistant pallet. If one of the exchangers have too few plates this will reduce the pressure on the entire column, which in turn may result in that some contact points within the exchangers do not fuse together properly. Conversely if one exchanger has to many plates this may reduce the pressure on the adjacent columns. In Figure 20 the pallet with columns of heat exchangers can be seen.

When the pallet is full it is placed in a furnace that heats to 1200 °C, where the copper or nickel plates melt and the exchanger is brazed together. After a certain time the furnace is turned off but kept closed, and the heat exchangers cool slowly. When the heat exchangers are cool enough they are taken from the furnace and are then either labelled with the internal white labels (Figure 17), or if they are E-type exchangers, they are sprayed with their batch number. The exchangers that receive the white internal label are also etched with their serial number in the front cover plate.

All heat exchangers are tested and all tests, except those on the E-type exchangers, are logged. The log is linked to the serial and work order number and is used mainly when SWEP receives some type of claim. If one of the exchangers with an asymmetrical design was incorrectly assembled it will be discovered during testing if this has so far managed to go undetected. The products that were rejected during testing are scrapped. However if some of the exchangers did not have the correct pressure while in the furnace this might go undetected until the unit suddenly fails while in use, often much earlier than anticipated. With the current level of traceability employed by SWEP, notice will be taken if several exchangers from the same batch receive claims and an investigation into the cause of these failures may be conducted. If needed an entire batch can be recalled and replaced before the rest of the products fail. The percentage of scrapped material vary greatly but at periods it has reached 1% which equates to a substantial cost when considered that material represents 70% to 80% of the cost of producing the exchanger.

After testing, the approved exchangers that are not of E-type, and are not going to CEW, are labelled with the silver labels (Figure 18). The exchangers are packed into pallets which are then placed in a loading space awaiting shipping, either to the customer, CEW or EDC. The reason for not labelling the products going to CEW is that some customers wants custom made labels, and the customer is not known at this point for the products shipped to CEW. For each pallet, each individual product is registered by reading the barcode on the silver label or the white internal label. At times the customer wants the pallet to be shipped with a list of the serial number of the contents so that the customer can scan the list instead of scanning each exchanger individually. Other requirements related to packing and shipping can be certain layout of the pallet label, specific prefixes on barcodes to prevent human errors such as reading serial numbers as quantity, or specific orientation of the product within the pallet to facilitate unpacking or production at the customer production site.

4.5.2 Goods reception

When incoming shipments arrive at the goods reception they can be either accepted immediately or checked and then either accepted or rejected. For new suppliers or suppliers that have recently had a rejected delivery, all received deliveries are inspected. After eight accepted deliveries the supplier receives a higher rating and now only one in four deliveries are inspected. After twelve inspected and approved deliveries the rating will once again be raised and only one in eight deliveries are inspected. If any discrepancy would be detected during an inspection the rating of that supplier would be reset and once again all deliveries will be inspected. All accepted deliveries are relabelled for internal use, and the material receives a unique id number. If the material was delivered together with a certificate, the certificate is labelled with the material id number and stored separately. Within the plant all material and components can be identified by either a material id, for externally produced goods, or an article number, for material or components produced by SWEP.

4.5.3 Purchase

SWEP uses local purchase organizations that are located in proximity to the production sites. Direct material (steel excluded) is being purchased according to geographical and volume factors. If the supplier is situated in for example Sweden the purchase organization in Landskrona is used, regardless of which production site is requesting the material. The purchase contracts regarding steel are negotiated globally for all production sites.

SWEP purchases around 11,000 tons of steel annually and this is the major material cost for SWEP. SWEP is although only a small customer from the steel suppliers' perspective. SWEP uses five different steel suppliers and 11,000 tons of steel equals to about one day's production, for one single supplier. Since the steel suppliers strive for a broad customer base, SWEP is an important customer in the meaning that SWEP represents a different industry than most of the steel suppliers' customers.

SWEP uses both 304 and 316 steel and has been requesting a clear marking that can be used to distinguish between the different types of steel. One such request has been to use different colours on the shrink wrap that surrounds the steel coils when delivered. The problem is that the steel suppliers use highly automated processes and in combination with SWEP's small volumes this request has not been met by the suppliers.

At present all steel suppliers but one places a label on the side of the steel coil which can be used to decide what type of steel the coil contains. The label also contains a serial number that can be used for traceability purposes. Since the label is placed on the side of the coil it needs to be removed before production can start. As long as the steel coil is used until empty this imposes no great problems. If however a coil needs to be replaced, for instance because a batch consisting of another type of steel is to be produced the traceability of the coil might get lost. It has occurred that the marking has not been reattached to the partly used steel coil which has resulted in problems regarding identification of the steel coil and lost traceability. With regards to this problem, SWEP has requested the label to be placed inside the steel coil. This would make it possible to leave the label on place when the steel coil is used in the production process. As in the case of the coloured plastic film, the suppliers have not been able to meet this request.

To be able to decide what type of steel a non marked coil contains a spectrometer has been purchased. Although the spectrometer can distinguish between 304 and 316 steel without damaging the steel, the serial number attached to the label generally cannot be regenerated if lost. The spectrometer is generally only used when a confusion of the steel types is suspected.

We have been in contact with suppliers of steel coils regarding marking of their products and we did not find anyone offering RFID marking of the steel coils and the customer specific marking is limited.

When steel is purchased a 17-18 week prognosis of demand is used. SWEP then orders the required amount of steel for the next two to five weeks period. No automatic system is used for purchase; it is handled with the help of Microsoft Excel, by email and by telephone and is managed by a few people at the corresponding sales department.

When SWEP discovers a problem in the ordered material a claim is created. This claim consists of information about the problem and what consequences this has for SWEP. If possible, photographic documentation is also used. This claim is then sent to the supplier which has a time period of two days to solve the initial problem. Within one month a plan including preventive actions should be created by the supplier and received by SWEP, showing how future problems of the same kind will be avoided. This procedure is referred to as Corrective Action, Preventive Action (CAPA). If SWEP discovers a problem the whole shipment is returned to the supplier, SWEP does not sort the material in regards to defects.

There are also suppliers that heavily depend on SWEP, for instance suppliers of laser cut material. However, there is no present problem regarding marking and traceability in this area.

4.5.4 Customer claims

SWEP like any other company wants to avoid causing claims to as high extent as possible. In 80 % of the cases the cause of the problem is wrongful handling of the product by the customer. Other causes for claims are that the product was damaged during transport, that the sales officer misunderstood the customer needs or that the wrong item was shipped. In the case of damage during transport, SWEP and the shipping company settles the issue among themselves. The failure of the equipment may also originate from any number of production errors or what is known as a field failure, where the product fails while in use. The production errors are handled by the production site that manufactured that product, while the field failure is sent to Landskrona and examined in a full scale test facility. There are also a number of less common causes for claims, for example a Japanese customer who felt that the silver label was rotated in the wrong direction, however no agreement specifying this had been made.

4.6 More on the silver label

The layout of the silver labels is affected by both the customer and the product and type. By default the layout and contents is determined by the customer's country of origins, however if the customer requests a different layout this can become, if requested, a standard option for all future orders, or all future orders of that product type. Depending on where the product is produced certain options are not available. Also the specification of the product itself can affect the label, for example if the pressure multiplied with the volume is less than 25 barliter CE-marking is not required and was previously not allowed. Due to this the system was originally designed to block CE marking on this type of product and it still does by default.

Some customers require an extra silver label to attach outside isolation and other covering material, however such requests are unusual thus the number of produced silver labels can be approximated to the number of sold products. So far no customer has reported any quality problems regarding the silver label but some customers have commented that the label is too difficult to remove, a matter that SWEP is reluctant to rectify as the silver label is the main way of identifying a product.

4.7 Internal traceability

A process that complicates traceability in the production is the brazing process where the heat exchangers are brazed at a temperature as high as 1200˚C. The temperature makes it hard to create a marking that is readable after the brazing process.

If a heat exchanger is found to be wrongfully assembled in some way after the brazing process the entire exchanger is scrapped, too much administrative work is needed to find an order that corresponds exactly to the heat exchanger. Furthermore, there are many varieties of connections making the possibility to change a certain exchanger to another order small.

It is possible to trace the tools and the operator batch wise since the operator registers the corresponding operator number when performing a certain task. This information is then related to a work order/material id in the business system Avanté, so that it is possible to find out which operator performed a certain task.

To be able to perform an internal quality inspection of incoming material, such as the coils of steel, instead of buying this service could increase the internal understanding of the relations between material and the quality of the finished product. The steel delivered is of varying thickness and therefore it has been discussed to measure the thickness with laser prior to the press process. There is a problem with how to connect the information about the quality of the material and the quality of the finished product.

It has been mentioned that RFID technology might be used to distinguish the type 304 steel from the 316 steel so that the risk of using the wrong type of steel could be minimized. The difference between these types is that the 316 steel is more corrosion resistant; however the 316 steel is more expensive than the 304 steel. The cover plate usually does not come in contact with the medium in the exchanger making it possible to use 304 steel for cover plates and 316 steel for channel plates. Due to having different types of steel a mix problem has been introduced. A reader nearby the machine can make it possible to check if the order number corresponds to the steel being used. The problem with the marking not surviving the brazing process still remains.

In Slovakia and China laser marking equipment is used to laser mark the individual channel plates. SWEP is trying to find a good pattern that can be used together with a vision system in order to verify that the asymmetric channel plates are oriented correctly. This is a request that has been raised from the production managers at different production sites.

4.8 Transportation

One goal of future technologies in the transportation sector is to keep minimizing the amount of time that vehicles are driven without any load. Examples of technologies used today are GSM and GPS systems that are combined with a vehicle computer. These are technologies that the customer of the transport service is not in direct contact with. EDI solutions are used extensively for communication purposes between the sender, the transportation company and the receiver of the goods however we have seen that this is provided as a service by the transportation companies, which in turn use standards such as EDIFACT.

The use of RFID for marking the actual goods is expected to grow in the future and extra features such as temperature and acceleration/tilt logging of the goods might introduce new possibilities. Temperature logging is interesting for temperature sensitive goods such as food products, but the benefits related to non temperature sensitive industrial goods such as heat exchangers might be limited. Tags for sensing the acceleration of the good and if it has been tilted might be interesting for heat exchangers to a certain extent and if this information becomes available the corresponding threshold values needs to be defined. Barcode is still the dominant auto readable technology for identifying goods and shipments and with the use of the more modern 2D barcodes significant more information can be stored compared to the traditional ones.

Is has been hard to get good answers to our questions about future technologies and some answers indicates that this is because the transportation companies have limited information and are unwilling to share this type of information.

4.9 Odette

Odette is a network based on membership in national organizations and its members are mostly companies with connection to the automotive industry. There are other similar organizations in North America and Japan that Odette cooperates with in order to provide more global standards and recommendations. However Odette is currently looking to expand its member base to include industries outside the automotive sector.

One of Odette's responsibilities is to create and maintain marking standards for components. Odette's solutions rely on ISO and ANSI standards and include areas such as:

- EDI messages
- RFID
- Various types of labels
- Logistics concept
- Protocols for data communication

In order to handle EDI messages, members can use a web based interface or create an integration with its Enterprise Resource Planning (ERP) system. The EDI messages are divided into the following areas:

- Product data information
- E-invoicing
- Logistics
- B2B

One area typically includes around forty different EDI messages and, according to Odette, the number of messages is enough to cover the various demands handled by EDI services. The frequency of change in messages is low.

In order to handle sharing of production data, such as Computer Aided Design (CAD) files, amongst participants in the supply chain, Engineering Data (ENGDAT) was created. ENGDAT is a recommendation that specifies the content, structure and format of EDI messages. This is now maintained by Strategic Automotive product data Standards Industry Group (SASIG), an organization with members present in the automotive sector.

Odette has developed a standard for transport labels and the Odette Transport Label 1(OTL1) which was introduced in 1986 is still the most common transport label used by the Odette members today. The barcodes in OTL1 is based on the Code 39 standard.

In 2001 Odette created the Global Transport Label (GTL) that is intended to replace the OTL1 in the future. The GTL is based on Code 128 and can also include a 2D barcode such as the data matrix or the PDF417 standard. One major difference between OTL1 and GTL is that GTL introduces a so called license plate. The license plate is a globally unique identifier and is basically the only data needed in order to identify a certain delivery. The idea is that the license plate can be used to request other information about the product via EDI. Odette has developed a standard for this, but it is still only used to a limited extent in the automotive sector. The license plate consists of the following segments:

- ANSI standard Data Identifier
- The organization that has published the company identity (such as Odette)
- Company identity
- Serial number

The label is divided into different areas and the information in these areas can to some extent be modified to meet various customer demands. Odette has also chosen to use an ISO standard[76] that refers to the ANSI standard MH10.8.2 for handling prefixes to be used with barcodes.

Odette has developed recommendations for the use of RFID. This recommendation is not published at the time of writing but, according to Odette, it is finished and will be published in late 2009. Odette has chosen not to use the EPC standard since they believe that this standard is more appropriate for the retail sector than for the manufacturing industry. Odette's recommendation includes the following areas:

- Returnable Container Management
- Vehicle distribution

[76] ISO 15418

- Component marking

4.10 Price estimates of RFID equipment

We have collected price estimates from suppliers of RFID related products in order to understand the economical possibilities of RFID implementation at SWEP. A relative simple RFID inlay of WORM type that is used in smart labels cost between 0.08€-0.25€ a piece. This is only the price for the inlay, not the entire smart label. The price interval is related to what specific tag is chosen and the ordered volume. These types of tags are generally not reusable and are designed to work with labels attached to paper and cardboard items. Another supplier has a list price of approximately 0.75€[77] for a smart label that is made for use on paper and cardboard items, when purchased on rolls containing 1,000-1,500 smart labels. The same supplier has a tag that can be applied on metal and is protected to withstand a harsh industrial environment and that is of the WMRM type. This tag has a list price of 5.5€[78] a piece. Another supplier states the price interval 1.5€-4€ for WMRM tag that can be attached to metal, as before the price interval depends on the specific tag chosen and the volume ordered.

Handheld RFID readers and writers (encoders) with a reading and writing distance of 0.05-2.5 meters cost between 2,000€ and 3,000€ and a stationary writer costs around 3,000€. A reader gate that can be placed where items are passing through costs around 3,000€-5,000€ and such a gate is composed by a gate structure, a reader and antennas. The price varies depending on how many antennas that are needed and what extra equipment is asked for. The number of antennas needed depends on the design of the items being read as well as the reading environment. Examples of extra equipment could be touch screens and traffic lights.

The suppliers contacted in this thesis work uses middleware software as an interface between the RFID hardware (readers etc.) and the existing ERP system. One of the suppliers uses a license based pricing system where the number of supported readers decides the price of the middleware. The middleware in its standard form which

[77]Price based on exchange rate 2009-11-02: 1€=10.8 SEK
[78] Ibid.

supports the use of up to five readers has a list price of approximately 2,800€[79] and a version that supports up to 20 readers has a list price of approximately 9,300€[80].

4.11 Compilation of customer demands

In general, requirements for labels are composed when the first customer order is placed. If there are no specific requirements at this point of time, SWEPs standard labels will be used. These requirements not only regard the silver label but also pallet label and packaging lists in order to facilitate efficient handling of the products at the customer sites. Customer support is handling non standardised solutions that a customer might require. In order to keep track of the different requirements, a cross reference between SWEP's article number and the customer number is created. Customer support also deals with special labels for occasional customer orders, but the design and integration with the business system of these labels are the responsibility of the product management department.

The customer demands are gathered from interviews and a survey with the sales department at SWEP as well as from requirement specification documents sent from customers to SWEP. The survey conducted with the sales department showed that there was a difference related to what customer the sales person represented; the representatives for smaller customers generally experienced no, or a limited set of customer specific demands, while the representatives for larger customers experienced more customer specific demands. These demands were generally the same as those revealed during interviews with the reference group. One whish that was not revealed by the reference group was that one customer wanted to know what place in the stack a certain heat exchanger was placed during the brazing process.

Some customers require barcodes to be of the symbology Code 128, SWEP currently uses Code 39 which is the most commonly used symbology in industry at present. Code 128 is however becoming more and more common.

[79] Price based on exchange rate 2009-11-02: 1€=10.8 SEK
[80] Ibid.

4.11.1 Product marking (Silver label)

The heat exchangers of E-type are currently not being marked with serial numbers; they are only marked with batch numbers. One of SWEP's largest customers requires individual marking with serial number on these exchangers and this imposes problems since these exchangers do not have cover plates to which labels can be attached or serial number can be printed. The customer would also prefer the use of 2D data matrixes. The manual labour associated with attaching the labels on these exchangers along with the technology to produce the labels is estimated to result in a price increase of 3-4%, an increase that the customer might be reluctant to pay.

The same customer has, at another production site instead asked for labelling, containing a five digit supplier code followed by month and year, in the format SSSSSMMMYY where S represents the supplier code, M the month in abbreviated English and Y the year.

Some customers have asked for having their own serial number in a barcode format on the silver label. Some customers would prefer that the barcode on the silver label was in a 2D format but do not say that it is necessary. At least one customer wants the barcode on the silver label to be preambled with a DI.

SKA customers often demand their own logotype to be printed on the silver label.

Those exchangers that are to be used in marine solutions must be approved by an external inspector. SWEP does not have the right to carry out these inspections and will not acquire such rights since the volumes are too small to rectify the investment required.

There is an idea of testing lower pressure heat exchangers with air instead of helium in order to keep costs at a lower level. These exchangers can then only be approved for a lower maximal work pressure than the helium tested ones. This lower pressure needs to be stated on the silver label.

4.11.2 Transportation marking

Some customers require SWEP to provide an additional information sheet along with pallets as the pallet label is not sufficient. On this extra sheet more and more customers want SWEP to preamble the barcodes. Presently SWEP supplies the extra sheet of information but do not preamble any barcodes on this sheet. One reason for not implementing prefixes in their information system is that making such a system adaptable for different customer demands would be too expensive, because of this SWEP has requested information on standard prefixes used in industry. All customer demands that SWEP has received where specific prefixes has been requested have been compliant with the ANSI standard for prefixes except that some have requested the prefix be printed in the plaintext.

Some customers also request that SWEP provides each pallet with a list of all serial numbers of the components in the pallet. The numbers are to be in a barcode format and some customers want the barcodes to be preambled with DIs. Currently SWEP provides the list for the customers that want it, but SWEP does not preamble any barcodes.

These demands might not seem very complicated, however to demonstrate the complexity they introduce we will show two examples differing widely. The examples are from two of SWEP's major customers.

Customer 1's requirements (see Figure 21) state that the transport label shall contain the following, DI within parenthesis:

- **Part number (P)** Code for identifying the parts on the pallet assigned by the customer
- **Quantity (Q)** amount of items on pallet
- **Supplier (V)** The supplier number assigned by the customer (SWEP can have different supplier numbers for different customers)
- **Pack slip number (2K)** Number that identifies a container (e.g. a pallet) in a shipment consisting of one or more containers.
- **PO number (K)** Purchase order number assigned by customer
- **Ship Date** the date the shipment is sent, shall be in plaintext without DI

General demands:

- Barcodes in format Code 39
- Except where stated otherwise, all fields containing barcodes shall contain the appropriate DI both in the coded format and in the plaintext

- The order/placement of the fields is not fix

This label is a part of a larger label also containing address and contact information for both supplier and customer.

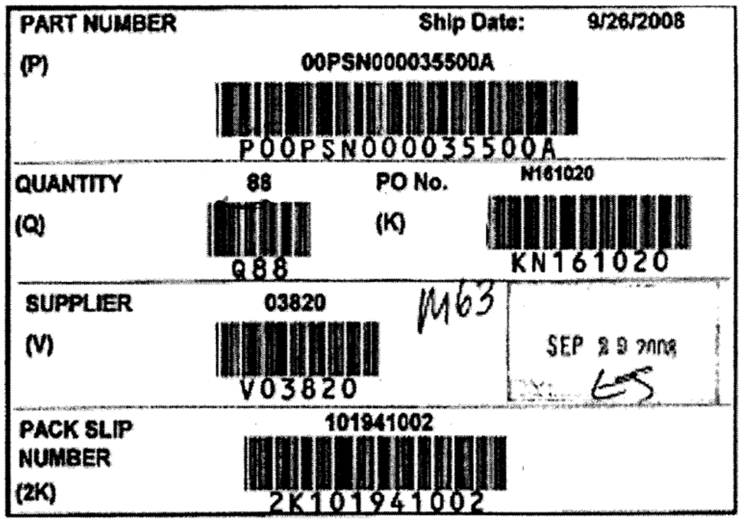

Figure 21 Customer 1's requirement for transport label

Customer 2's requirements (see Figure 22) state that the transport label shall contain the following, DI within parenthesis:

- **Part number (P)** Code for identifying the parts on the pallet assigned by the customer
- **Quantity (Q)** amount of items on pallet
- **Supplier (V)** The supplier number assigned by the customer (SWEP can have different supplier numbers for different customers)
- **Serial number (S)** Pallet identification assigned by SWEP, cannot be reused within a year
- **PO number (K)** Purchase order number assigned by customer
- **Release id (5K)** Shipments reference number assigned by customer, used among other things in the customer's ERP system
- **Required delivery date** in plaintext without DI

General demands:

- Barcodes in format Code 128
- All fields containing barcodes shall contain the appropriate DI in the coded format only
- The order/placement of the fields for part number, quantity, supplier and serial number are fixed the other fields are not fixed
- The 2D barcode is in Data Matrix format and contains a copy of all the information on the label

Figure 22 Customer 2's requirement for transport label

5 Data analysis

In this chapter we analyse traceability and quality in the production, as well as possible ways of meeting customer requirements on both item level and transportation level marking.

5.1 Production

Below work methods and the use of marking technologies are analysed in the production from a traceability and quality perspective. Each subchapter will begin with an illustration showing where in the production process the discussion is most relevant.

5.1.1 Metal coils

This subchapter will discuss the metal coils used in plate pressing, as illustrated in Figure 23. The chapter will mainly discuss the steel coils however the points made can be extended to include other material types such as titanium.

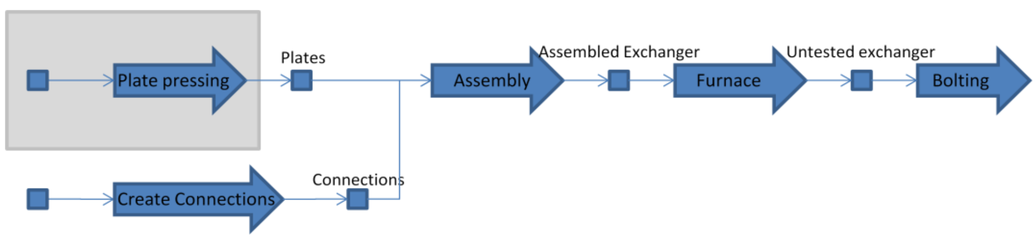

Figure 23 Section of the production where the steel coil discussion is most relevant marked in grey

The steel coils that constitute the raw material for the steel plates in the heat exchangers are delivered by large suppliers that use a process oriented manufacturing system. As we see it, this has two consequences for SWEP; firstly SWEP's negotiation power towards its steel suppliers is limited and secondly it is hard for the suppliers to offer non standardised alternatives, such as customer specific marking. This discussion is also supported by several members of the reference group at SWEP. This means that if we are to recommend a solution including a specific marking of the steel coils that can be used to limit the problem of mixing steel types, this kind of marking must likely be carried out by SWEP rather than SWEP's suppliers. SWEP has at an earlier stage tried to get customer specific marking of the steel coils, as described in the data gathering part, but the suppliers have not been able to meet those requests.

SWEP's only requirement regarding the serial number marked on the steel coil is that SWEP should be able to use it when contacting the steel supplier if a material fault is discovered. The supplier should then be able to use this serial number for traceability purpose. SWEP currently marks the steel coils at the goods reception with an internal label containing a material number used by SWEP.

We see four alternatives for limiting the risk of using the wrong type of steel in production, these are:

1. Use the barcode on the internal label to automatically compare the information regarding steel type with the intended product data provided by the work order.
2. Colour code the steel coils in order to simplify manual and visual control of the steel type.
3. Place an RFID tag on the steel coil to automatically compare the steel type information with the work order.
4. At the production line, verify the actual steel type using a spectrometer instead of relying on the information provided by the material label.

Prior to a steel coil is used in the production line the operator scans the barcode so that a relation between the steel coil's serial number and the heat exchangers batch number is created.

Alternative 1 could mean that every time a product configuration or a steel coil is changed, the barcode on the steel coil is read, either by the operator or a fix reader that is places appropriate, and the steel type is then compared with the product data (not done at present).

Alternative 2 means that the material label would be printed in a specified colour or that a separate coloured label is used. At present, incoming material is marked with not only the material label but also with a coloured label stating if the material is ok or not. If a green label is used then the material is ok to use in production, but if a red label is used this means that a material fault has been discovered and that the material is to be sent back to the supplier. Therefore one could use for instance a blue colour to indicate that the steel is of 316 type. This alternative does not improve the traceability or eliminate the risk of marking the material wrong, but it might help the operator to verify and notice the steel type. If the label is placed so that it does not need to be removed prior to using the steel coil in the production line the label can be reused together with the steel coil. One possible way of achieving this is to place the label inside the steel coil while letting a bit of the label stick out.

Alternative 3 would mean that the tag could be automatically read by a RFID reader to compare the steel type with the product configuration. If requested, it would be possible to read the tag every time a channel plate was cut, making it unnecessary to store information about which steel type is currently used in the line. There is a risk that a tag cannot be placed on the steel coil without breaking and there still exist some technical difficulties when reading RFID tags that are close to metal, although special tags designed for use with metal exists.

A possible problem with alternatives 1, 2 and 3 is that one cannot be more sure about the steel type than one is that the marking is correct. If the marking is wrong, then the wrong steel type will be used. Alternative 4 means checking the steel type rather than the label. It is not possible to separate the steel types by using a scale to weigh the plates since 304 and 316 steel has similar density, so a spectrometer is currently used when a suspicion of mixed steel types is introduced. The downside is that a spectrometer is expensive and with ten production lines just in the production site situated in Landskrona, the cost makes this an unrealistic alternative. If SWEP mistrusts the marking of one of its suppliers, a centrally placed spectrometer could be used.

A common challenge for alternatives 1, 3 and 4 is that the production line needs information about the product configuration in order to automatically compare the steel type with the one in the product configuration. The system needs to be flexible in the sense that you need to be able to change the work order before or even during a production run.

A possible idea to circumvent this need of system integration would be to use a barcode on the work order to represent the requested steel type, and simply have an algorithm that verifies that the current steel type matches the type stated in the work order. This idea introduces a risk of wrongful handling and the operator will have to read two barcodes.

Alternative 2 introduces some extra work in the material receiving process that probably involves a risk of marking wrong, and the alternative does not automatically block other mistakes further down the production line, but it will probably prevent some mistakes since the operator gets another way of distinguish between steel types.

Alternative 3 firstly requires that a RFID tag can be placed in a way so that it will not be damaged. The alternative also introduces some extra work in the material receiving process and might create a need for additional system integration between the production line and the ERP system. The tag itself could be read several times during the production process and it could be reused.

5.1.2 Marking of individual channel plates

This subchapter will discuss the part of the production process illustrated by Figure 24.

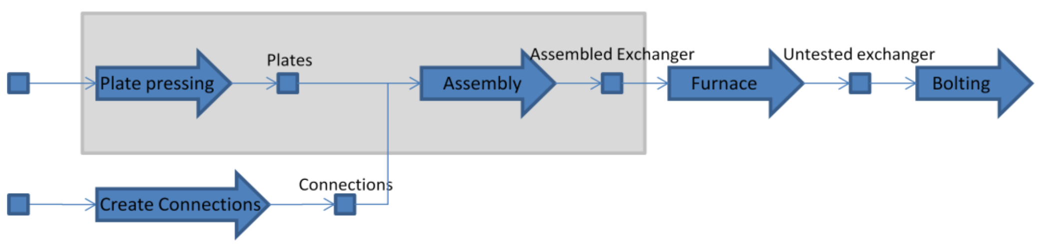

Figure 24 Illustration of where the discussion regarding individual plates is most relevant

In chapter 4.5.1 we discuss two problems that occur when assembly of the channel plates is carried out. One of the problems is that asymmetrical plates are not rotated in the correct manner, and the other problem is that the exchanger is assembled with an incorrect number of plates. Within SWEP there have been several suggestions to mark each plate individually, there are however differences of opinion regarding the purpose and expected results of such action. During our thesis work SWEP decided to implement one such solution in a test line in Landskrona, and our reasoning will touch both upon the tested method and other possibilities. The actual marking will be performed in the press line between the cutting and the pressing of the plates, the result of this is that any “loose” or unassembled plates will have some kind of marking.

As people have different expectations on individual marking there are different demands on the design of the marking. One desired design contains the work order number (w/o) of the plate in order to increase the traceability in production; another design contains marking of the steel type. SWEP also wants to reduce the number of incorrectly assembled heat exchangers either by making assembly easier for the person doing it or by validating that the assembly is correct.

We would argue that having the w/o will not increase traceability as the w/o specifies the batch and cutting and pressing of the plates is done batch by batch. To increase the traceability compared to the present level, SWEP would have to mark the plates with the individual serial numbers of the exchanger. The serial numbers used by SWEP consists of thirteen characters however at the production site that has the longest available time for marking there is only enough time to print ten characters.

Marking a plate with its supposed steel type will not reduce errors, the steel type is determined when the coil is mounted in the press line and without confirming this, any marking on the plates will only display the desired type of steel and not the actual one. Such action might cause a false sense of security.

Errors should be eliminated at its source or as close to the source as possible, therefore marking the plates to the benefit of the person assembling a heat exchanger is something we consider to be positive. If there is a wish for a computerised validation of the assembly it should be done as close to the assembly as possible so that the error can be corrected with minimal cost. If the error is detected after the exchanger is brazed the entire exchanger and all work done with it will be wasted.

5.1.2.1 Method

Marking individual plates with labels or RFID tags is not possible partially due to the relative size of the marking compared to the plate, and partially due to the low value of a plate compared to a RFID tag or even a label. Therefore there are three available ways of marking the plates:

- Ink jet
- Laser
- Engraving

SWEP ruled out ink as this leaves contaminating particles in the furnace; SWEP also ruled out engraving as this might cause leaks as well as damage the surface of the metal which in turn can lead to corrosion of the heat exchanger. This leaves laser marking, which additionally will be legible after the heat exchanger has been brazed unlike marking made by ink jet.

5.1.2.2 Symbology

In the press line with the most time for marking there is enough time to print ten characters, the fastest line press plates more than twice as fast so in order to use the same solution at all production sites and all lines no more than four characters should be used when marking the plates. There is also a risk that SWEP updates their production equipment during the printing equipments expected lifetime. Due to this and the discussion above we will mainly discuss solutions using only one character to avoid making marking of plates a bottle-neck.

Having a clear visual indication regarding the orientation of an asymmetrical plate might help the person assembling the heat exchangers in his or her work. We cannot find any indications on how such marking should be designed except that it should be distinct and consistently placed in the same position on plates of similar types. If computerized control of the correctness of assembly is desired, a vision system can be used. By vision system we refer to a type of image recognition software designed to look for specific patterns in an image. We advocate first evaluating the change of the work by the assemblers before investigating possible gains with further error detection. Whether or not a vision system is implemented some marking must be used because systems able to detect the number of plates without marking are unreliable, and the rotation of the plates cannot be seen without some marking when the exchanger is assembled.

Using a vertical line on the side of the plate would for correctly assembled asymmetrical heat exchangers form two dashed lines, one on either side of the exchanger. It is generally difficult to adjust a vision system so that it reliably can detect the length of a line or gap, which would be required for it to detect one improperly rotated plate resulting in one line being longer than the others. When the plates are assembled they overlap one another and this overlap can vary slightly. To handle this, the tolerance of the vision system must be fairly generous; this is one of the reasons that the length of a line will be hard to reliably asses in production. If the heat exchanger is of a symmetrical design several lines can align without implying an improperly assembled exchanger, in this case the vision system is likely to be unreliable for calculating the number of plates.

The plates can also be marked with a horizontal line; the number of plates can then easily be calculated as long as an entire line is not covered by the plate overlap. However to verify the rotation of asymmetrical plates the vision system will need to separate between long and short distances.

A combination of the two above, in other words a plus sign or similar can be used both for verifying the number, by counting the horizontal lines, and the rotation of plates, by looking for two horizontal lines connected by a vertical line (see Figure 25).

Besides using a vision system, weighing or measuring the height of an assembled exchanger can be used to confirm that the correct number of plates is used. We believe, without having testing it, this method to be more reliable and easier to maintain than a vision system solution.

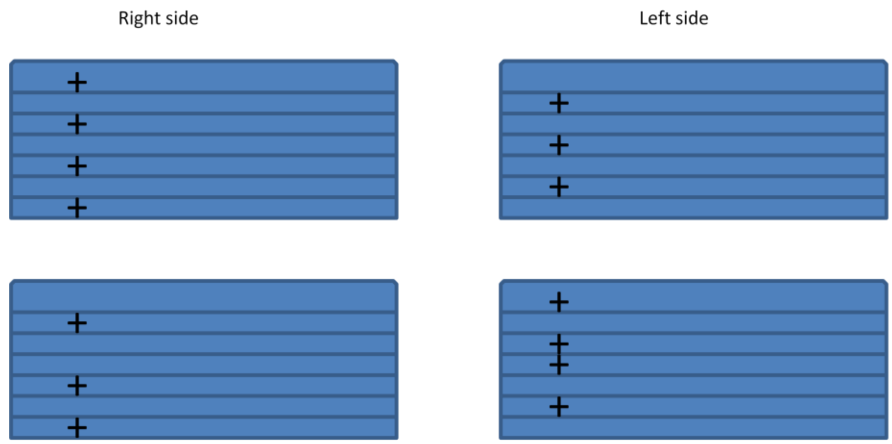

Figure 25: Above a correctly assembled asymmetrical heat exchanger, below an incorrectly assembled asymmetrical heat exchanger

5.1.3 Connections

This subchapter will discuss the part of the production process illustrated by Figure 26.

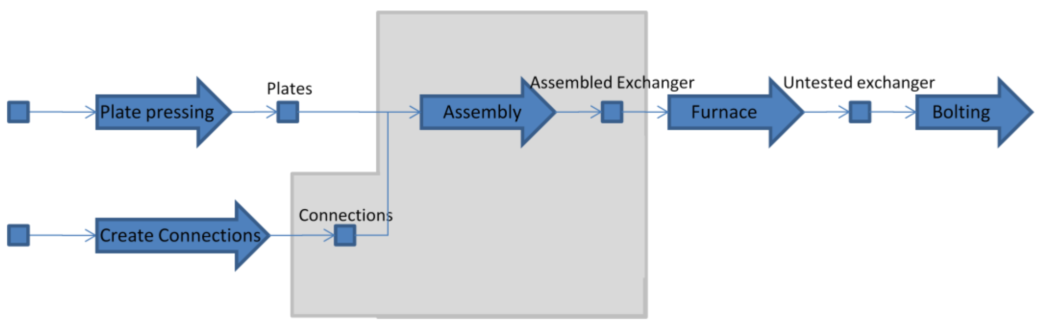

Figure 26 Illustration of where the discussion regarding connections is most relevant

The connections of the heat exchangers lie in boxes next to the assembly station. Many of the boxes contain connections that cannot be distinguished with the naked eye. For instance the inner diameter of a connection can differ by as little as one millimetre. One of the problems that arises is that the assembler might take a connection from the wrong box. Another problem can be caused by the assembler needing to return a connection for some reason, and by mistake puts it in the wrong box. If this is not discovered the assembler will assume all connections in that box are as labelled on the box. The exchanger where the connection of the wrong type is assembled will have to be scrapped.

To verify correct assembly by measuring the properties of the connections is not a reasonable solution, first relevant measures needs to be found, and second all connections must be verified individually, preferably with as little risk of human errors as possible. Pre-brazing verification will likely end up more expensive than scrapping products that fails during testing.

One solution that has been used in several Swedish car manufacturing plants[81] is to separate the process of picking components from assembling them. This method would minimize unnecessary material at the workstation. If the person picking the components makes a mistake there is a risk for the whole batch to get the wrong connections, but with suitable procedures, such as separating similar types of connections, this risk can be minimized. If a configuration has two different but similar connections there is also a risk that these connections can be mixed when assembled, this also is a factor that can be handled with proper procedures.

As the connections will be brazed the only viable part marking method is laser marking, using the same reasoning as in 5.1.2.1. Theoretically using laser marking it would be possible to mark all types of connections with a model number. If this number is printed on the label on the box containing the connections as well as the connections an extra opportunity of verification of proper labelling arises, allowing for the removal of misplaced connections. In reality this solution is unreasonable due to the low value of individual connections.

5.1.4 Use of RFID throughout production

Below follows a discussion about the usability of RFID on item level throughout SWEP's production process. Firstly a compilation of general pros and cons associated with RFID is listed.

[81] (Engström, Jonsson, & Medbo, 1998)

Pros

- Can be read at a distance and is not dependent on free line of sight.
- Large data storing capacity.
- Re-writable tags exist.
- Easy to automate readings.
- The tags can be reused in specific processes.
- Can possibly be used to read an amount of tags within a short time frame.
- Fast readings, especially for greater amounts of data, compared to barcodes.

Cons

- Price of a single tag.
- The investment cost for readers and system integration.
- The technology is still new, reading and writing problems can occur.
- Problems with the reading and the writing of tags that are attached to specific materials, such as metal.
- Tags might be damaged easier than a barcode.

The use of RFID with steel coils has been discussed under heading 5.1.1. After the cutting and pressing process there is no use of RFID since the marking needs to be removed before the bracing process. A RFID tag does not survive the heat needed in the bracing process and the reason why it needs to be removed is related to contamination of the furnace.

After the bracing process the internal white label could be replaced with a smart label containing an RFID tag. If the heat exchanger will be bolted the information stored on the tag could be used to see how this should be done without the need for a connection to the ERP system. Since the operator at present has access to this information we cannot see how the use of RFID could create significant advantages.

The next step in the production process is the testing of the heat exchanger and as with the bolting process the information stored directly in the tag could be used and simplify the necessary adjustments of the test equipment. The advantage of faster reading of and RFID tag compared to a traditional barcode would probably not be significant since every single heat exchanger needs to be placed by hand in the testing equipment. If an RFID tag would be used, there would be a possibility to save test data directly to the tag.

If the silver label would contain an RFID tag this could be beneficial when the exchangers are to be packed and shipped to customer. Instead of reading the exchangers manually one by one as is the case when using barcodes, the exchangers could possibly be read automatically. The tag could also be used to verify that the pallet contains the correct heat exchangers and that the heat exchangers have been approved after testing. One problem with this scenario is that the exchangers are made of metal and, when placed close together might introduce disturbances to the radio signal.

If SWEP had an aftermarket in the form of service, RFID could potentially be advantageous since the service personnel could get all relevant information directly from the RFID tag placed within the silver label. This means that the service personnel would not need to be connected to SWEP's internal computer systems.

5.1.4.1 Pallet with RFID tag

One idea is to use RFID to mark the pallets that are used within a production site. If this tag was of read many/write many type it could contain information about the contents of the pallet and along with strategically placed readers one could track the movement of the pallet within the site. Then RFID could be used to reach a better understanding of the use of resources and resource planning. Since RFID could be read automatically, the extra work introduced could be kept at a minimum. Another possible effect of RFID integrated with pallets is that a higher certainty of that the correct pallet is moved could be achieved.

5.2 Transportation level marking

Below follows an analysis of different solutions for transport level markings including labels, RFID and EDI. The solutions are based on industry standards.

5.2.1 Comparison of standards

In Table 1 we have made a comparison between the demands on transportation marking from the two customers presented in 4.11.2 with the standards found. These customers represent two examples of sets of demands but are among the most demanding customers that SWEP has.

The demand of customer 1 that DIs are to be written in plaintext does not comply with regards to ANSI MH10.8.2 and will therefore not be covered by any label standard relying on this document. The OTL1 label is widely used in the automotive industry but it lacks the possibilities to use more modern symbologies such as Code 128 and Data Matrix. The more modern GTL label has these features but lacks the support of linear barcodes in addition to the license plate barcode.

The flexibility of AIAG's B-10 label allows it to accommodate all the demands of both customers except the on the points of DIs in plaintext, and the barcode symbology (Code 39) in customer 1's demands. The downside of this standard is that it will place some demands on SWEP's business system Avanté that this system is unlikely to support. Also this solution will require some time for customising the label, to a limited extent, for some customers when first used. It will also require some time to make sure that the set-up SWEP chooses as standard (to use when no demands are specified) works for as many of the customers as possible. However quite a few of the customers currently do not support the newer Code 128 symbology.

			OTL1	GTL	SWEP current
Both customers	Barcode	Part NO (P)	x		
		Quantity (Q)	x		
		Supplier (V)	x		
		PO NO (K)	x		
	Plaintext	Date	x	x	x
		Ship To	x	x	x
		Ship From	x	x	
		DI in barcode	x	x	
Customer 1		DI in text			
		Code 39	x		x
	Barcode	Pack slip NO (2K)			
Customer 2	Barcode	Serial number (S)	x		x
		Release NO (5K)	x		
		Code 128		x	
		Customer 2 order			
		2D barcode		x	

Table 1 Comparison between customer demand and industry standards

5.2.2 Suggested solutions relying on B-10 guideline

One goal when it comes to transportation marking is to limit the number of different labels as much as possible while at the same time conforming to as many customer demands as possible. A good part of the customers are not presently ready to change barcode symbology from Code 39, but at the same time an increasing number of customers request the use of Code 128 instead. Thus SWEP needs to consider offering a choice between these two symbologies, creating (at least) two different solutions. Later in this chapter we will present the size limitations of labels and barcodes, these calculations will be done with Code 39. As Code 128 is denser any solution that works with Code 39 will also work with Code 128.

SWEP has a large group of customers that are not in the forefront of technology and may not be able to accept too advanced solutions, but are satisfied with the current one. Because of this it may be suitable to keep offering the current pallet label and in some sense be backwards compatible.

OTL1 and GTL do not support all the data required by both example customers mentioned in 4.11.2. Whether or not it is possible to create one label adhering to the AIAG guidelines, and conforming to as many customer demands as possible but no less than the ones by the example customers, will be seen in the paragraphs below.

The first problem is that these customers require different symbologies. AIAG support both these symbologies so it is possible for SWEP to offer both alternatives with an otherwise unchanged label layout, given that a solution can be found for Code 39.

The most common demands are:

- Part number (P)
- Quantity (Q)
- Supplier (V)
- Serial number (S)
- PO number (K)
- Release id (5K) or Pack slip number (2K)
- Date
- Data Matrix

- Address field
- Type of label

On their current label SWEP uses a customer number that would have the prefix 9V if DIs were used; this number however is redundant as SWEP can retrieve this information by using the pallet serial number. This is why the customer number is not prioritized in our solution.

The order of the first four demands in the list above must be fix to be in accordance with the AIAG guidelines and customer 2's demand. AIAG also demands that the label type is printed in plaintext to differentiate between loads that are mixed or consisting of several containers etc. The date is one of three types, production date, shipping date or delivery due date. The address field is required by the transportation companies.

The requirement that the DIs are to be in the plaintext as well as in the barcodes is not in accordance with the AIAG reliance on ASC MH10.8.2 and will be omitted. However as the DIs are written under the title of each block customer 1 is expected to accept this. Release id (5K) has a similar function to Pack slip number (2K) and we consider it unlikely that a customer requests both these fields on the same label (currently there are no such requests).

The current SWEP pallet label is printed in an A6 format which is close to 4*6 inches, a common format. AIAG recommends that the label is divided in rows one inch high, with max one double row two inches high. AIAG states that the smallest accepted x-dimension is 0.01 inch and the smallest accepted difference in width of narrow and wide elements of Code 39 bars is 2.8, a comparatively strict requirement. The length of a barcode can be calculated as in Equation 1.

$$(C + di + ss) \cdot (3 \cdot r \cdot x + 6 \cdot x) + (C + di + 1) \cdot x + 2 \cdot M$$

Equation 1 Length of Code 39 barcode

In Equation 1 C is the number of characters used for data, di the number of characters used in the DI and ss the number of start and stop characters, in other words two. This first parenthesis contains the total number of characters in the barcode. In the next parenthesis the length of each character is calculated, r equals the ratio between wide and narrow elements and x is the x-dimension. The last parenthesis gives the number of spaces between each character. The equation is ended with M, AIAG's required margin (the quiet zone).

Table 2 contains the different fields, the number of characters is chosen as the maximum numbers this field may contain if such number exists, otherwise the longest found requirement. This column includes the number of characters used for DI and start and stop characters.

	Total number of characters	**X-dimension**	**Wide / narrow ratio**	**Margin both sides**	**Length**
		0.01	2.8	0.5	
P	18	0.01	2.8	0.5	3.262
Q	7	0.01	2.8	0.5	1.568
V	9	0.01	2.8	0.5	1.876
S	13	0.01	2.8	0.5	2.492
K	10	0.01	2.8	0.5	2.03
5K/2K	22	0.01	2.8	0.5	3.878

Table 2 Compilation of data for the corresponding field

Using a rectangular label it can be oriented either in a standing (width 4' height 6') or lying (width 6' height 4') manner. Using Code 39 and a lying layout we started with the address field and the mandatory barcodes, P, Q, V, S, see Figure 27. It becomes clear that this label cannot fit both the Data Matrix that requires a double row, and the 5K/2K field that requires a block 3.9 inches wide.

Figure 27 Lying transport label with Code 39 barcodes

With the standing layout we proceeded in a similar fashion and the result can be seen in Figure 28, what is not included and do not fit is the date and label type.

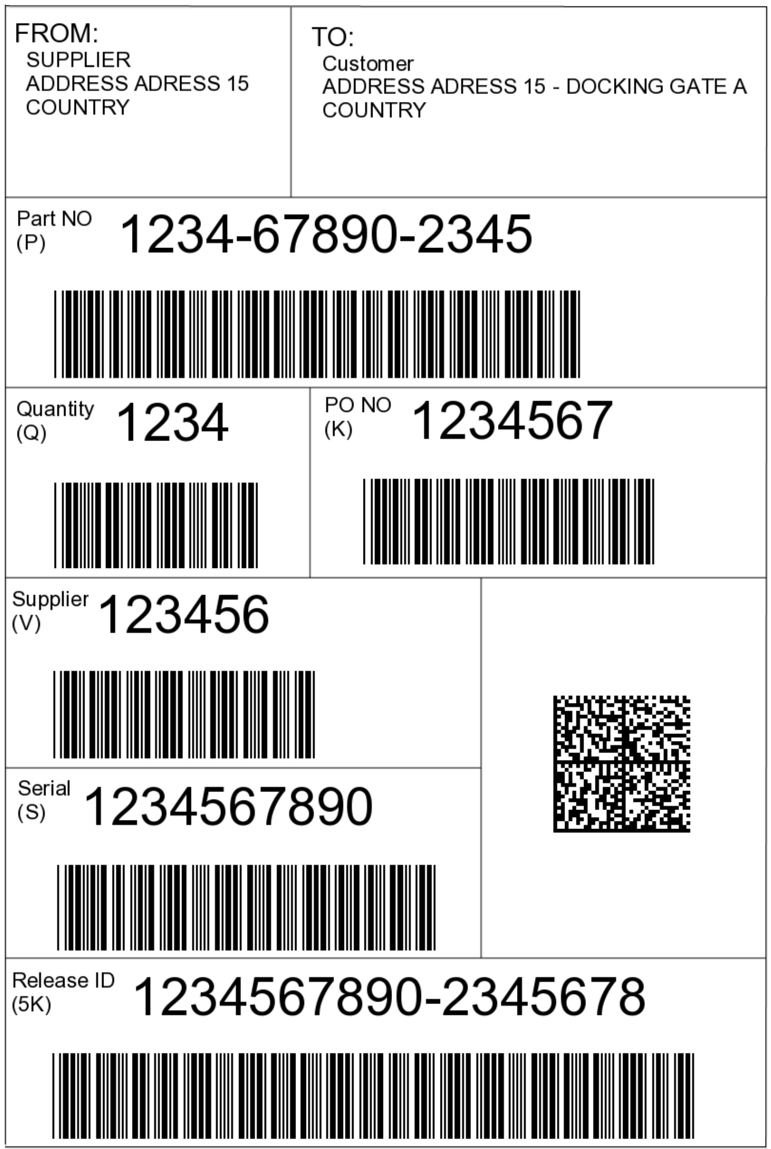

Figure 28 Standing transport label with Code 39 barcodes and a Data Matrix

It seems hard to fit all the necessary information in a 4 by 6 inch label using Code 39 format and we therefore investigated the use of a larger label. Our solution is based on combining the present pallet label with the required new information. This results in a label that is backwards compatible so that it still can be used by the customers not demanding the new information. This will result in that the information of the pallet identification number will occur on two places; firstly on the present label part without DI and secondly on the new information part containing DIs.

Since the requirement of the order of the first four blocks remains, there exist a limited number of alternative layouts. The standing layout does not work well if it is to be combined with the present label of lying layout, seeFigure 29 . It is possible to change the orientation of the present label but we do not see obvious benefits by doing this.

Figure 29 Standing layout combined with present transport label

The lying layout combination is shown in Figure 30. In this layout the demands are met. In this layout the maximum number of characters for the corresponding block can be (total length including start and stop characters and DI):

- Part number (P) – 22 characters
- Quantity (Q) – 7 characters
- Supplier (V) – 10 characters
- Serial number (S) – 13 characters
- PO number (K) – 12 characters
- Release id (5K) or Pack slip number (2K) or another customer defined field and DI – 25 characters
- In this layout the shipment weight (2Q) block was also included – 8 characters, this block is demanded by others than the example customers

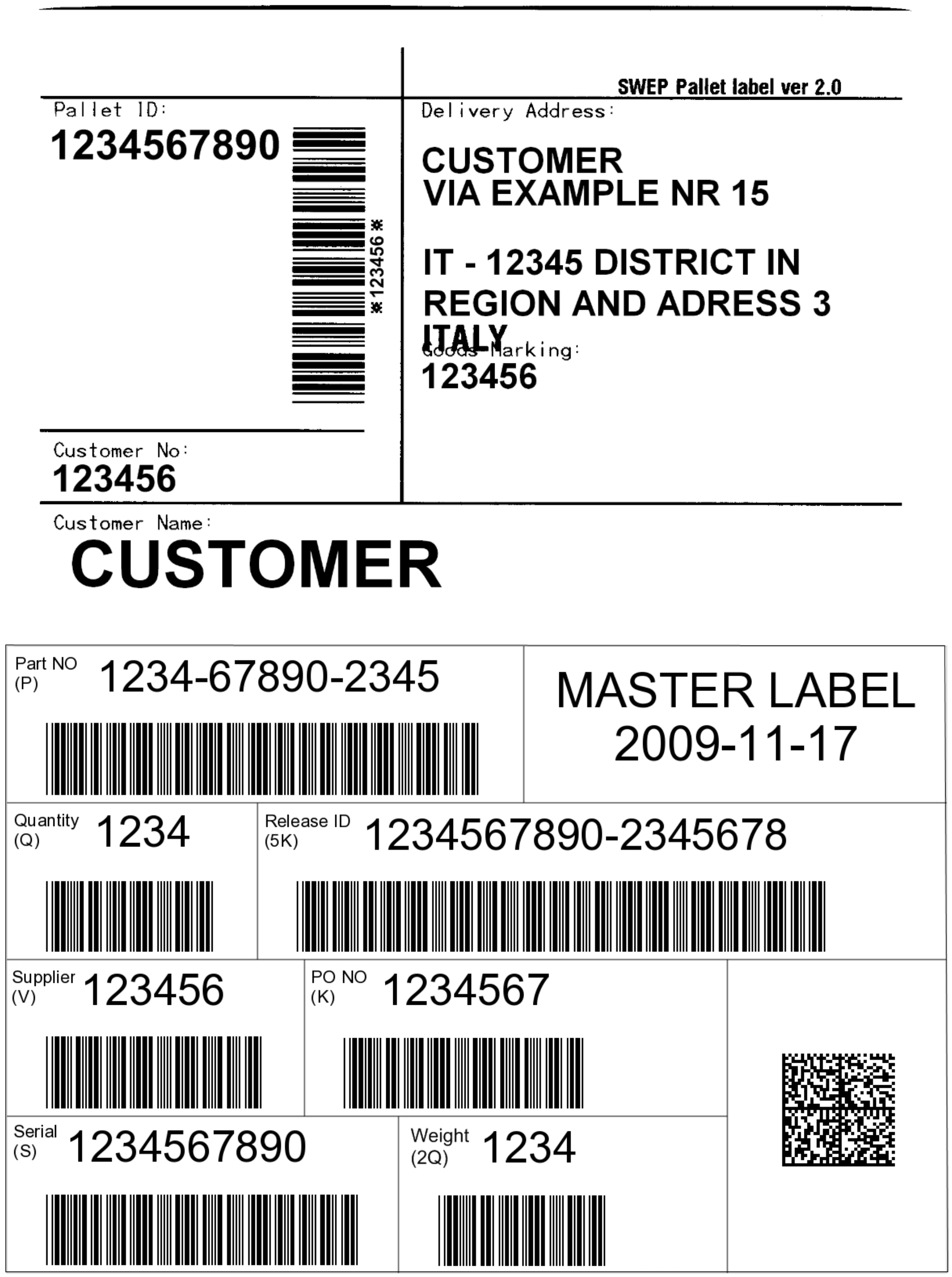

Figure 30 Lying layout combined with present transport label

The blocks of the barcode part of this label can be seen in Figure 31, the width of the block is shown in the bottom right corner of the corresponding block.

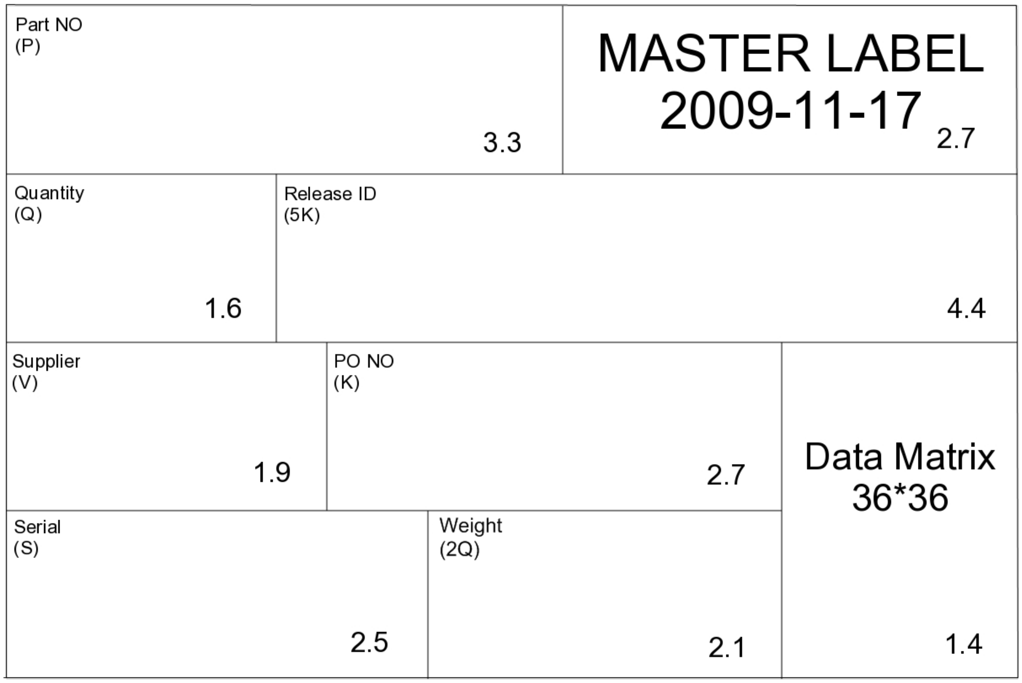

Figure 31 The blocks of the lying label

In this layout the Data Matrix consists of 36 rows and 36 columns which results in a storage capacity of 127 alphanumeric characters. The total number of characters in the linear barcodes is 99 and the date will require eight characters which results in a total of 107 characters.

5.2.3 Pallet with EDI combination

At present the serial numbers of the individual heat exchangers are recorded when placed on a pallet prior to shipping. This creates a relation so that SWEP knows which exchangers a certain pallet holds. Some customers have requested a list containing all serial numbers on the pallet, so that when they receive the pallet they only need to scan this list. A problem is that this is not a standardised extra label so customers may require different types of information, such as their internal product number.

To solve the problem of having a potentially high amount of combinations an electronic system could be used, see Figure 32. The basic idea is that the information required in plaintext and a pallet identifier is all that is needed to handle a pallet. When the pallet arrives at the corresponding location at the customer site, all the customer needs to know is the unique identifier for the pallet, all other information can be sent electronically. This is an idea that is supported by Odette and AIAG, the GTL label and the B-10 label supports the use of a so called license plate that uniquely identifies a pallet and the excess information can be sent by EDI.

When the individual exchangers are scanned prior to shipping this could be registered in a database at SWEP. Since SWEP knows who the customer for a certain pallet is, the customer can be granted access to the information related to their pallets. As long as the database contains enough data about the shipment and the heat exchangers, this solution can be made standardised but still flexible to different customer demands. The fields in the database can remain the same for all customers, if certain data does not exist for a certain heat exchanger model it can simply be left blank, or the software can deny access to that field. The customer can then choose what information is relevant for them, and where the information is to be stored. There can be a field with for instance a product code defined by the customer, since SWEP has a customer number for every variation this number can be related to SWEP's customer number.

From the customer perspective this solution can speed up the receiving process, since they only need to scan one barcode and the excess information can be copied into their business system automatically. The risk of scanning a barcode into the wrong data field will be eliminated, without the use of prefixes which are needed if several barcodes are to be used.

The downside is that a middleware that can translate a standard EDI message into a specific business system is needed. This is why we think it is important for SWEP to rely on a standard such as the ANSI X.12. If SWEP would use its own solution the idea will probably be hard to sell to the customer since the customer uses products from a variety of suppliers. The upside is that the EDI standard is widely used, especially for transmitting information used when shipping goods.

Another critical factor is the uptime of the database and the connection to it. In order to be able to provide data within an acceptable timeslot the system probably needs to be redundant.

SWEP's customers are not in the front when it comes to using IT and electronic systems such as EDI which means that there are currently few requirements regarding this, but for SWEP to be proactive, the possibilities of future technologies needs to be kept in mind.

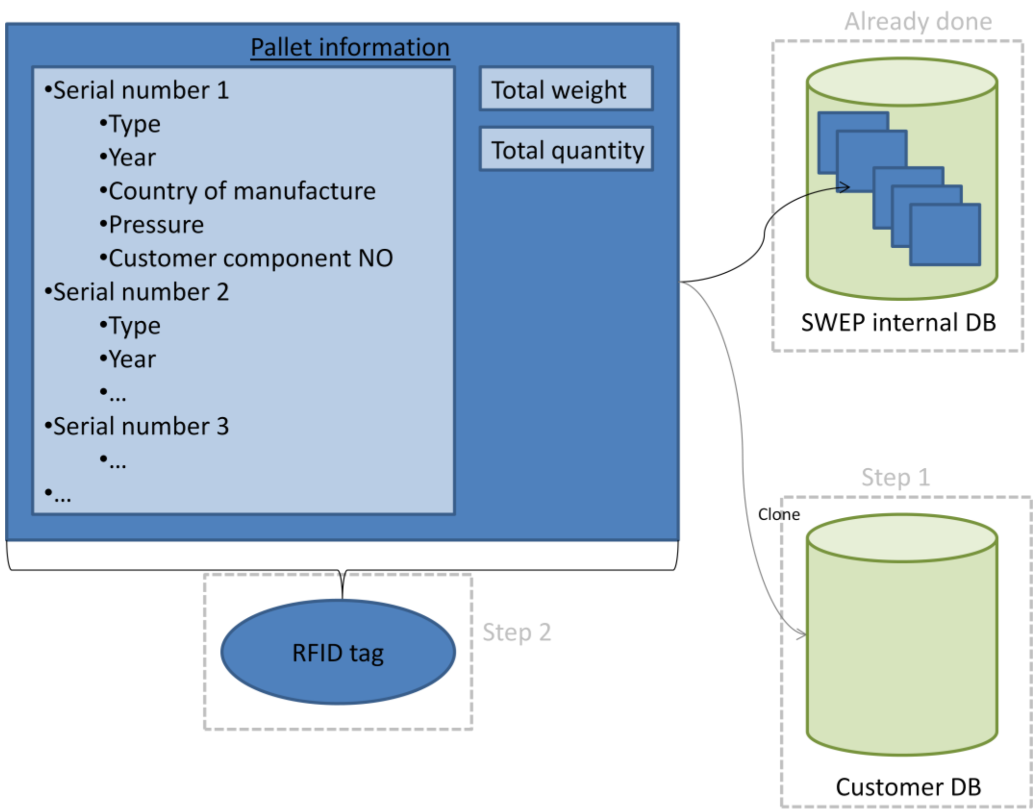

Figure 32 Pallet label in combination with EDI

5.3 Item level marking

SWEP's customers have, as discussed in 4.11.1, various requests regarding the silver label that is used for item level marking of the heat exchangers. The requests include additional information, such as customer specific information represented by a barcode on the silver label that is presently not supported. If the same silver label layout is to be used on all exchanger types (that are currently being marked with the label) the silver label cannot be made larger since the smaller heat exchangers will not have sufficient room for the label. SWEP is also reluctant to making the font of the plaintext as well as the margins on the silver label smaller since it is important to keep the readability at a high level.

At present the heat exchanger‘s serial number is represented in barcode using the Code 39 symbology. More modern symbologies such as the Data matrix symbology can be made denser so that space can be freed that can be used for other purposes.

Since the physical size of the silver label, the amount of plaintext, the font of the plaintext and the margins should not be altered the factors remaining that can be altered is the auto readable information and the graphical contents. It is hard to meet the customer request regarding specific information in a barcode format just by adding an additional barcode due to size limitations. If two barcodes are to be used on the same label there is also a need for data identifiers in order to minimize the risk of scanning the wrong barcode, this means that the customer needs to be able to handle these data identifiers.

If the size of the graphical contents could be reduced slightly a relative small Data Matrix could be placed on the silver label and it could hold information such as the serial number. The AIAG guideline recommends a x-dimension between 0.01-0.017 inches (0,25-0,43 mm). If the x-dimension is lower than 0.013 inches special care regarding readers and writers must be taken. For this reason we have chosen to let the x-dimension be 0.13 inches. In a square Data Matrix symbol consisting of 16 rows and columns, 16 alphanumeric characters can be represented. This means that SWEP's serial number consisting of 13 numbers along with the appropriate DI (S) can be represented in the symbol. One side of this symbol has the size:

$$16 \cdot 0.013\, inch = 0.208\, inch \approx 5.28\, mm$$

The recommended quiet zone is 1-1.5 times the x-dimension:

$$1.5 \cdot 0.013\, inch = 0.0195\, inch\ \approx 0.5\, mm$$

It might make sense to create a layout that can support a larger Data Matrix so that it is possible to store more data, such as customer specific information. If the symbol's side scan be made twice as large, 32 rows and columns it can hold 91 alphanumeric characters. In Figure 33 this is shown and the difference between the densities of the two marking technologies can be clearly seen, the data matrix can hold up to 91 alpha numeric characters and the traditional barcode only holds 13 characters. The Data Matrix is constructed by four 16*16 matrixes.

Figure 33 Silver label with Data Matrix (32*32) holding up to 91 alphanumeric characters

All customers do not presently request the Data Matrix format, but in combination with a traditional barcode SWEP could let the customer use the linear barcode for the customer information. The idea is that SWEP could use the Data Matrix for their internal purposes, and the customer could use the traditional barcode for their needs. If the customer requests the use of Data Matrix, the customer information can be added to the Data Matrix. At present a customer can have specific information, such as a customer item number, written in plaintext on the silver label. Since SWEP does not want to increase the number of silver label configurations it might be necessary to limit the information in the barcode to the information already written in plaintext.

Another possibility that arises when using the Data Matrix is that the symbol can be engraved directly on the cover plate of the heat exchanger. This requires that the engraving is carried out by a machine rather than by hand. Whether or not a Data Matrix is engraved, the use of a machine can minimize the risk of engraving the wrong serial number if the number to be engraved is sent to the machine without human interference. We do not see significant benefits of engraving a Data Matrix compared to engraving the serial number in plaintext, except that a Data matrix does not need as large physical space as plaintext does. If SWEP for some reason wants to engrave more information than the serial number on the heat exchanger then a Data Matrix can be beneficial, but since the Data Matrix can be placed on the silver label these benefits are limited. A somewhat distant problem when using a Data Matrix instead of plaintext is that the symbology used by SWEP can be changed during a heat exchangers life time, therefore SWEP still needs to be able to interpret the old symbology.

At present the silver labels are handled by using fix configurations for different silver label types. The varying customer and third party demands has contributed to the vast number of configurations that presently exists. One alternative is to create a more dynamic silver label by using data fields. If the label is divided into fields that can contain varying information SWEP could define these fields with regards to customer and third party demands. Instead of creating a new configuration a label could be created by defining the contents of the fields. This information could be tied to the customer and heat exchanger type as is done presently, by using information such as customer number, country and heat exchanger type. If the customer requests information in barcode format a function for selecting which information to be coded can be implemented. This alternative way of creating silver labels could reduce the amount of configurations, but it is associated with much implementation work. Therefore it is probably not possible to change the current business system to support the alternative, but it can be kept in mind when it is time for replacing the current business system.

We have not received any customer requests regarding use of RFID on item level and as discussed in 5.1.4 we do not see substantial benefits for SWEP that would justify the investment. If customer demands regarding RFID is placed in the future, the additional cost probably needs to be covered to a large extent by increased price.

5.4 Economical analysis of RFID

As the prices of RFID equipment indicates, it is a quite large investment to introduce the use of RFID throughout a production site. It is important that this investment shows a reasonable payback time in order to justify the costs involved. As described earlier we have found little use for RFID in SWEP's production process and this indicates that there are not enough possibilities for efficiency improvements in the production that will lead to the reasonable payback time. Since SWEP does not have an aftermarket there is no significant cost savings that can be made in this area. This means that SWEP needs to be able to charge their customers extra if they are to implement RFID, which in turn means that SWEP's customer needs to perceive added value through RFID labelling of their received products. We have found no present customer requirements regarding RFID which means that at present time, it is hard to justify the introduction of RFID.

The price of a single tag that can be applied to metal makes it difficult to place RFID tags on item level for the smaller heat exchangers. It is also for the smaller heat exchangers which are produced in higher volumes the possibility of automatically reading and writing operations has the greatest impact from an efficiency point of view.

During recent years the production of tags has been made more efficient which has had an impact on price levels. Theory indicates that this price trend will continue which will make tags cheaper. The various performances related to RFID technology will likely become higher. This might make the technology interesting for SWEP in the future.

6 Results and Discussion

Here we present the results of this work by relating back to the four main questions from the problem description (see 1.4). We also discuss the work in general, thoughts that arose during the work and the result.

6.1 Results

Are there standards for marking available that could help SWEP improve its marking offerings and cover the majority of customer requests?

There are standards for labels, barcode symbologies, and prefixes available at present. The two most common standards for prefixes are Data Identifiers, mostly used in industrial contexts, and Article Identifiers, mostly used in retail contexts. The standards for marking we chose to investigate, that used prefixes have relied on DIs, and all customer demands regarding prefixes has been in accordance with the DI standard.

With regards to symbologies, there are two main groupings that we have observed, linear barcodes and two dimensional barcodes. Code 39 is still the most commonly used symbology for linear barcodes however this symbology is, by many companies, being replaced by Code 128. In regards to two dimensional symbologies Data Matrix is the most common in Europe and Asia, and PDF417 is dominant in North America.

Several industries have developed their own transportation marking standards but as the purpose has been to limit the number of solutions, we have only investigated those not in direct opposition to any customer demands. For instance as all demands on prefixes has been in accordance with the ANSI DIs all label solutions using GS1 AIs has been disregarded. Some customers demanded a solution in accordance to AIAG's B10 standard and we investigated whether or not a single B10 label could fit all demands. We found that because there are different demands regarding the linear symbologies this was not the case, and as a result we designed two labels with identical layouts but different symbologies, where one field was customer defined. We expect this label to satisfy most demands on the transportation marking. The solution can be seen in Figure 30, the field titled Release ID (5K) represents the customer defined information. We also suggest that SWEP offers to preamble the list of serial numbers sometimes requested with prefixes.

The problem regarding the silver label is the amount of information sometimes requires. We recommend that SWEP puts as much as possible of the information that SWEP requires, in a compact electronically readable format such as Data Matrix. SWEP should leave the plaintext areas to the information that must be in this form, either due to third party approval organization or customer demands. For the benefit of the customers that have requested a linear barcode with information specified by themselves, we suggest that SWEP leaves the linear barcode for this purpose, and sets a maximum number of characters that the customer can specify. If SWEP changes the symbology of this barcode to Code 128 the maximum number of characters can be increased.

How can SWEP improve material tracing with the use of modern identification technologies?

The solutions that can be provided when using RFID can to a certain extent be provided by other less advanced methods such as barcodes. Due to the relatively short production process together with the low value of the heat exchanger components, we have not found costs savings and production improvements that justify the investment required for introducing RFID. Since we have not found any customer requirements regarding RFID it is hard to justify an increase in product price due to RFID marking. Possible advantages for RFID are mainly introduced if RFID is used on item level for heat exchangers produced in high volumes. However, the advantages that have been found are limited for SWEP since the heat exchanger in practice needs to be brazed before this type of marking can be attached. The limited after market in terms of service decreases the need for storing large amount of information directly on the heat exchanger (through the use of a RFID tag).

Marking of individual channel plates has been discussed and our recommendation is to use a simple marking that can assist the operator when assembling the heat exchanger. Markings such as the steel type do not improve the traceability since the marking does not guarantee that the correct steel type was actually used. If the plates would be marked with the corresponding heat exchanger serial number this would be advantageous since this would provide a possibility to relate a loose channel plate to the corresponding heat exchanger. However such marking is not attractive since it would create a bottle neck in the production process.

There exist a number of methods that does not use advanced technology that could be used in order to increase the production efficiency. These methods, such as colour coding of the steel coils, does not provide a higher level of traceability or a guarantee that the heat exchanger corresponds to its specifications, but can limit the risk of using the wrong material type.

We have seen examples from other industries[82] where the process of picking components has been separated from the assembling process and this could be used by SWEP for handling components such as the connections.

What are real customer needs and what is considered added value?

This question has to be answered individually for each customer as it may vary widely. The answer can also vary from different production sites belonging to the same customers. We were not able to answer this question as our contact with the customers was limited. The intention was to use the questionnaire in 8.3 to get these answers for key customers, but interest from them regarding our thesis has been low. We have gathered information on customer requirements via requirement specifications sent to SWEP as well as information from personnel at SWEP. Using literature and experience from tutors and the reference group, have tried to understand background of the customer demands.

What do SWEP's suppliers offer in terms of marking of incoming goods?

Currently SWEP's suppliers only mark their products using labels with barcodes. These labels can to some extent be adapted to customer needs even by the larger suppliers. The smaller suppliers, dependant on SWEP, currently marks according to requirements. The most important requirement from SWEP is a unique identity, which is met at present. We have found no steel coil supplier that currently offers RFID marking of their products.

6.2 Discussion

One of the major problems during the course of the work with this master thesis was communication with SWEP's customers. The goal throughout the work has been to

[82] (Engström, Jonsson, & Medbo, 1998)

interview the customers to better understand the background to their demands, and so be able to suggest alternatives that solve the same underlying problems but that is easier for SWEP to implement. We did not want to initiate this contact too early, in order for us to better grasp the problem SWEP was facing, and hence structure the interview in a better way as well as choose more suitable and relevant questions. The problem that arose was that from the time we initiated our contact with the customers till the time, two months later, when we were finishing the thesis, the only customers that had even bothered to answer, either answered that they did not have time to answer our questions, or they just wanted to know if SWEP could and would conform to their requirements. It is quite possible that many customers reasoned that as students we had little influence at SWEP, and therefore we were not worth the time. Possibly this type of contact needs to be maintained by representatives that work at SWEP, and preferably have some authority. The questions we intended to ask can be found in 8.3.

In the thesis we suggested that a flexible solution for labels should be developed where the customers are able to specify the contents of several parts of the label, this however is not supported by the current business system. When SWEP eventually choose to update or acquire a new business system it is worth considering the strategic consequences of this choice. SWEP has by their method of production chosen to be a flexible company adapting to customer demands, and producing short series of many different configurations to attract customers wanting this type of service. It is important that SWEP follows through with their strategy throughout the entire company including customer relations and marking of products and shipments. If this is difficult to achieve with the current tools, it is suitable to consider alternatives when these tools are to be updated.

Many of the solutions suggested solve the problem by supplying all customers with the information any customer require, instead of just supplying the relevant information for the particular customer. If a system designed to support adaptability to this type of demands were to be used, SWEP could supply only the requested information.

In hind sight we can claim that this assignment was too big for two persons to complete in 20 weeks as originally planned. The two most time demanding parts were to understand the problem, and the relevant technologies, standards and industry organizations that were a part of our analysis. We would have loved to do the planned interviews with the customers in order to be able to do a deeper analysis, but this would likely have come at the expense of one of the other areas. At the same time we were not able to specify delimitations at an early stage as this assignment require knowledge in both SWEP's production, as well as the requirements from the customers.

SWEP should continue to communicate with the customers regarding the underlying causes for their demands; however this is something we believe should be done by an employee at SWEP, not a student doing a maser thesis.

In the analysis we discussed that there were different demands and expectations regarding the marking of channel plates, the cause of this is that different production sites' development departments have tackled the problem in different ways, and have different part-solutions. As none of these departments produced a complete solution the development was moved to Landskrona. This made us wonder about the pros and cons of a decentralized R&D and how to tackle the organizational problems that arise. This is in part relevant for this master thesis work, but it was not possible to understand during our limited time, and could possibly be a suggestion for a future master thesis work.

A perspective that has been mentioned but not thoroughly analysed is the environmental perspective where additional marking at product level could ease the recycling process of exchangers which has served its time. This is probably an area that can be widened to include other products than heat exchangers and might be an interesting field to investigate.

6.3 Recommendations

Based on our analysis we can give the following recommendations:

- Produce a transportation label relying on the B10 standard, and consider using both this and the old transportation label together
- Allow customers to choose either Code 39 or Code 128 symbology
- Allow customers to freely specify the contents of at least on field on the B10 label

- Add a Data Matrix on the silver label, allow the customers to specify the contents of the linear barcode
- Do not use RFID in production or transportation but pay attention to customer demands for RFID
- Mark channel plates in order to make assembly easier, and thus reduce the risk of human errors
- Evaluate the possibilities of separating picking of connections from the assembly

7 References

In this chapter the references for the thesis work is outlined.

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7.1 Interviews and surveys

SWEP International

- David Persson
- Staffan Selander
- Ronnie Olsson
- Lennie Liegnell
- Rickard Thorsell
- Katarina Andersson
- Anna Nava
- Thomas Davidsson
- Thomas Öhman
- Gunilla Öberg
- Tobias Petersson
- Olof Jepson
- Fredrik Gyllander
- Johan Landé
- Johan Rissler
- Jonas Hansson
- Pär Björkman
- Richard Thorssell
- Rikard Johansson
- Shwan Lamei
- Thorbjörn Wilén

Odette Sweden

- Sten Lindgren

Consafe Logistics

- Mats Kronblad

7.2 Pictures

8 Appendix A: Interview and survey guides

Here we list the interview guides used in corresponding interviews, actual questions deviated as we adapted the questions to the answers of previous questions.

8.1 Reference group

A selection of questions we are looking to answer is:

- What information is used in you part of the supply chain and how is this information coded and related to a physical product?
- From which systems do you collect information?
- Which are the demands on marking and traceability presented by previous and following links in the supply chain and what are you current routines in this regard?
- Are there any problems related to marking and traceability at present time?
- Do you see any future requirements or requests?

8.2 Sales department

We hope you have the time to answer the following questions. If you have any specifications from customers including their requirements of marking, we would be happy if you could attach it to your reply.

- What kind of customers do you work with, mainly large or small ones?
- What is your customer's geographical location?
- What type of customers do you manage, SKA, HUB or e-business?

We are trying to compile a list of customer demands regarding marking, and we have found out that common requirements for silver labels are the customers own logotype and the logotype of CE or other approvals.

Do you experience other requirements, regarding:

The silver label (for instance bar code or human readable information)?

- The pallet label?
- Other type of marking on the BPHE (engraving etc.)?
- Anything else?
- Are there any present requests regarding other marking technologies, such as Data matrix or RFID?
- What future requests do you see?
- Do you see present or future requests regarding individual marking of E-type exchangers?
- Do you see any requirements from customers concerning traceability that is not met today?
- Do you know any case where SWEP has lost a customer to a competitor because of marking or traceability reasons, and if, why?

Is there any other information, not covered by the questions above that could be relevant?

8.3 Customers

- Could you please describe how the information attached to the pallet/product is used in your arrival process?
- Is the same standard regarding marking used at all your productions sites? If not, is there an ongoing/future project for creating a standard?
- Are you currently using any industry standard, issued by a third party organisation, towards your other suppliers or customers and, if yes, which?
- Are you at present using any type of technology for transferring product information electronically, such as EDI or RFID? If not, do you see a future need?

8.4 Suppliers

- Are you currently supporting the automotive industry's standard for marking of material, such as Odette?
- 2. If you support the Odette standard, which if any of their labels are you presently supplying SWEP with on metal coils?
- 3. Do you have other layouts on labels or other types of marking, such as RFID, compared to what SWEP receives today?

- If yes, what do these alternatives cost compared to SWEP's current option?

8.5 Transportation service suppliers

8.5.1 Background questions

1. What position do you have within your company?

2. How long have you worked at your company?

3. What type of customers do you serve?

8.5.2 Transportation questions

1. Which technologies are presently used, and to what extent, for:

    a. Identifying shipments both at pick-up and delivery? For example do you use a linear barcode symbology, RDFI or any other method?

    b. To track the current status of a shipment, and to communicate this status to clients/recipients? Status in this context is referred to for example position, damage, or delay.

    c. To facilitate booking of shipments?

    d. Other needs that above stated?

2. Which technologies will be used in a couple of years? Will there have been a change compared to today? What are the current buzz words?

3. Which of the technologies you mentioned in question two do your company already support?

4. Does your company currently support any of the following technologies:

    a. EDI (edifact, X.12 or other)?

    b. RFID?

    c. 2D symbologies such as Data matrix or PDF417?

5. Where and for whom do cost advantages of new technologies arise?