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Natalja Skverskaja

IMPROVEMENT OF QUALITY INSPECTION PROCESS FOR WELDED CONSTRUCTIONS IN NTM BALTIC LTD

Author applies for academic Master of Industrial Engineering and Management degree

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Author's Declaration

I have written the Master's Thesis independently.

All works and major viewpoints of the other authors, data from other sources of literature and elsewhere used for writing this paper have been referenced.

Master's Thesis is completed under .... supervision

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Supervisor …... signature.

Accepted for defence

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TUT Faculty of Mechanical Engineering

Master's Thesis task

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Student: Natalja Skverskaja, 132235 MARMM (name, code)

Field of study: Industrial Engineering and Management

Supervisor: Researcher, Tatjana Karaulova (position, name)

Consultant(s): ……………………………………………....(name, position, phone)

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(in English language) Improvement of Quality Inspection Process for Welded Constructions in NTM Baltic Ltd
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Nr	Task description	Completion date
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2	Analysis of bin lifts constructions and identification of common critical dimensions between different models	**02.03.15**
3	Description of the necessary actions to improve the quality of welded constructions	**23.03.15**
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Engineering and economic problems to be solved:
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Student Natalja Skverskaja /signature/………..…………. date…..........………

Supervisor Dr.Tatjana Karaulova /signature/ ……………….…… date…...........……

Phone ……………… E-mail: ………………………

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INTRODUCTION

Motivation

NTM Baltic Ltd (NTMB) is small developing subsidiary company of Finnish parent company NTM Ltd. To remain competitive in highly globalized market it is crucially important for the company to constantly develop quality of its products and to reduce different types of manufacturing costs. However, constantly growing volume of products with frequent changes in constructions has led to the significant production losses and delays in NTMB. The only possible way to solve these problems is to constantly improve quality control mechanism, as well as to monitor and analyze the quality affecting factors. Besides that, it is crucially important to develop relevant quality inspection documents. These documents have to include an analysis of the causes, perpetrators, ways to eliminate and prevent the failure in the future, in order to take most realistic and rational management decisions based on all available information.

A thesis presents a systematical analysis of the possible causes of a deficient output, using Cause-and-Effect diagram. Further review of company’s performance, exploring opportunities for improvement, was taken based on the most critical causes that were identified during the analysis. Two main options are considered in this work - the option of increasing stages of quality inspection and the improvement of existing ones. Therefore, third chapter is aimed at the development of regulatory documents for improved incoming, inter-operational and outgoing quality inspection. In order to make quality inspection more accurate, rapid and flexible, was developed a functional model to facilitate inspection processes.

Developed model could considerably reduce the preparation time of technological documentation for the quality inspection procedure. The model gives an opportunity to be flexibles in terms of the technical requirements. Moreover, it gives an overview of the places requiring special attention of the inspector and can be adapted to other product groups.

Objectives and tasks

The main objective of this work is to develop universal quality inspection documents, confirming the quality of the steel welded constructions in company NTM Baltic Ltd that manufactures components for refuse collection vehicles. As well as cost-effective implementation of quality inspection processes improvement. The object of study is bin lift of refuse collection vehicle- the largest and the most problematic product group. The main goal of the quality inspection documents is to reduce time for inspection and the number of defects, thereby improved quality inspection will increase productivity of the manufacturing process.

To achieve described above objective is necessary to obtain following task:

- To perform the analysis of the main factors that influence quality of steel constructions in company NTM Baltic Ltd.
- To make the analysis of the present situation regarding quality inspection processess, identifing its weaknesses .
- To offer an alternative scenario of the quality control process in order to avoid the appearance of defects in the early and intermediate stages.
- To perform the analysis of the of bin lifts construction and its possible defects
- To identify common parameters and critical dimensions of the various sub-assemblies of bin lifts that will allow to take measurement from them with less time losses, using universal quality inspection cards.
- To create a functional model of the quality inspection procedure using IDEF0 method.
- To describe the main parameters, required data and standards in the functional model, by which the quality control procedure have to be conducted,. taking into account the features of each considering bin lift.
- To develop the form of the quality inspection documents by applying the report builder.

The model is developed by applying the CASE (Computer Aided Software Engineering) system - *All Fusion Process Modeler* 7. The functional process model performs a graphical representation of the quality control procedure sequence. Common schemes for inspection were done in *Autocad Mechanical*.

1 OVERVIEW OF PRODUCTION AND QUALITY INSPECTION PROCESSES AT NTM BALTIC Ltd

1.1 Organization overview

NTM Baltic Ltd is a subsidiary company of Finnish parent company NTM Ltd. NTM Baltic Ltd was established in 1996. Starting from 2005, the company focuses on production of steel constructions. In addition, the company sells NTM products and offers their servicing for the Baltic countries and Russian market. The organisation exports about 99% of its products to Finland, where components and semi-finished products are assembled with others products that are manufactured in Finnish regions. The number of people employed at the moment is 35. From this quantity - 28 persons are production workers. The company’s process management team consists only from 7 persons: warehouse manager, production superviser/foreman, production manager, purchasing assistant, accountant, sales person and managing director. In total, the NTM Baltic Ltd produces about 20 kinds of different semi-finished products, depending on the refuse collector’s body type and chassis.

Parent company NTM was founded in 1950 by Lennart Nordin and currently has around 400 employees. It is an engineering company that develops, manufactures, sells and maintains transport equipment such as cargo bodies, trailers and refuse collection vehicles. By adopting a goal-oriented approach to product development and quality, the NTM Group has evolved into one of the biggest players in the Nordic region. The Group’s parent company is based in Närpes on the Finnish west coast, and has subsidiaries in Sweden, Estonia, the UK and Poland. The company’s success is based on three strengths: a customer-oriented approach, know-how and quality. *(NTM, 2015)*

Customer-oriented approach

Each product has to satisfy the operational requirements and special needs of the customer. This principle serves as a starting point for NTM’s activities and is the reason why all development work of each product is carried out in close collaboration with customers. The concept of customer-oriented strategy also encompasses a desire to offer the best possible level of service in relation to customer needs. *(NTM, 2015)*

Know-how

NTM’s know-how is a combination of professional knowledge, industry experience and dedication. Since its inception more than 60 years ago, NTM has gone to great lengths to stress the importance of professional know-how. This is achieved by staff continually being presented with new challenges and requirements. The company constantly develops strong team spirit. Each member of the team knows his or her roles and feels empowered to work towards achieving the company’s common objective – to develop and manufacture high quality products that are tailored to the needs of customers. *(NTM, 2015)*

Quality

NTM quality is achieved by applying a goal-oriented process that extends all the way from order to delivery. During the manufacturing process, each component or product is put through a series of rolling checks. A thorough final inspection prior to delivery to the customer concludes the process. *(NTM, 2015)*

1.2 Standards

SIS Standards

As most of NTM's staff has Swedish as their mother tongue and the most of the products goes to Sweden, the company uses mostly the SIS standards. The Swedish Standards Institute (SIS) is an independent organization, founded in 1922, with members from the private and public sector. SIS and its members develop standards within different domains, including construction, safety, healthcare, consumer products, management systems, engineering, environmental issues and safety. SIS participates in the European and global network which develops international standards. SIS is a member of the European cooperative effort CEN as well as the global ISO. First standardization was to introduce an A4 format on paper, in 1923. In the standard designation shortens Swedish standards to SS. An example of the standard designation may be the SS-EN-840. The standard number is 840 and it is a standard for waste containers, EN means that it applies in Europe and the SS that is published by the SIS. *(www.sis.se, 2015)*

EN Standards

EN standards are standards of the European Committee for Standardization, which is as the name says a committee of European standards organizations, such as for example the SIS (Swedish Standards Institute) and SFS (Finnish Standards Association). This organization affects over 460 million people. This is the standard for CE marking, CE marking does not mean that the product is made in Europe, but approved for sale in Europe. Within the construction of waste bins lifting, NTM uses standards EN-840, which is a standard for different garbage bins in Europe and the standard EN-1501 is a standard for refuse collection vehicles and their associated lifting devices.

ISO standards

NTM Ltd is certified according to ISO 9001 and 14001. The ISO 9001 and 14001 standards are so-called "Generis standards". This means that despite the fact that ISO 9001 is a quality standard and ISO 14001 is an environmental standard both can be applied to all organizations. These standards are standards that must be continuously evaluated and improved, in order to be allowed to continue as a certified company. Therefore, it forces the organization to continuous improvement. NTM Baltic as a subsidiary company does not have separate certifications.

1.3 Main product groups

NTM Baltic Ltd produce components and semi-finished products for two main product groups of parent company: 1. Bodies and trailers (Figure 1); and 2. Refuse collection vehicles. (Figure 2)

Figure 1 Main product group-Bodies and trailers

Figure 2Main product group- Refuse collection vehicles

Bodies and trailers for vehicles such as vans, insulated refrigeration and freezer trailers (FNA, FRC), flatbed, enclosed body, container and timber trailers, and equivalent superstructures. All bodies are equipped and adapted according to the specific requirements of the customer. *(NTM, 2015)*

NTM Baltic produces frames for trailers and several trailers' components for NTM.

*Refuse collectors***,** comprising a wide range of vehicles, from traditional rear loaders to side and front loaders, as well as a number of different variants and equipment alternatives, focusing particularly on units suitable for the collection of material sorted at source. These include multi-chamber vehicles, different types of bin lift and balance systems.
(NTM, 2015)

NTM's customer has the right to choose and order the chassis from any preferable manufacturer and construction of the refuse collection vehicle can be adapted to its dimensions. The type of chassis and local waste utilization requirements are the main factors of the large number of different models. NTMB produces the most of all subassemblies for refuse collection vehicle.

Roughly three quarters of NTM's total sales are occupied by the refuse collector department (Figure 3), which has grown tremendously throughout the company history. The other major part of NTM operations is the trailer business, corresponding to roughly a quarter of annual sales as of 2014.

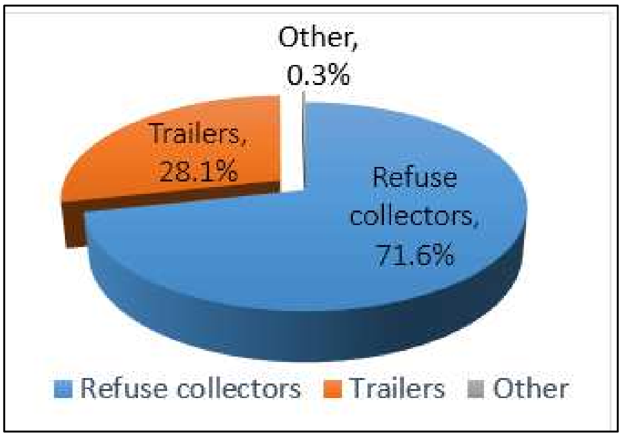


Figure 3 Distribution of main product groups

1.4 The refuse collection vehicles

Manufacturing of refuse collection vehicles at NTM began in 1975, but only some 20 trucks were manufactured in the 1970s. Because of quality problems were renewed construction with the motto "garbage trucks to grow old with dignity." The refuse collection vehicles have since been continuously renewed with electronics, hydraulics, shared lockers, front loaders, side loaders with pendulum compactor, and many more. The technology of garbage truck manufacturing continues to develop with the using of different adapters, cameras and antennas. NTM has now been primarily concerned with the development of hybrid cars. According to the EU directive the garbage trucks today are called refuse collection vehicles. *(NTM, 2015)* Today excists four maint type of refuse loading system: rear loder, side loader, front-loader and multi-chamber-loader (Figure 4)

Figure 4 Main types of refuse collection vehicles

Rear loaders as well as multi chamber refuse and recycling collection vehicles constitute the majority of the production line. During year 2014 production of rear loaders got 59% from total sales. (Figure 5)

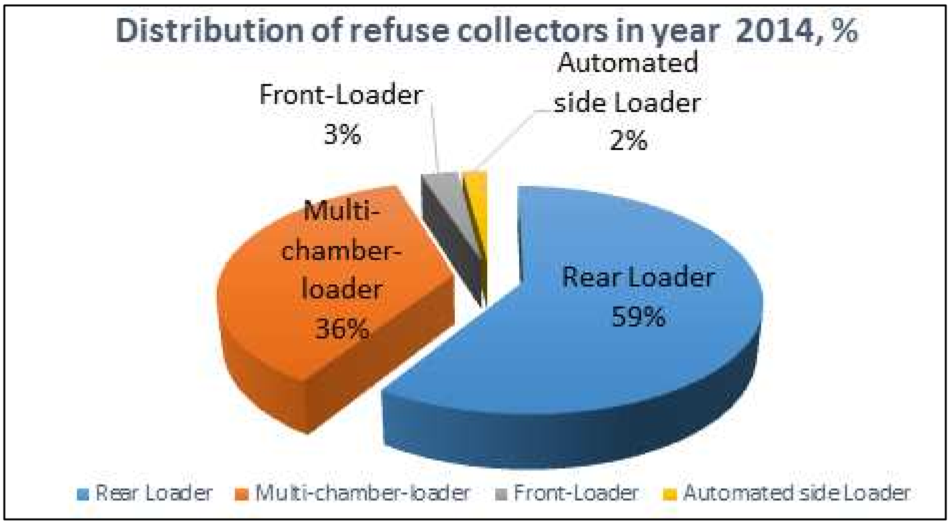


Figure 5 Distribution of refuse collection vehicles production

NTM Baltic Ltd produces 80% of the refuse collection vehicles components (mainly for rear loaders). On the picture below (Figure 6) are shown only externally visible components of the common rear-loader. Additionally, NTMB manufactures all internal components, which compress and utilize waste. The names of components are given is Swedish, as same name are in used in all production subsidiaries to eliminate misunderstandings.

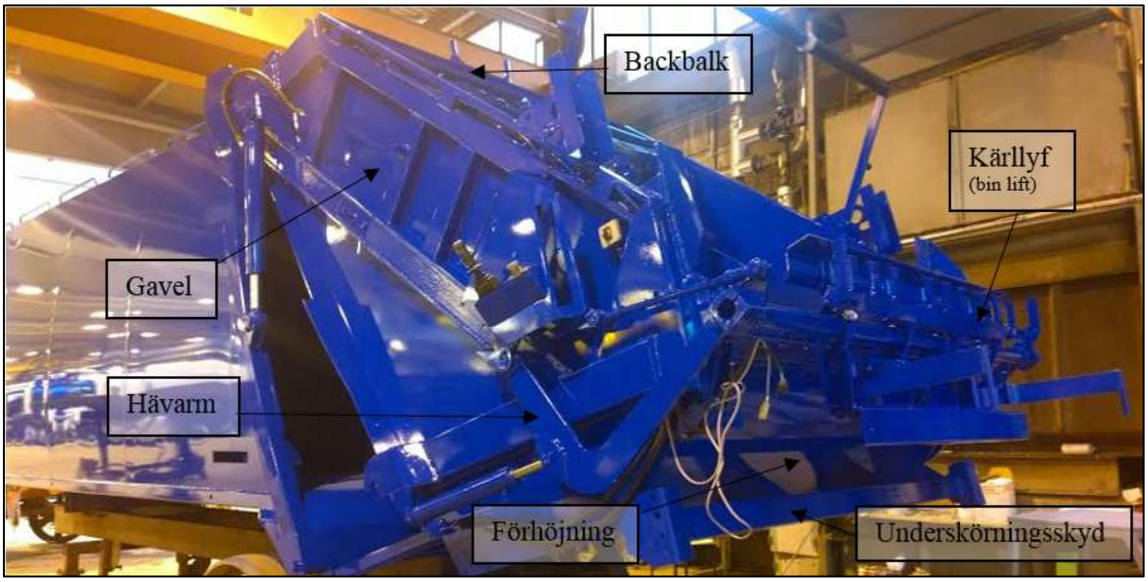


Figure 6 Picture of pre-assembled refuse collection vehicle in Närpes, Finland

NTMB has three main groups of semi-finished products and components: *Gavel, Kärllyft* and *UTP* (Figure 7), as these products are essential for the most of refuse collection vehicles.

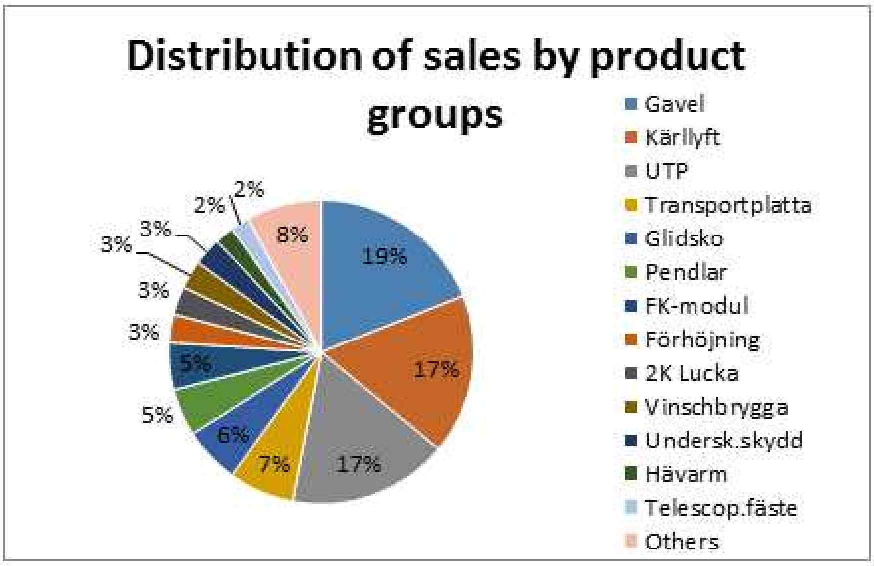


Figure 7 Distribution of sales by the product groups in NTMB

On the diagram below (Figure 8) are shown the qauntities of produced products during year 2014 and additionally are shown the amount of defected products.

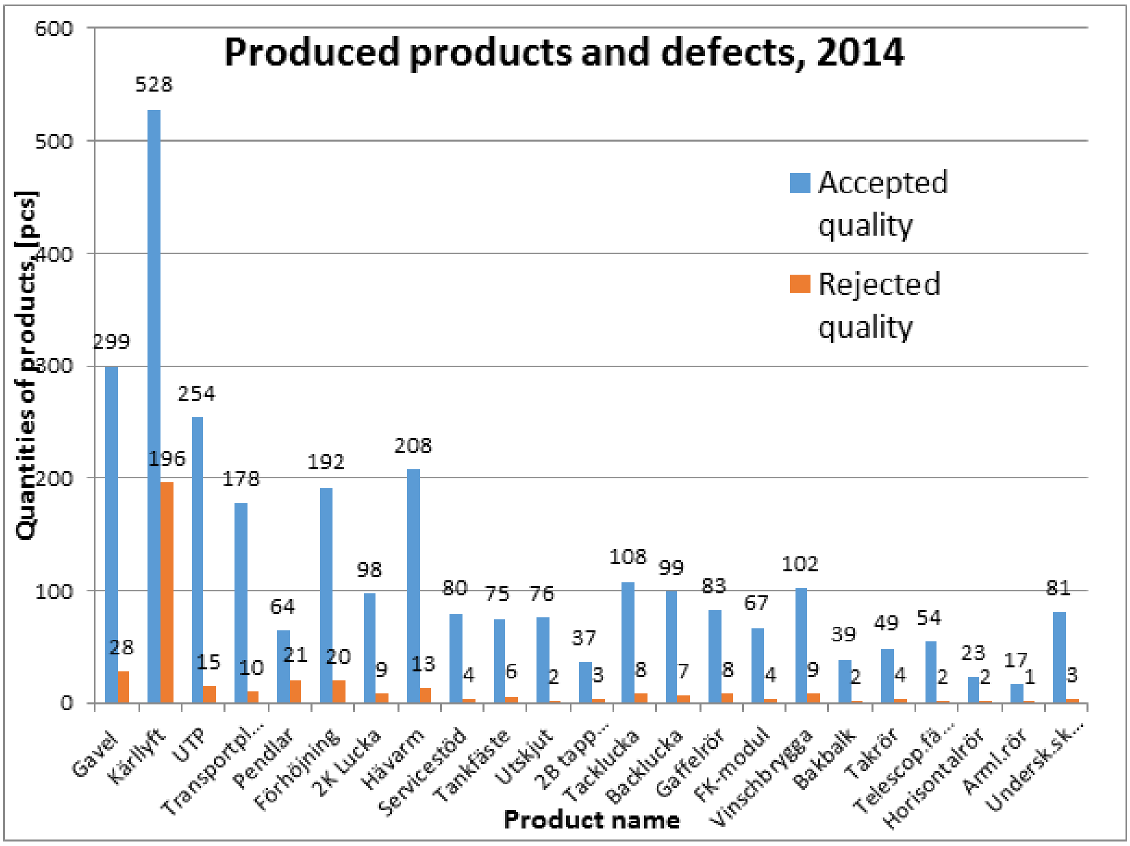


Figure 8 Chart with distribution of produced products during year 2014

As internal cost of welded metal construction at NTMB mainly consist of raw material and labor costs, the appearance of defects or scrap strongly influences the return on product. (Figure 9) All production losses related to material has to be covered by auxilirialy material costs and overhead costs. The income percentage adds by parent company and it is based on the final price of the finished product. Defects in 40 % of the bin lifts are unacceptable under severe internal production framework.

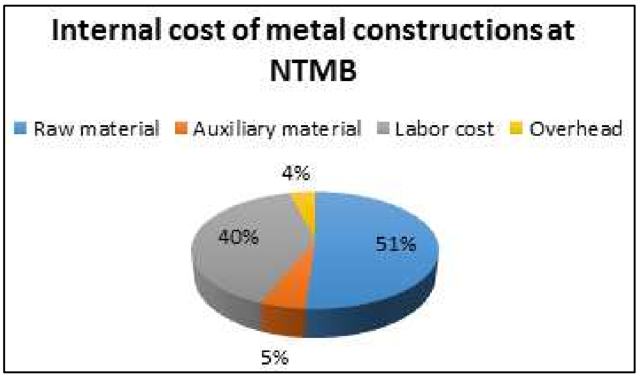


Figure 9 The percentage of the internal price-forming factors in NTMB

1.5 The object of study

This year NTM has a record number of orders for its products, due to the successfully won tenders and particularly flexibility in design, which means that production losses must be minimized. As NTM products are designed to meet custmer needs, it often results in large variery of different product types and models. Any new product is not the exact copy of the previous one, but it is similar enough with previous product from same product family in the majority of production operations. Due to the large variety of different models, the bin lift (Swedish – Kärllyft) is the most problematic group. Almost 40% of the bin lifts had different kinds of defects during last year (Figure 8). Therefore, to review company's performance and quality inspection processes are taken bin lifts, as a object of study.

Bin lift description

The objective of a waste-collection system is to transport wastes collected from specific locations, at regular intervals, to a disposal site at minimal cost. The size and type of the vehicle and the capacity of the body fitted to it, will depend on a number of factors. These factors includ road conditions, width of streets, haul distance, waste characyeristics, and method and frequency of waste collection. Additionally, the design of bi lift device depends on local regulations, governing maximum permittted gross vehicle weight and permitted or practical axle loading. *(UNCHS, 1988)*

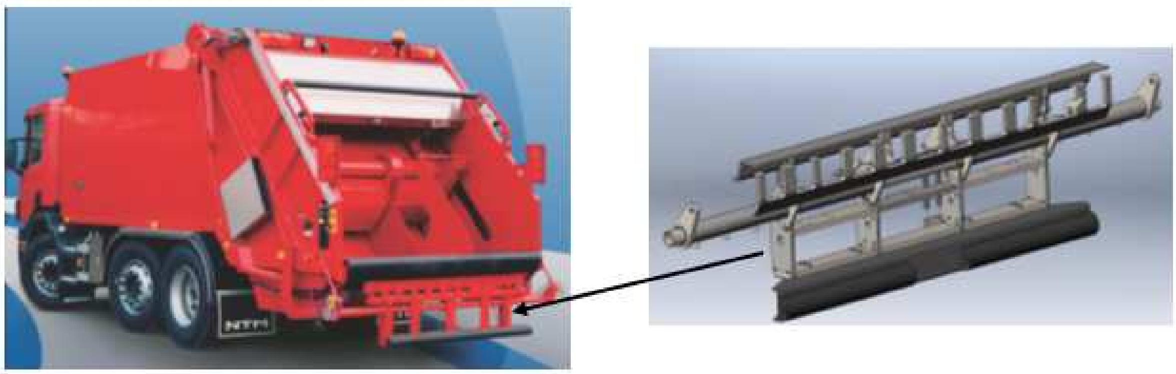


Figure 10 Bin lift device

NTM bin lifts are installed on two types of refuse collection vehicles: rear loaders and multi-chamber loaders. Working principle is same, the only difference is that multi-chamber loader is designed to completely eliminate cross-contamination. It has two separately operated bodies and tailgates which makes mixing of the two fractions impossible. The reliability is guaranteed by the simple design. A further NTM's option is to fit the bin lift device with one or several fold-down platforms for lifting of heavy refuse containers.The bin lift device grips the refuse bins from below the edge with a toothed gripping plate (comb) and lifts it. A clamping plate holds the bin against the comb blade and rotates the bin into the loading hopper and drops the refuse. The bin lift device lifts and empties wheeled bins compliant with EN 840. (Figure 11)

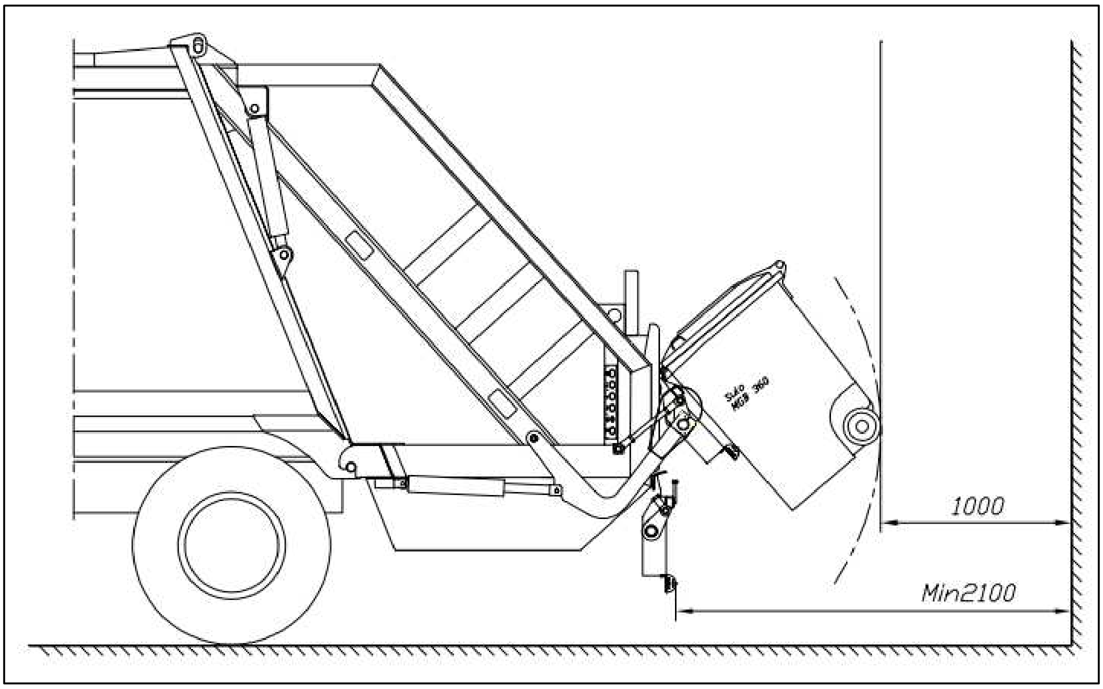


Figure 11 The bin lift device lifts and empties wheeled bins at safety distance

Overloading test for bin lifts:

The following overloading test has been performed to the bin lift:
(Bin lift's maxload = 500kg)
Static loadtest; 1,5 x 500kg = 750kg
Dynamic loadtest; 1,1 x 500kg = 550kg

Despite the fact that the lift's maximum load an other limiting properties are specified in the documentation and manual, the failures still appear. Especially when refuse vehicles are not equipped with weight cells and the driver can not accurately determine the weight of the container.

1.6 Main components of NTM bin lifts

Despite the apparent simplicity, the bin lifts are quite complex products in terms of turning, milling, as well as an assembling during welding. Assembling and welding of the products requires a large number of templates, fixtures and jigs, as each model has own individual features and strict dimensions. Especially a lot of time is spent on the production of new models.

Since the product contains various types of bushings (three-layered DEX bushings, bronze bushings), bearings (radial spherical UK20-2RS) and shafts, special attention is payed on processing and welding of the seats for them. Before dispatch all bin lift subassemblies are sand-blasted, primed and assembled. In Finland all lifts are installed on the machine, painted and performs final assembly.

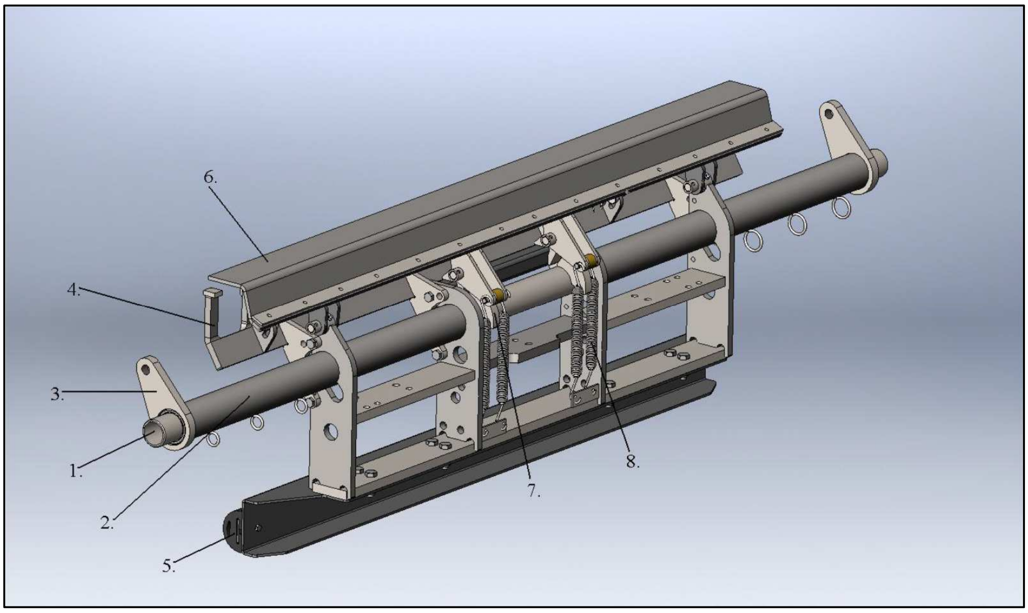


Figure 12 3D Model of Bin Lift Device (Designer- Conny Bergfors)

Main components of the most common bin lift model (Figure 12):

1. Internal frame tube
2. External frame tube
3. Mounting ear
4. Toothed gripping plate (comb)
5. Rubber D-shape protetctive plate
6. Clamping plate
7. Locking plate
8. Spring

Some components like D-shape protective plate and springs are installed on the final production stage in Finland.

For each subtype of refuse collection vehicle exist own groups of bin lifts that can be chosen by the needs of the customer. (Table1) Bin lifts also differ by regional affiliation (NTM produce special models for Poland, England, Danmark): in each country uses its own types of garbage conteinesr, despite their volume meet the European standards, the technology of their devastation can significantly vary.

Rear loader		
Subtype	**Description**	**Possible type of bin lift (drawing number)**
 K-type Rear loader  KGLS-type Rear loader  KG-type Rear loader  KGH-type Rear loader	▪ Body is optimised to chassis ▪ Extensive range (4,5 - 25m^3) ▪ Mounting height low ▪ Robust design ▪ High compaction ratio	**K-type**: 71851000, 1000063482, 71851200, 71851535, 71851580, 1000063406, 71850500, 71851300, 1000067706, 71851540, 71851585, 100019862, 71850600, 1000109862, 71850450. **KGLS/KG/KGH-type:** 1000044279, 1000042892, 1000044883, 1000044000, 1000103821, 1000055762, 1000099621, 1000100028, 1000100683, 1000033433, 1000057217, 1000063027, 1000062756, 00044284
Multi-chamber vehicles		
 FK-type  KG/KGLS-2B-type  K-2K - type  KG-2K type  OM-2K-type  QUATRO-type	▪ Maximum collection efficiency in separation at source collections ▪ Flexible solutions ▪ 2-compartment automated sideloaders ▪ 4-compartment rear loader based on the pendulum principle	**FK-type:** 71859049, 71859040, 71859025, 71859035 **KG/KGLS-2b – type:** 93968/93967, 96993/96994, 88251/88752, 58316/88752, 96451/95773, 96847/96849, 93960/93954, 91727/92171, 92367/92990 **K-2K- type :** 71852600, 71852500, 1000044127, 1000067881 **KG-2K-type:** 1000044819, 1000044885, 1000068454, 1000044853, 1000044681

Table 1 Main types of refuse collection vehicles with corresponding bin lifts

1.7 Bin lift's defects

On the pictures below (Figure 13) are shown the most common types of bin lift defects: like:

- Metal fabrication defect (**1,2**- cracks in sheet metal left by quillotine blade; **5**- cracks on outher surface of the part);
- Wrong welding or machining technology (**3,4**-concentricity faults of bushings, tubes)
- Weld imperfections (**6**,**8**-unfinished weld joint, porosity)
- Dimensional faults (**7**- wrong dimensions of the welded part)

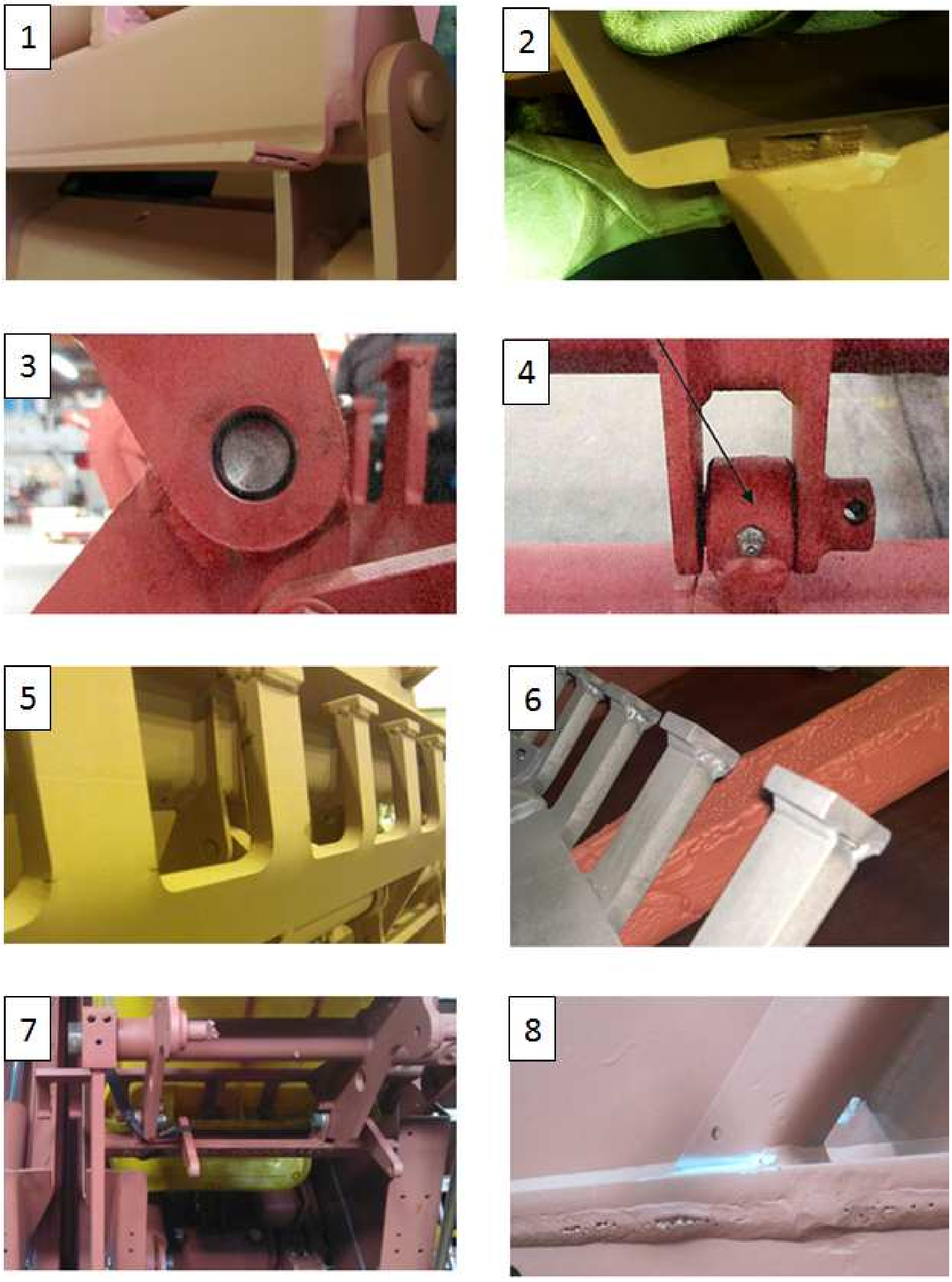


Figure 13 Different types of defects and production errors

1.8 Weaknesses of quality inspection process before improvements

Despite the fact that the finished products (refuse collection vehicle and trailers), before reaching the customer is thoroughly checked, tested and documented by quality inspectors in Finland, manufacturing defects at various stages still frequently occur by different reasons. These defects often cause delays and time losses. And one of the ways to make production process more rapid - is to monitor defects in the early stages of production with the necessary documents, and to implement quality inspection improvement, starting from receiving of raw materials and ending with inspection of assembled product before transportation to Finland. Thus, the subsidiary company NTM Baltic Ltd may significantly increase the quality of the finished products and facilitate assembling operations in parent company. Nevertheless, insufficient quality inspection process has been aggravating the situation.

Currently quality inspection is performed only on two production stages (Figure 14): during raw material and purchased components receiving and before dispatch, when products are already assembled.

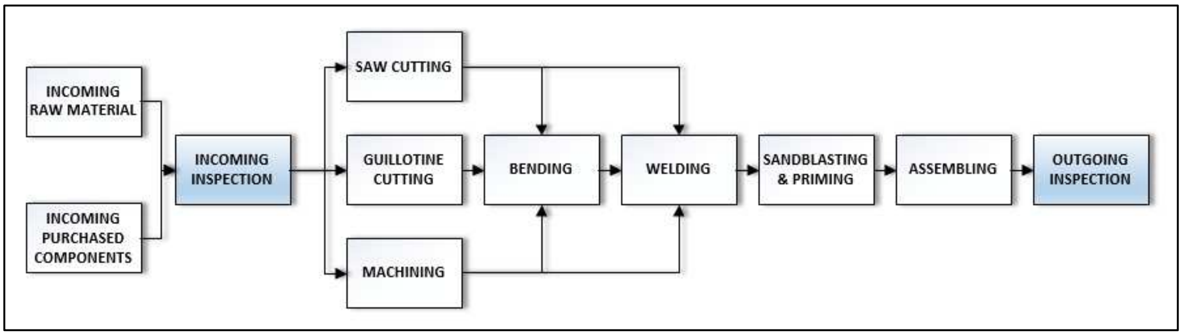


Figure 14 The sequence of production processes and inspection steps before improvements

Incoming goods inspection

Incoming good inspection (IGI)- A verification check if the product is arrived in good conditions at the warehouse, before accepting them into the stock. The functionality is, or should be, guaranteed and proved with a measurement report from the vendor. *(www.isixsigma.com, 2015)*

Initially, incoming raw materials are checked quantitatively and compared with the information in the invoice. The quality of incoming goods (mainly rolled metal and half-finished products from vendors) is checked visually. The dimensions of steel products are checked selectively. The inspection is performed at the plant. In some cases it is taken at supplier's gate.

Due to the fact that NTM Baltic Ltd over the years did not change its suppliers and fully trusted them, quality control process did not take much time. As well as the problems with raw materials and half-finish products appeared rare.

Since parts are either not compared or poorly compared with drawings, recently it started resulting in major problems. Details can be cut by the wrong drawing or incorrectly entered from DWG file into the program of laser or plasma cutting machine. This causes the situation, when the company often receive incorrect products which are not suitable for production. The most critical point is that low-quality product can get to the welder, and he may not notice the defect.

Many defects that could be detected in the early stages, during incoming inspection, are often detected when it is already too late (purchased components already machined or bent). In this case, the company loses the purchased component, time spent on the machining or processing, and the time to order new replacing component.

Intermediate (operational) quality inspection

It is carried out at certain points of the manufacturing process to confirm compliance with technical requirements. Visual and measuring quality control of parts is performed before each technological operation. Inspection has to be taken to ensure that faulty or defective items do not proceed to the subsequent operations. And also in order to predict when the process is likely to produce defective items so that necessary preventive adjustments can be made. *(R.Wild, 2002)*

NTMB does not have officially required inspection between operations with using of the appropriate quality inspection documents. The locksmith / driller checks the dimensions for compliance with the drawings, that he gets together with the items after bending or guillotine cutting. Welder checks visually quality of parts for assembling and welding operations. For typical frames are made jigs that are used during the assembling and welding to ensure the accuracy of the assembly and the correct sequence of welding. However, the jigs and other supportive devices cannot absolutely guarantee the accuracy of dimensions after cooling of welded construction. To avoid further defects is necessary to inspect quality of all sub-assemblies, before sandblasting, priming and assembling.

Outgoing goods inspection (OGI)

By outgoing goods inspection is considered quality inspection, before produced goods are transferred from NTMB to the parent company in Finland.

At this stage, the control of quality is taken over next characteristics: appearance, painting, and installation. The production of NTM is often experimental-type - it produces samples or batch of products for research, testing and improvement of the design and drawings. The design and drawings are developed by the done prototypes for further production. This fact as well as a large number of diverse products and the limited number of staff is the reason of difficulties in the process of outgoing good inspection. The absence of technological documents like technological maps and routings causes the reason of handling a large amount of drawings during the quality assurance steps. To perform full quality inspection of one product is necessary to handle about ten or more different drawings. The drawings NTB receives from Finland. But as 3D-modelling and development of drawings are done by the same person, often drawings require additional revision.

The time frames for production are very strict. This affects the lack of time to fully develop and control the drawings. Moreover, customer can make small changes in order, that cause significant changes in the whole construction of refuse collection vehicle.

Final inspection and documentation are performed in the last stage of production after installing the whole construction on the chassis in Finland.

2 DEFECT CAUSAL ANALYSIS

A large number of different factors affect product quality. Nowadays, many different methods exist for their analysis. To analyze the causes and effects of steel construction defects there has been decided to use Cause-and-Effect analysis. This analysis does not isolate specific factors that caused the failure, while other approaches and techniques provide the means to isolate specific changes and actions that caused the failure. Analysis has done mainly based on the defects of bin lifts. Considered caused and effects can be also applicable to other product groups in NTMB.

Cause-and-effect analysis (also known as Fishbone Diagram or Ishikawa Diagram), is a graphiphical approach to failure analysis that was first used by Dr. Kaoru Ishikawa of University of Tokyo in 1943. This aüüroach relies on a logic evaluation of actions or changes that lead to a specific event, such as machine failure. Fish-shaped grapgh is used to plot the cause-effect relationship between specific action, or changes, and the end result. *(R. K.Mobley, 1999)*

Ishikawa diagram gives us grapfical representation of relationship between possibilities of quality improvment of metal contruction in NTMB and all possible causes of the defect occurance. Main advantage of Ishikawa diagram is that it gives a clear understanding not only of the factors that affect the studied object, but also about cause-and-effect relationships of these factors, which is especially important.

The following factors that affect quality of the products have been identified: production technology; raw materials; equipment; management; organizational structure; production personnel; assessment and evaluation of the environment.

1) **The incorrect production technology is one of the causes of defects in metal contractions manufacturing.**

Welding:

- Contamination is caused by holding the torch at too low an arc length, causing the tungsten to touch the weld puddle or the filler metal rod.

- Contamination causes poor welds. It can come from dirty gloves, residual cleaning solvents, cutting tools. Careful cleaning is very important.
- Undercut caused by too much heat, not enough filler metal, or wrong torch angles.
- Incomplete fusion caused by too low a current, traveling too fast, too long an arc length.
- Open defects are the result of erratic travel speed sticking the tungsten to the work, or not adding enough filler metal
- Porosity occurs from holding too long an arc length, using contaminated tungsten; setting the gas flow rate too low; or not properly cleaning the base metal. The weld puddle will become oxidized or appear dark. *(R.Mohler, 1983)*

With improper welding technique, the material may lose some of its corrosion resistant properties, break or look unaesthetic.

2) Raw materials

Poor-quality raw materials is one of the most common causes of the defects and the same time is one of the most controllable factors, as well as semifinished products that are being mainly ordered from laser, plasma and waterjet cutting companies.

Sheet metal

Visual inspection of sheet metal does not allow us to make full analysis of receivid sheet metal, but visual inspection can prevent such surface defects as cracks, chips, indentations, scratches, and corrosion. *(R.Creese, 1999)* These defects can be identified during incoming inspection and further failures can be avoided.

Laser cutted products

Laser cutting offers advantages such as cutting of complex geometries, faster processing speed, cutting of wide range of materials, clean cut, etc. But this method of metal cutting may also be associated with certain defects such as striations (periodic pattern on the cut edge), dross, heat-affected zones, etc. *(N.B.Dahotre, S.P.Harimkar, 2008)* The quality of the same products purchased from different companies can vary significantly, as quality of products also depends on the CNC operator's skills and the written program for the machine

Plasma-cutted products

The inclination of cutting edge after plasma cutting can be up to 5 degrees and can occur slight calcination to a depthh of 0.5-1.5 mm. After processing of medium and large thichness parts always occur „mark“ in the form of smooth wave – the entry and exit p oint of the plasma beam. *(www.metalurg.su, 2012)* With increasing thickness of the metal the probability to get high-quality cut is reduced. Often, plasma cut parts need to be peened.

Defects of the tubes:

- Lap: Fold or metal that has been rolled or otherwise worked against the surface of rolled metal but has not fused into sound metal.
- Pit: A depression resultinf from the removal of foreign material rolled into the surface during manufacture,
- Seam: Crevice in rolled metal that has been more or less closed by rolling or other work but has not been used fused into sound metal.
- Hard spot: An area in the tube with a hardness level considerable higher than that of surrounding metal; usually caused by localized quenching
- Crack: A stress-induced separation of the metal that, without any influence, is insufficient in extent to cause complete ropture of the material.
- Additionally, defect can by caused by external or internal environment degeneration of the tube (selective corrosion). *(E.W. McAllister, 2014)*

Depending on the batch, the quality of tubes can vary. Even ordering a cylindrical tube there is a probability to get a tube with maximum deviation external diameter. It may affect the further production and may require additional processing of the outer surface of the tube. Same situation happened last time when was ordered tube for the bin lift frame, which was impossible to insert in the outer tube of the frame. Processing such tubes in the case of bin lifts, very time-consuming work, as internal tube length vary from 800 to 1500 mm.

3) Technology equipment

Technology equipment can affect the quality of both blanks and finished products may increase the level of defects, If it is out of date or maintanave have not been performed in time. Technically outdated machines are subject to frequent breakdowns. This leads to a decrease in productivity and product quality, increase the percentage of defects and therefore to the low competitiveness of products and the company as a whole.

4) Management

Management of the enterprise determines the quality policy, and the effectiveness of quality management in the enterprise depends largely on the degree involvement of management and employees in these processes.

5) Organizational structure

The organizational structure of the enterprise (or units) assumes the number and structure of personnel, as well as its responsibility. There also can distinguish the character of subordination units that determines the speed and quality of various tasks. The structure also determines the character of the various processes by building effective communication mechanisms between departments and staff.

6) Production personnel

Production personnel directly affects the production process

There are important skills, qualifications and interest personnel, as well as by working conditions. Much attention should be given to motivation. Management efforts should be focused on engagement production staff in quality management processes.

7) Assessment and evaluation of the environment.

It is necessary to properly assess the environmental factors, as well as outlining the strategic objectives of production. Product quality is the most important competitive advantage that will certainly be reflected in the company's strategy.

Evaluation of the most important factors

After developing of the Ishikawa diagram the work on identification of the most significant factors was performed. All members of the group analysis on the NTMB, independently of each other, marked on their copies of the Ishikawa diagram, the three most important in their opinion the factors. Then each member of the group comes to the overall diagram and noted her "own" factors by placing points on the Ishikawa diagram. Finally, after all the members of the group marked their options, the most important factors from the point of view of all members of the group were identified by the number of points on the arrows .

The diagram below (Figure 15) shows the results of the analysis. By a group of four members was determide the relative importance of the defect causing factors of the steel products. The diagram shows that the most significant (in accordance with the number of points on the arrows factor) are:

- **Interoperatinal control – 4 points;**
- **Quality inspection of incoming goods - 4 points;**
- **Production technology methods (welding, bending, cutting) - 3 points.**
- **Measuring – 3 points;**

Undoubtedly, all causes that are given in the diagram, have an impact on product quality, but in terms of small collective is hard to deal simultaneously with the improvement of all areas of the company. Therefore, it was decided to evaluate the most important of them. Further analysis and implementation of improvements are related mainly to selected the causes.

„*“ – importance of the factor influencing quality of product

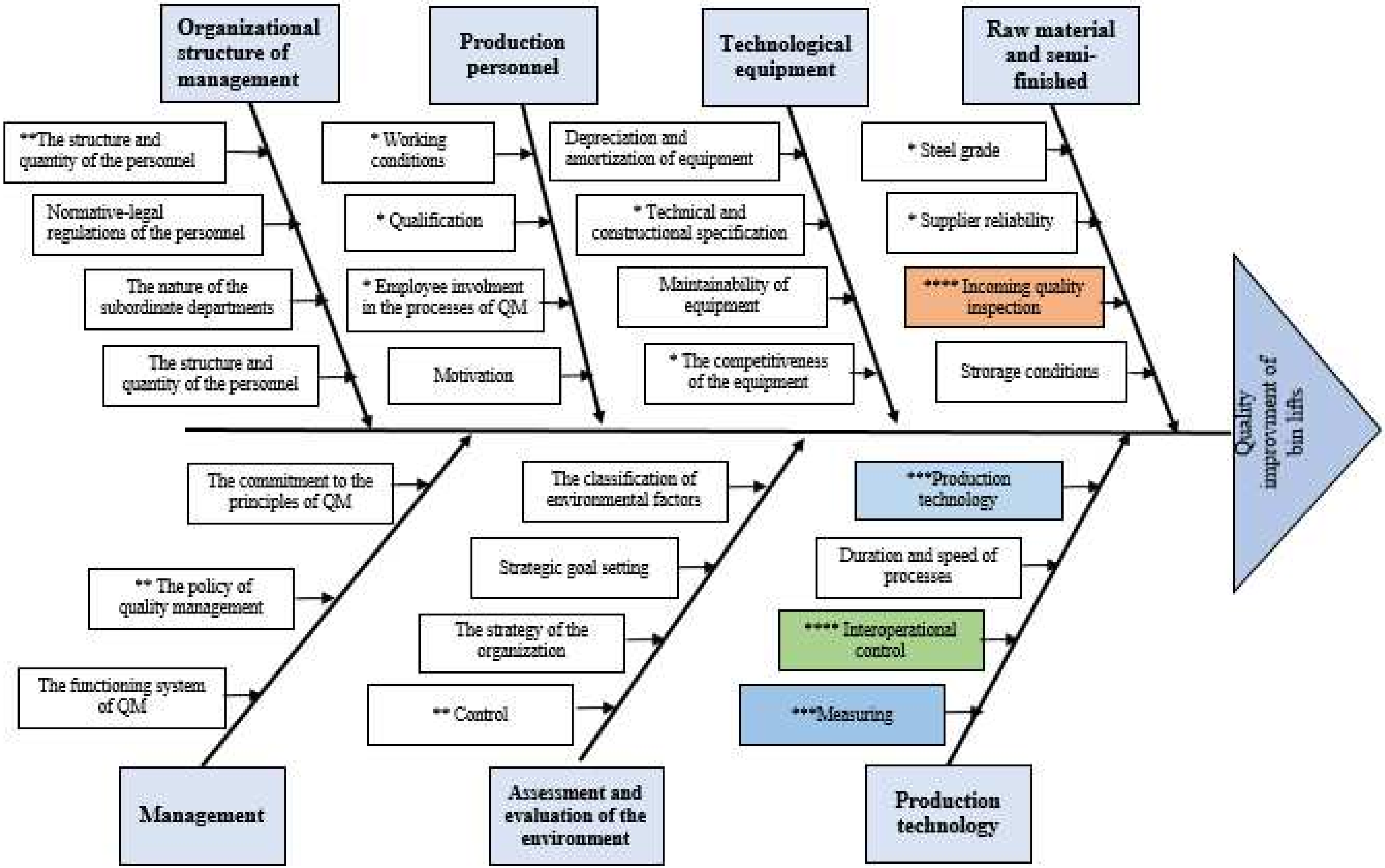


Figure 15 Cause-and-Effect diagram of bin lifts' quality

3 IMPROVEMENT OF QUALITY INSPECTION

Described in the previous chapters defects can be rapidly corrected in the early stages of detection. In terms of quality inspection in the late stages, the amount of time losses increases. Therefore, two main options are considered in this work - the option of increasing stages of quality inspection and the improvement of existing ones (Figure 16).

Incoming raw material and purchased components will be inspected according to ISO 9002 and NTMB quality requirements, to avoid further quality problems. Inter-operational inspection will be done before welding, to eliminate the use of low-quality semi-finished products in welded steel contractions. Before sand-blasting and priming will be done another quality inspection of welds and dimensions of the products, as well as to verify the absence of the most encountered defects of the most common sub-assemblies.

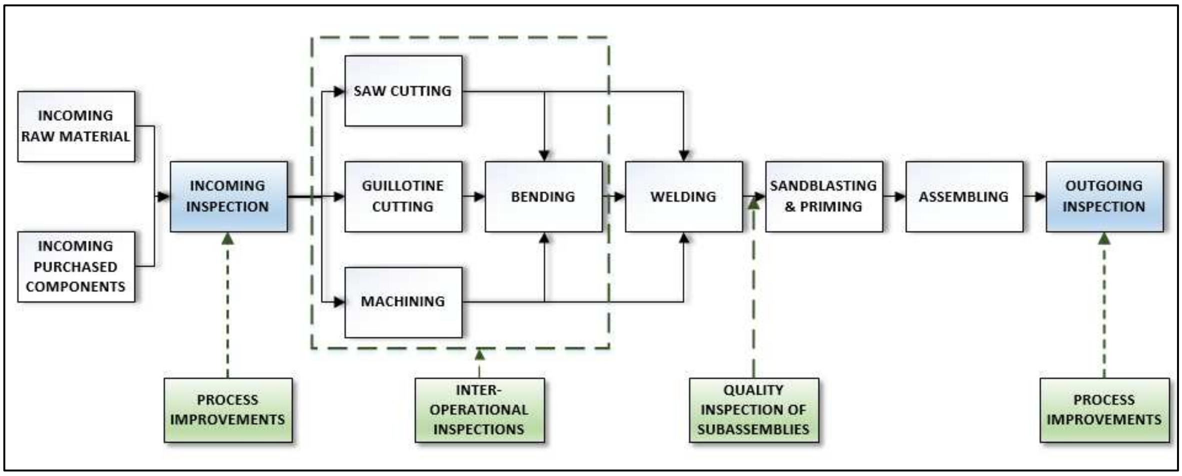


Figure 16 Production and inspection processes after improvements

3.1 Development of regulatory documents for quality inspection of welded joints

Since NTMB did not have documents related to quality inspection of welds, it is necessary to create the instructions to improve the quality inspection processes, based on the internal company quality requirements. This instruction sets the control methods by visual inspection and measurement control of the steel welding joints that are made by MIG/MAG welding in shielding gases, for the compliance with technical documentations. The instruction is guidance material for quality inspector.

Imperfetions is welded joints affect the ultimate fitness for purpose of the joints and thus directly determine quality. If repair or reworking is required to assure quality, or if scrap results, then they directly affect productivity. The reduction of the weld imperfections though the use of real-time control is a long-term objective. However, practices, procedures, and a wide range of institutional requirements are all important factors and in some instances predominate. *(J.G.Bollinger, 1987)*

Visual inspection

Visual inspection is nondestructive method to test welds for surface defects such cracs, arc strikes, undercuts, and lack of penetration. Visual inspection is the first step before other inspection process. The majority of welds receive only visual inspection. The procedure is often mistakenly overlooked when more sophisticated nondestructive testing are used. An active visual inspection schedule can reduce the finished weld rejection rate by more than 75%. Visual inspection should be used bofore any other nondestructive or mechanical tests are used to eliminate the obvious problem welds. *(L. Jeffus, L. Bower, 2010)*

Scope

This manual applies to products produces by the NTM Baltic Ltd. The established guidelines and standards requirements must be followed.

Links to documents

The references to specific regulatory documents or quoting of its provisions are given in the relevant sections and paragraphs of instructions.

Terms and definitions

The terms appearing in this manual are given in ISO 6520-1 “Welding and allied processes -- Classification of geometric imperfections in metallic materials -- Part 1: Fusion welding”.

General provisions

- Visual and measurement control must precede all other control methods, and conducted in accordance with ISO 17635 and EN 17637
- All unacceptable defects detected by visual and measurement control, must be removed before the subsequent control methods.

- Illumination of controlling areas should be at least 150 lux at the overview control and control of 500 lux at the local control.
- The visual and measurement control shall comply with the general safety requirements for the production unit.
- Personnel performing visual and measurement control must be protected from the effects of direct and reflected glare.

Visual inspection is performed to detect weld imperfections that are given in table below (Table 2):

Defect	Definition	Main causes	Measures
Hot crack (crater crack, pear-shape, crack)	A crack that develops during solidification	(1) Too high welding amperage (2) Too narrow welding groove	(1) Use proper welding amperages and crater treatment. (2) Use an appropriate groove angle.
Cold crack	A subsurface terrace and step-like fracture in the base metal with a basic orientation parallel to the wrought surface	(1) Inadequate ductility of the base metal in the thickness direction (2) High sulfur content of the base metal(3) Nonmetallic inclusions in the base metal (4) Tensile stresses in the thickness direction of the base metal	(1)-(3) Use a base metal which has higher ductility in the thickness direction, low sulfur, and low inclusions. (4) Modify the joint details and the welding procedures to decrease the stresses.
Excessive melt-through	A hole through the weld metal	(1) Too much root opening (2) Too high welding amperage	Use appropriate root openings and welding amperages.
Incomplete joint penetration	Joint penetration is unintentionally less than the thickness of the weld joint	(1) Too narrow welding groove(2) Too low welding amperage(3) Too much arc length or arc voltage	(1) Use appropriate groove design.(2)-(3) Use appropriate welding amperages, arc lengths (or arc voltages)
Porosity (Blowhole)	Cavity type discontinuities formed by gas entrapment during solidification	(1) Rust, oil, paint, or moisture on the joint fusion faces and high sulphur content of the base metal (2) Moisture in coatings, fluxes, or shielding gases (3) Too little shielding gas or flux-burden height (4) Too much welding amperage, arc length, or arc voltage	(1) Clean the joint fusion faces. (2) Refry coatings and fluxes and use suitable shielding gases. (3) Use proper amounts of shielding gas and flux-burden height. (4) Use appropriate welding amperages, arc lengths, and arc voltages.
Underfill (Internal concavity)	A depression on the weld face or root surface extending below the adjacent surface of the base metal	(1) Too small root opening, groove angle, or too much root face (2) Too low amperage, or too long arc	(1) Adjust the root opening, groove angle, and root face. (2) Use appropriate welding amperages and keep the arc length short.
Herringbone (pock mark, mouse footmark)	Shallow indentations on the surface of welds	(1) Moisture in coatings or fluxes (2) Rust, paint, or moisture on the joint fusion faces	(1) Re-dry the coatings and fluxes. (2) Remove rust, paint, and moisture from the joint fusion faces

Defect	Definition	Main causes	Measures
Overlap	The protrusion of weld metal beyond the weld toe or weld root	(1) Too low welding amperage (2) Too short arc length, or too low arc voltage	Use appropriate welding amperages, manipulation speeds and arc lengths
Uneven weld ripples	Abrupt changes in the profiles of weld bead ripples	(1) Too low or high welding amperage or voltage (2) Too much moisture in coatings or (3) Too much flux-burden height	(1) Use proper welding amperages and voltages (2) Re-dry coatings and fluxes. (3) Use a proper flux-burden height.

Table 2 Types, causes and measures of weld imperfections

The classification of weld imperfections is taken from the textbook *Weld Imperfections and Preventive Measures* written by Kita-Shinagawa and Shinagawa-Ku.

Requirements for visual weld inspection

Additional non-destructive testing should not be completed before the xpirations of the minimum holding time after welding. For welds requiring heating, these periods can be reduced if the piece being welded is heated for a period of time after the completion of welding in accordance with Appendix C of the standard EN 1011-2: 2001. If the weld becomes unavailable during subsequent works, it must be inspected before performing these operations. Each weld is positioned in the zone where an unacceptable distortion has been corrected should be re-examined. If the weld becomes unavailable during subsequent works, it must be inspected before performing these operations.

Controlled surface before visual inspection must be cleaned from slag, spatter, and other impurities, difficult to control.

Visual inspection of welds performed throughout their length on both sides (in the case of availability for inspection). Controlled zone should include a welded seam and the adjacent portions of the base metal on both sides of the seam width 20 mm from the fusion boundaries.

Visual inspection should include:

a) The availability and location of all welds;

b) Inspection of welds in accordance with ISO 17635 and EN 17637;

c) Inspection of random region and splashing places of the weld;

In the process of geometry and surface of the welds checking in the branched joints with the profiles, special attention should be paid to the following points:

a) For round sections: the middle edge of the front surface of the seam, the middle and rear two points in the middle of the side portions;

b) For square or rectangular sections, four corner points.

Visual inspection is carried out with the naked eye, and in questionable places - with the use of optical devices 4-7 fold increase. Visual inspection of welded joints from the inside must be done with the use of available technology on the factory.

Measurement control of welds in steel products

Visual inspection is compulsory for all of welded joints as a primary control. All other quality inspection of welds should be made only after obtaining positive results of visual inspection. Visual inspection should be performed after the completion of welding in the same zone and before performing any other non-destructive testing.

Measurement of welded joints in performed for verification of:

- The presence and location of all welds;
- Inspection of welds according to EN ISO 17637;
- Random arc and splashing weld areas;
- Joint width;
- The shape and height of the gain;
- Leg (thickness) of the weld;
- The length and pitch of intermittent seam;
- Depth and length of scores;
- Height scaly;
- The displacement of the edges of the joint;
- The value of the fracture of the axes of tubes in the presence of the requirements in the design document.

Requirement:

When measuring control (width, height gain, leg) of welds are conducted in accordance with the design documentation, but not less than 1 meter and no less than three places each seam.

When the number of the same type of welded joints of tubes with nominal outside diameter 50-90 mm inclusively the reducing of the measuring places is allowed, but not less than

10% of the total amount of compounds and at least one measurement of each controlled connection.

When checking the geometry and surface of welds are branched using profiles, special attention should be paid to the following points: a) for round sections: the middle edge of the front surface of the seam, the middle and rear two points in the middle of the side portions; b) for square or rectangular sections, four corner points

Subject to mandatory control areas of intersection and conjugation seams at least three nominal thicknesses of welded parts on each side of the point of intersection of the axes of joints. Measurements carried out primarily in the areas of dubious part sizes by visual inspection. The aim of the measurement of the welded joint is to establish its compliance with the requirements of the design documentation, and not fixing specific values.

The measurement control of the weld size is not performed before processing in case of the complete removal of weld reinforcement or its stripping with abrasive tool, if it is not specifically stated in the design documentation.

Test equipment and ancillary tools

There are different types of gauges that can be used to measure weld to make sure that they are within the correct parameters in terms of size. For example, controller can use a weld gauge to measure flat and concave fillet welds that are between 3 mm and 15 mm thick. The gauge has to be placed with the curved part in the fusion faces of the weld, so that there are three places where the gauge touches the weld and the work piece. This type of gauge cannot be used to measure a convex weld.

Equipment:
Sets of different gauges also can be used in which each one is suitable for welds of different dimensions. For example, bridge cam gage, digital welding gage. (Figures 17-20)

Figure 17 Digital welding gage with LCD display; (www.galgage.com, 2015)

Figure 18 Bridge Cam Gage; (www.galgage.com, 2015)

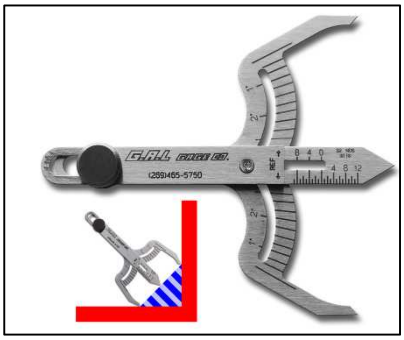


Figure 19 Weld Profile Gauge; (www.galgage.com, 2015)

Figure 20 Filled Weld set; (www.galgage.com, 2015)

Controller can also use a vernier, which is a graduated scale, to measure fillet welds that are flat or concave, and are up to 20 mm thick. The vernier can be also used to measure the reinforcement of butt welds, when we use backing. *(T. Swift, 2009)*

Leg depth gauge (view 1) must be sharpened so that the point of tangency is 0.4 ± 0.1mm.

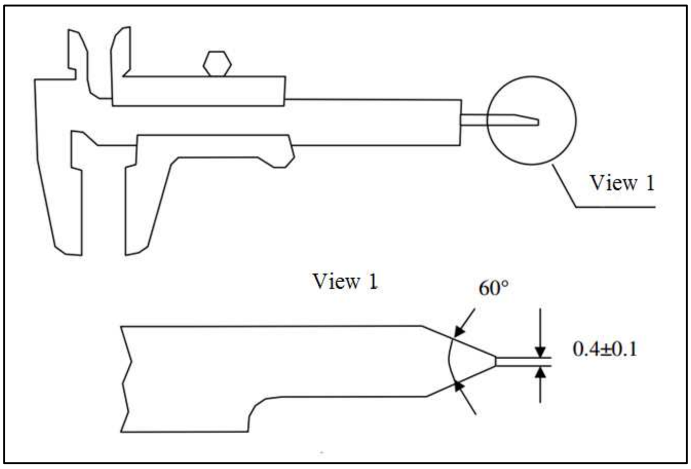


Figure 21 Vernier for weld fillet measuring

3.2 IDEF0 model development for quality inspection

Using *AllFusion Process Modeler* programe, is possible to create common block diagram that could serve as a basis for quality inspection documention. One developed block diagram will contain detailed information concerning quality inspection process and detailed imformation about the product.

AllFusion Process Modeler - a tool for modelling, analyzing, documenting and streamlining business processes, is referred to in this guide by its former name *BPwin*®. BPwin is a comprehensive business-modeling environment that helps to visualize, analyze, improve business processes and reducing the total costs and risks associated with adapting to operational changes. With User-Defined Properties (UDP), *BPwin* allows to custom-design a model that contains values specific to user's company's activities. Program supports various types of UDPs, including pull-down lists, command UDPs, and text lists. *(CA, 2002)*

The reason, why *AllFusion Process Modeler has* been used in this work is that this program is based on IDEF0 method. User-Defined Properties of the software give an opportunity to describe different processes with maximum amount of information and allows data filtering. IDEF0 in its turn gives opportunity to flexibly manage the quality inspection process and to easily and quickly adapt documentation to constant changes in product design or production technology.

Having common quality inspection technology will enable to quickly add new parameters into the model and prepare documentation on the new of updated product with minimal time expenses. Developed documentation is both a reporting on the product and helpful tool for quality inspector.

IDEF0 is a "methodology" that includes procedures for specifying its application and for accomplishing specific goals. The language of IDEF0 is written in graphical box-and-arrow notation on diagram forms that are structured to produce IDEF0 models (Figure 22). The boxes represent actions and the arrows interfaces between those actions. *(C.G.Feldmann, 1998)*

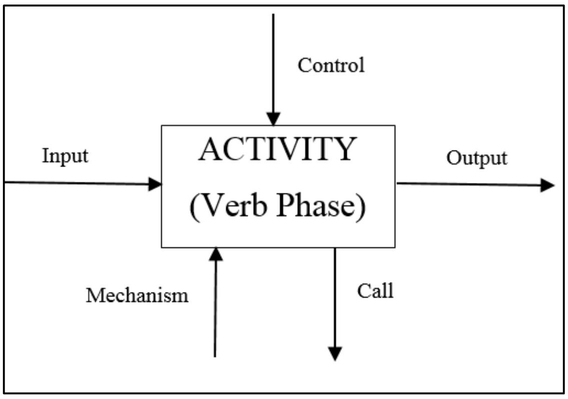


Figure 22 IDEF0 Activity syntax; (C.G.Feldmann, 1998)

A key aspect of IDEF0 characteristic is dealing with all aspects of a system (people, hardware, resources, raw materials, information, forms, and procedures), whereas these other methods typically handle one aspect only – information that is very important computer processing systems. Modelling of the enterprise's support systems typically occurs prior to the employment of CASE technology, which is very useful for identifying problem areas and for planning improvements. *(C.G.Feldmann, 1998)*

Bin lifts have 6 different product groups, but some lifts have common parts and sub-assemblies with lifts from other groups. The diagram will contain unchangeable information about each subassembly, its main characteristics and possible defects that allows adaptation it to all groups of lifts.

3.3 Guidelines for improved incoming quality inspection

Incoming steel products

NTM Baltic uses mainly steel sheet metal grade S355 MC/MCD in production, ordering through reliable suppliers. It also guarantees the good weldability of the product due to its low carbon equivalent. In case of components with extra high strength demand, NTMB uses Domex S650 MC/MCD. Company uses Hardox 400 steel grade less frequently for manufacturing products with the demands on the increased *hardness*. The steel plates are delivered with sheared or thermally cut edges.

During steel products reciving process next requirements have to be checked:

- Amount by theoretical weight, gauge and steel grades by the purchase orders, stampings/brandings and tags of the supplier;

- There have to be no visible bundles, cracks, shells, dents and general deformations that exceed the permissible relevant standards and specifications.
- Using measuring instruments geometric dimensions is necessary to check thickness of sheet metal, width and thickness of the steel strip, the outside diametr and wall thickness of the tubes.
- When company receives the new for it raw material is necessary to checked accompanying documents certifying the quality of the metal (passports, certificates) for the compliance of the steel grades with the marking on each product.

If there are deviations from the standard requirements is necessary to make a complaint notification. After acceptance, is necessary to make additional marking of the metal: the number of Acceptance Act and steel grade.

The results are documented in acceptance act and are included to general system of material movement at the plant. Metal must be stored in the warehouse sorted by steel grades. Metal have to be stored in enclosed spaces, equipped with special devices that provide mechanized warehousing operations. Steel profiles have to be stored in shelves with dividing racks and sheet metal – in specially designed areas with possibility of its transportation by cranes with magnet washers. During 3 moths from the date of shipment by the manufacturer metals can be stored in specially designed shelves outdoors.

(V.M Baryshev, 1999

Purchased components

First of all, is necessary to compare incoming purchase components with the drawing. Special attention should be paid to the holes in the components. They should be checked with a measurement tool. The edges of the product have to be checked, to make sure that they are smooth and cutting start is on the right place. Purchase components after laser or plasma cutting have to be without striations dross and heat-affected zones. If components have burrs on the edges, it is necessary to place them in a tumbler. Surface of the purchased components must be visually inspected and depth of the surface imperfections and discontinuities must lower than maximum permissible according to the EN 10163.

The diagram below (Figure 23) shows the sequence of the inscoming inspection processes. At the beggining, received raw materials and purchased components are checked quantitatively by comparing with purchasing order. After that the surface of the materials and components has to be visually checked according to the decribed above requirements and if quality satifies them, components are given to subsequent processing. The sequence of the processing operations for the various components may vary. The part of incoming products requires only machining (drilling operations, turning operations, milling) – thread cutting, turning of bearing or bushing, chamfering, turning of the outer and inner surface of the pipe, obtaining the necessary roughness of the components. If quality of these products satisfies requirements, product can be move to the further welding or to the stock. This sequence is more relate to the small purchased components or to cylindrical tube, purchased from a supplier, who has performed tube cutting to the desirable dimension.

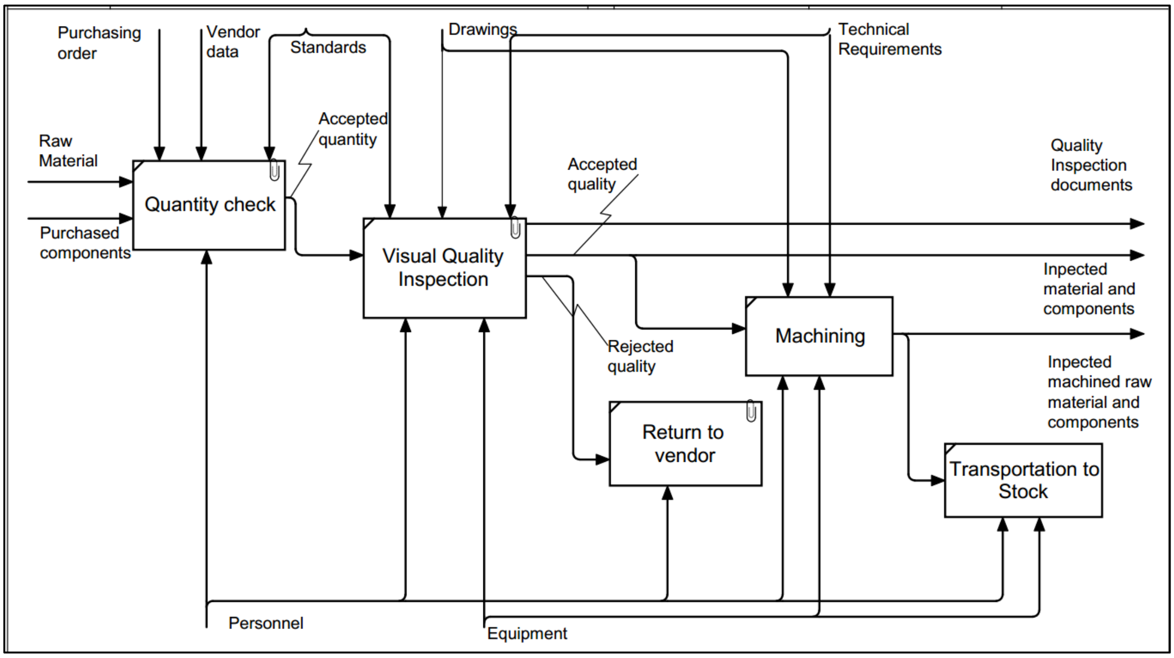


Figure 23 Sequence of the incoming inspection processes

3.4 Guidelines for improved interoperational quality inspection

When raw material is checked workers can start manufacturing semi-finished products according to production drawings and technical requirements.

Guillotine cutting of sheet metal

Sheet metal cutting performs on CNC controlled hydraulic guillotine shears. Cutting with guillotine shears of the manufacturing part should not be performed in case:

- Steel yield strength is greater than 350 MPa

- Part with thickness more than 25 mm from steel with a yield strength more than 275 MPa
- Part with thickness more than 16 mm from steel with a yield strength from 285 MPa to 350 MPa

The edges of the part after cutting with guillotine shears should not have cracks, bundles, burrs and debris greater than 1 mm. The edges that do not meet the requirements have to be machined. *(V.M Baryshev, 1999)*

Thickness of the steel metal can vary from 1.0mm up to 13.0mm and round bars up to 30mm in diameter. Maximum length of cut 1950 mm has tolerance ± 2 mm.

Saw-cutting

After saw-cutting of the steel product on the semiautomatic saw is necesarry to measure the dimensions of work pieces and compare them with the drawing. Additionally, all edges have to be checked. In the case of burrs, edges should be machined with abrasive disk.

Sheet metal die bending

Sheet metal bending procedure is performed on CNC controlled bending machine. Bent parts must meet the following requirements:

- The gap between the part's surface and the template should not exceed 2 mm on the each meter of the template;
- Displacement of the edges of cross-sectional profile parts shall not exceed the triple value of the maximum tolerance for the type of metal;
- During the bending into a corner for steels with the normative yield strength up to 350 MPa minimum inner radius should be at least not less than 1.2 of the III/IV group constructions thickness and not less than 2.5 for I and II group constructions.
- Deviations of the bending line from the stated in the drawing have to be lower than 2 mm.
- Tanget of the bending angle should not differ from the stated in the drawing more than 0.01. *(V.M Baryshev, 1999)*

- Verification of the geometric dimensions of components is carried out by measuring tool and with a set of gauges, designed to evaluate radius of convex and concave surfaces.

The diagram below (Figure 24) shows the sequence of the inspection processes between steel products processing operations. First of all, steel products have to be inspected after guillotine- or saw-cutting. Depending on the detail complexity, the sequence of operations can vary. After metal cutting can follow bending and/or machining. In some cases componens need at the beggining machining and after bending. When certain operation is finished, details have to eb transported to specially designated areas, where there performs inter-operational quality inspection. During inspection the inspector must complete the documents, where he have to specify the drawing number, product family, performed operation and the person; who has performed the operation.

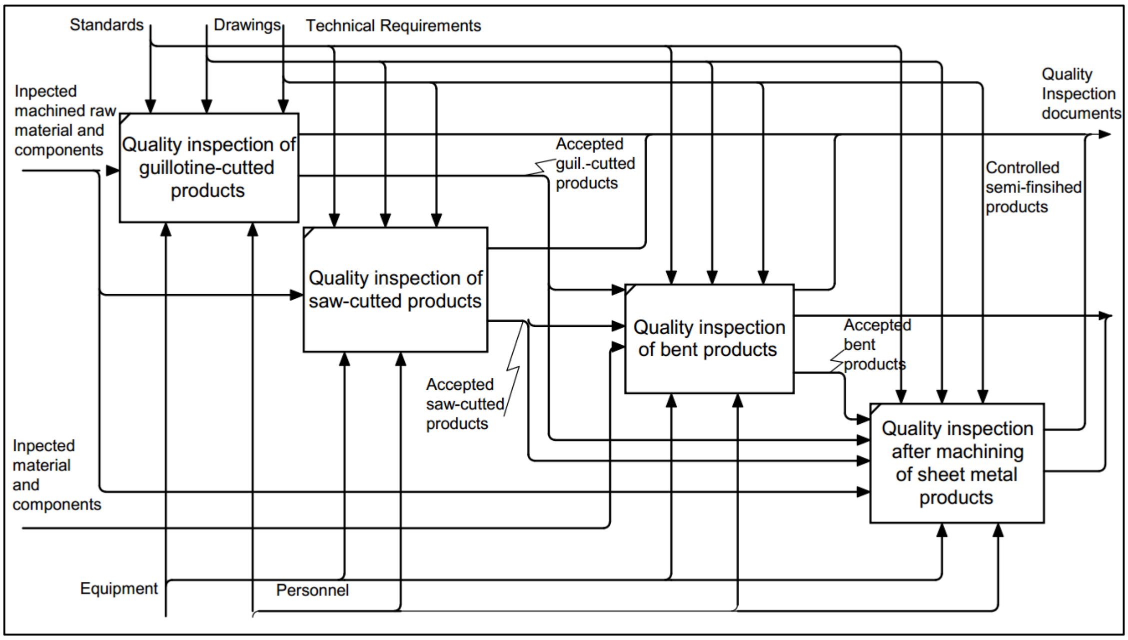


Figure 24 Sequence of the inspection processes between steel products processing operations

3.5 Quality inspection of subassemlies

As differents bin lift subasseblies (Figure 25) have own specifics it is necessary to consider them individually. For consideration were selected basic kinds of sub-assemblies with the most common defects.

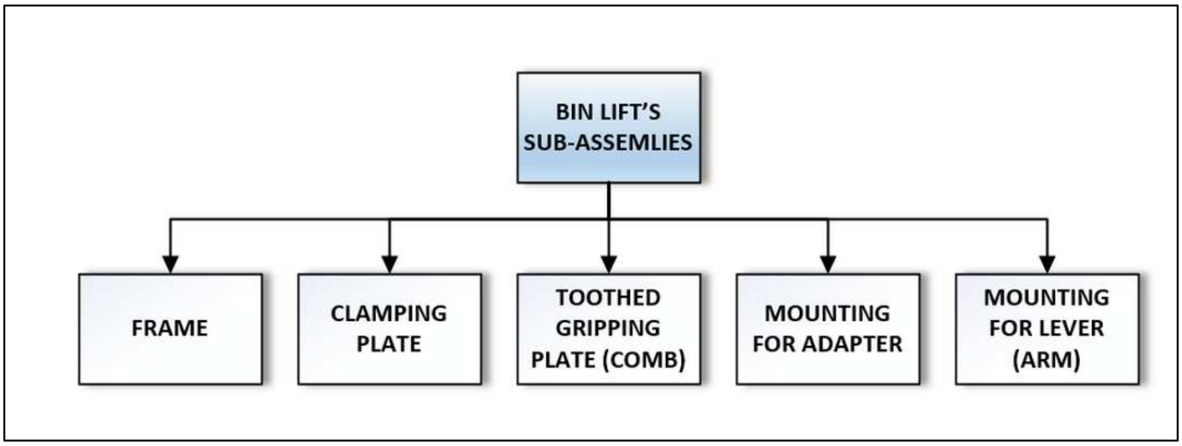


Figure 25 Main bin lift's sub-assemblies, requiring separate quality inspection

Since every week NTMB produces about 10 different products, the time for inpecction is limited. For this purpose were designed general / universal dimensions for each type of subassembly. For each dimension were given special characters that would be marked in the function model. The numerical value for each dimension that has to be measured, would be fiven in User Defined prorerties of easch sub-assembly (Figure 26). Possible technological defects were divided into groups and each was given a code. Each defect was carefully examined, as well as its causes. In most cases these defects are easily reparable in the early stages of detection.

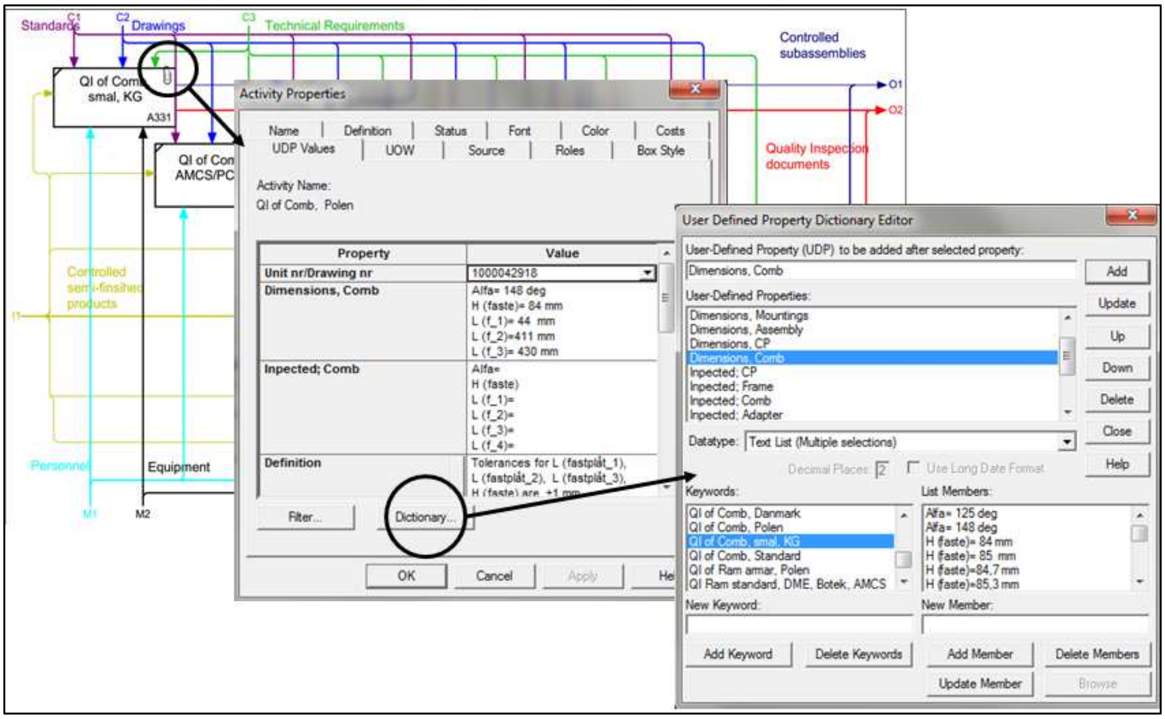


Figure 26 Specifying of the quality inspection parameters in AllFusion Modeler, using User Defined Properties

Detected defects have to be added to the table with final result of inspection (Table 4). This procedure has to be taken after filling by inspector of quality inspection documents that are developed during current thesis (Appendix 2)

Product name	**Drawing number**	**Defect name/ description**	**Decision of Project manager**	**Signatures of the respective persons**	**Notes regarding elimination of detected defects (signature, date)**	
					Foreman	**TC Inspector**

Table 3 Final results of quality inspection

Frame

The most important elements of the frame are the tubes. The most attention is paid on the quality of the treatment and their tolerances. Dimensional accuracy, concentricity and weld quality of the frame are especially important. On the image below (Figure 27) is shown the most popular type of the bin lift frame, where the most frequently met defects are marked with codes. Information related to the component's defects was collected and analyzed by the author of the current work. To facilitate the verification of the frame dimensions were determined standard dimensions for all types of frames. In the case of dimensions compliance with requirements the correctness of assembly of the entire frame is guaranteed. Each standard dimension is marked with a character. In the inspection card (Appendix 2) will be given numerical value of each dimension that has to be measured.

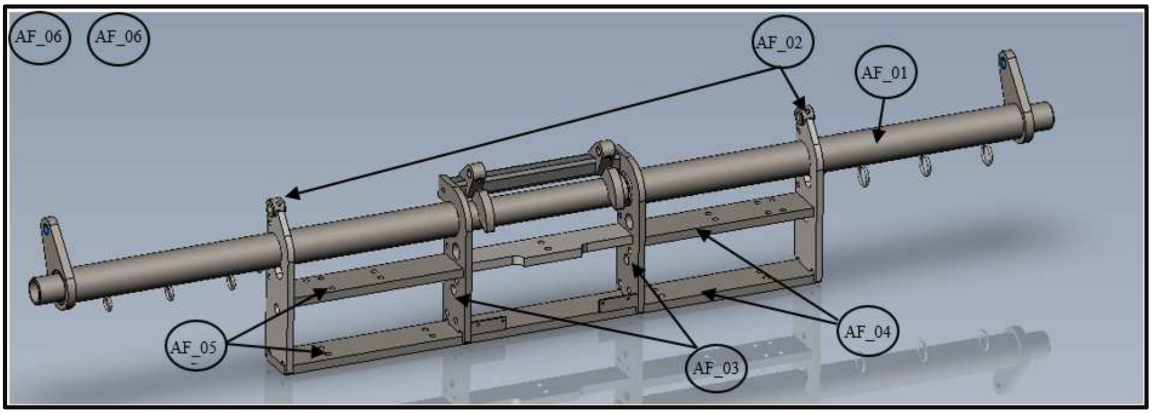


Figure 27 Frame with its defects designation

In the table below (Table 5) are given description of different deffect and possible causes. Described defects were mainly detected during assemling of the bin lifts prior to dispatch. Categorization of these defects is necessary to facilitate the process of visual inspection. Each type of frame defects must be checked during the inspection process.

Name of subassembly	**Defect code**	**Description**	**Causes**
1.1All types of frames	AF_01	Internal tube (Swedish. Lagringsrör) poorly rotates (scrolls) inside frame external tubes	• External tube is poorly machined inside • Tolerances of the internal tube' outer diameter • Tubes are poorly lubricated • Shrinkage after welding
	AF_02	Holes in side bushings for clamping plate installation are non-concentric	• Bushing are not properly welded on the frame • Bronze bushing are not properly pressed into it • Shrinkage after welding • Violation of the technology • Not proper use of a jig. Or the jig was not used.
	AF_03	Holes in central sidebars (Swedish. Ramjärn) of the frame are non-concentric	• Details were not properly installed into jig • Shrinkage after welding • Not accurate plasma or laser cutting of the parts – displacement of the holes
	AF_04	The crossbars of the frame are not parallel; different distances between them	• Not properly welded • Shrinkage after welding • Template (distancing bar) was not exposed or was not placed at a right angle
	AF_05	Holes in the crossbars are non-concentric	• Components is wrongly placed and welded • Not proper drilled holes • Not properly welded • Not correctly spotted size
	AF_06	Poor priming of the frame	• Inattention • Components was not checked after priming • Inaccessible places on the frame
	AF_07	Weld imperfections; Unfinished welds	• Inattention • Inaccessible components

Table 4 Main defects of the frame

As a basis for were taken mainly *L* and *H* characters, for the designation of the length and height of the certain parts, respectively. Clarifications in the brackets according to the name of the components in the drawings that NTMB receive from parent company NTM. Critical dimensions that are marked on the scheme below (Figure 28) were chosen according to the analysis of different bin lift frames. Critical dimensions have to be unified to minimize number of drawings and sheets during quality inspection.

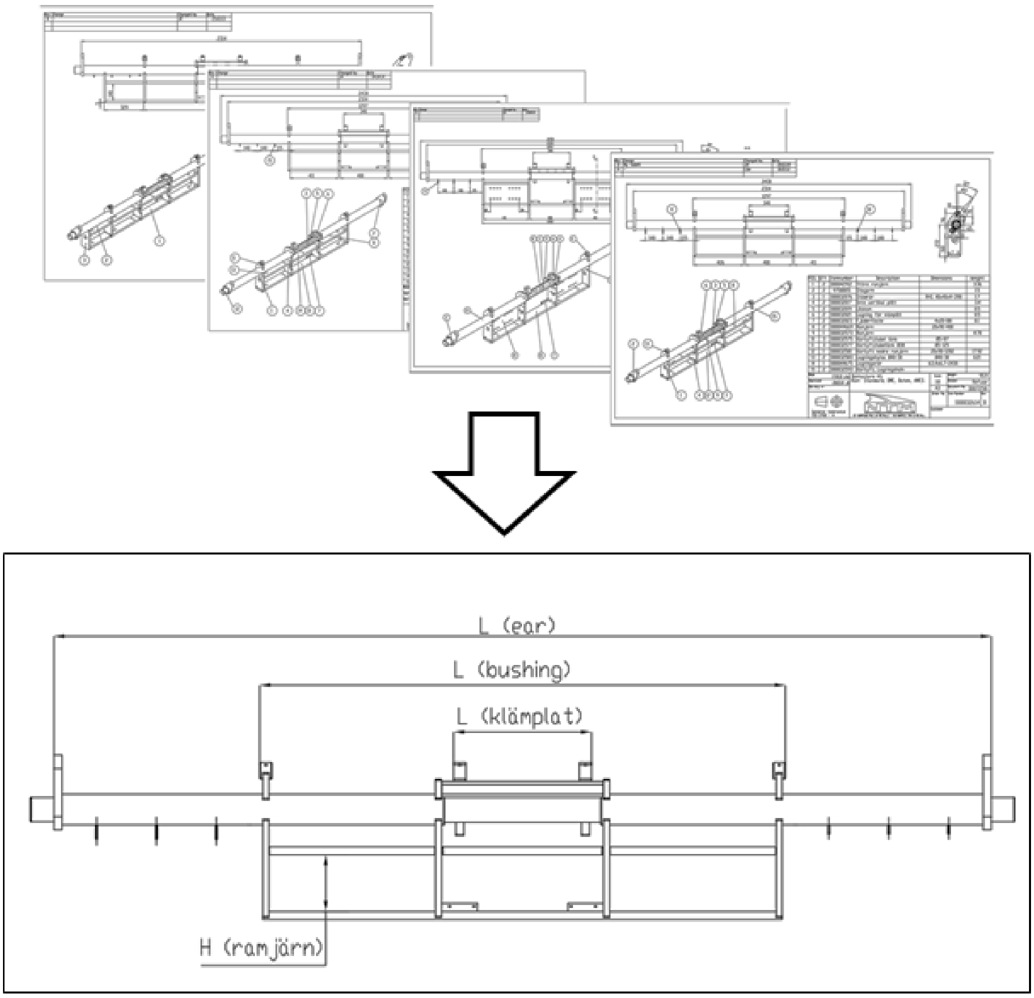


Figure 28 Common scheme for quality inspection of the frame with critical tolerances

2B-type frame (Figure 29) looks very similar with other frames, but the manufacturing technology is different. In case of common frame tubes are machines separetly and after are welded with side bars. In case of 2B frame, tubes and side bars are firstly welded together and after are machined on CNC milling machines by a vendor. When welder assembles 2B frame that consists of two machined parts it is very important to have hole alignment to easily insert internal tube. Problem with non-concentricity of the rame tubes have been appeared very often, before it it was decided to make annealing of the frame subassemblies, before mahcining. Nevertheless, the annealing is not completely solves the problem and control after treatment is still required.

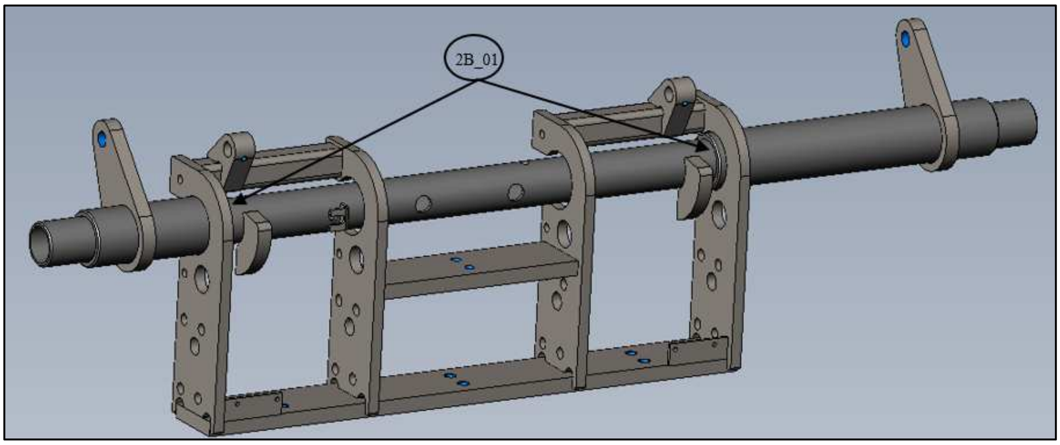


Figure 29 2B Frame with its defect designation

Name of subassembly	Defect code	Description	Causes
1.2 Frame 2B(s) type	2B_01	Tubes are misaligned	• Poorly machined tubes • Tablate/jg was not used • Shrinkage after weldingcooling • annealing is not made

Table 5 Types of defect on 2b frame

Because of contructional difference of common frame and 2B frame, the designations of contol dimensions are sligtly different (Figure 30). Additionally to critical measures on standard-type frame, on *2B* frame is necessary to check the distance between external tubes. In case of mismatch with dimensions specified in the drawing, the subsequent assembly will be incorrect.

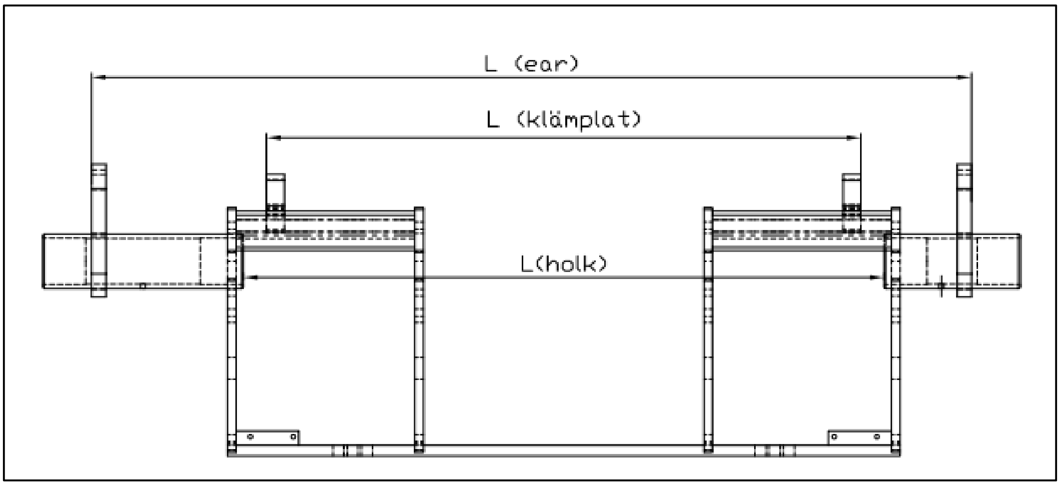


Figure 30 Common scheme for quality inspection of 2B frame with critical tolerances

Clamping plate

Generally, clamping plate is manufactured from Domex S650 MC/MCD, high strength cold-forming steel, that has high strength and form-ability. Despite the good material characteristics, after welding structure of the component can be deformed, causing distortion. Despite the relative simplicity of the design, welding of small components is often impeded by shrinkage process. This process occurs when heated and cooled regions are neighbored. It causes different angle deviations from nominal position and concentricity faults between welded parts. Concentricity faults would cause problems during assembling and movement of clamping plate may be impaired.

Another frequent defect is appearing of cracks on the outer surface of the bend. Since most steel sheets are formed by rolling, they have anisotropic properties (different yield strength along different directions). Thus, the orientation in which steel sheet was cut depends on the bending operations. Additionally, cracks can be caused due to too small inner bend radius. *(S. Mukherjee, 2011).* Therefore, prior to assembling, is important to check the dimensions presented in the picture below (Figure 31)

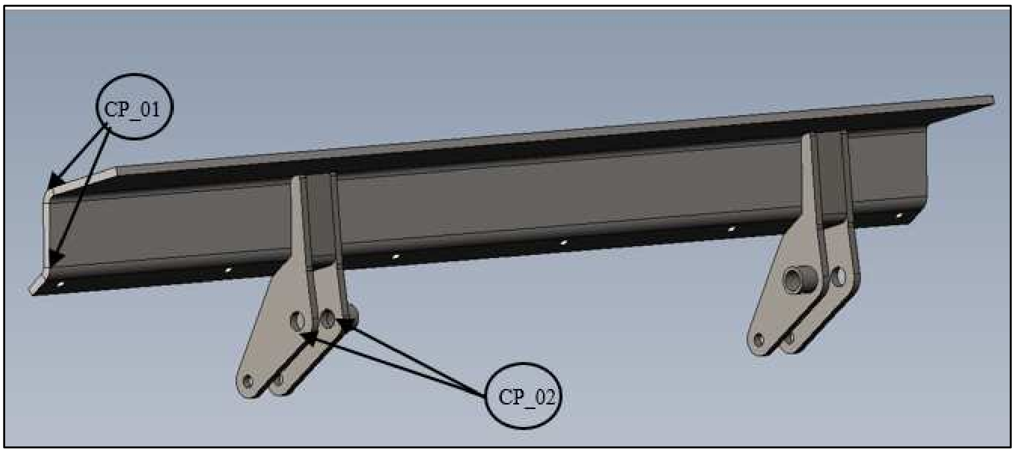


Figure 31 Clamping plate with its defect designation

Name of subassembly	Defect code	Description	Causes
2. Clamping plate	CP_01	Cracks on the outer surface of the bend	• Too small inner bend radius • Low-quality material • Wrong orientation of the sheet metal during guillotine cutting
	CP_02	Holes in welded parts are non-concentric	• Shrinkage after cooling • Not proper use of the jig/defected jig • Components are not properly machined/ bad laser-cutting

Table 6 Main defects of clamping plate

Critical dimensions thta have to be measured during quality inspection are shown on the scheme below (Figure 32). Dimensions specified on the scheme are the most important, because in case they do not meet the requirements proper installation of the clamping plate will be impossible.

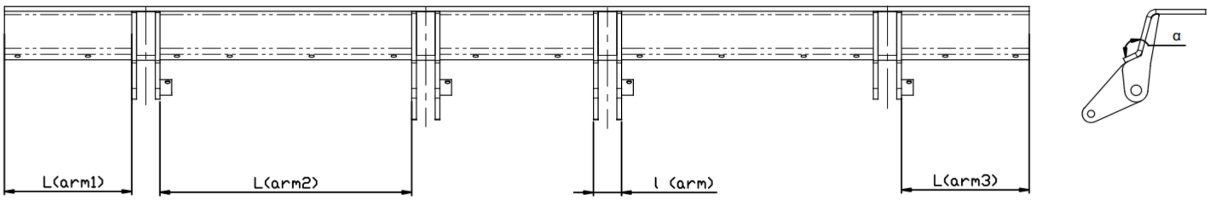


Figure 32 Common scheme for quality inspection of clamping plate

Toothed gripping plate (comb)

A toothed gripping plate (comb) serves to attach the container by its edge. The teeth are arranged according to the standards of waste containers that can vary significantly, depending on the country, city, region and type of waste. Standars variation explains the large number of different types of combs. The combs are usually cutted with plasma from S355MCD hot-rolled steel by the suppliers. After plasma cutting workers drill holes in the comb and make thread cutting, if it is necessary. Then workers bend combs at a certain angle, indicated in the drawing and after that small additional parts are being welded, which may vary depending on the type of bin lift.

One of the most common defects is cracks in the other surface of bend, which are often not visible after bending. Cracks are mostly visible after sandblasting and priming of the details. Causes of the cracks are similar with cracks on the clamping plate. Due to these components have purchased from suppliers, another possible cause of the cracks can be low-quality material. Despite the fact that the steel grade is indicated in the drawings and in the purchasing order, to check or to determine visually that required steel grade was used during manufacturing is hard.

Another type of defect is corrosion in the mounting plate that is welded to the comb. This item has small circle-shape cut in the center of the straight angle. This facilitates the installation of these details on comb and the same time it often remains not properly welded, due to its inaccessibility. Thus, welding imperfections or not finished welds cause the appearing of corrosion in this place. The quality inspector must check the defects identified below. (Figure 33)

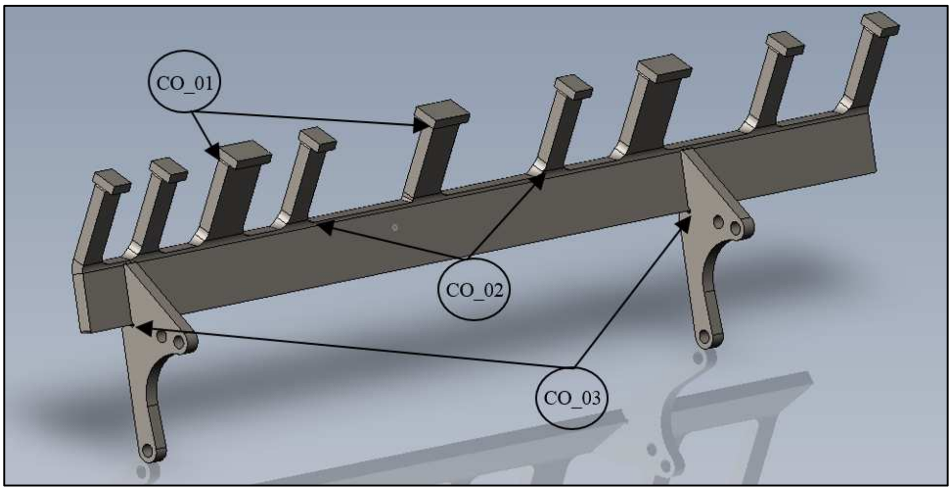


Figure 33 Comb with its defects designation

Name of subassembly	Defect code	Description	Causes
3. Comb	CO_01	Unfinished weld/ weld imperfections of the„teeth“	• Inattention • Inaccessibility for the welding torch
	CO_02	Cracks on the outer surface of bend	• Bending inner radius is too small • Low-quality material • Wrong orientation of the sheet metal during guillotine cutting
	CO_03	Corrosion in the corners of welded parts	• Not properly welded • Inaccessibility of the components for the welding torch

Table 7 Main defects of the clamping plate

In the scheme below (Figure 34) are shown dimensions that have to be checked prior to sandblasting, priming and its installation on the frame. Depending on the length of the comb, the number of mounting plates may vary.

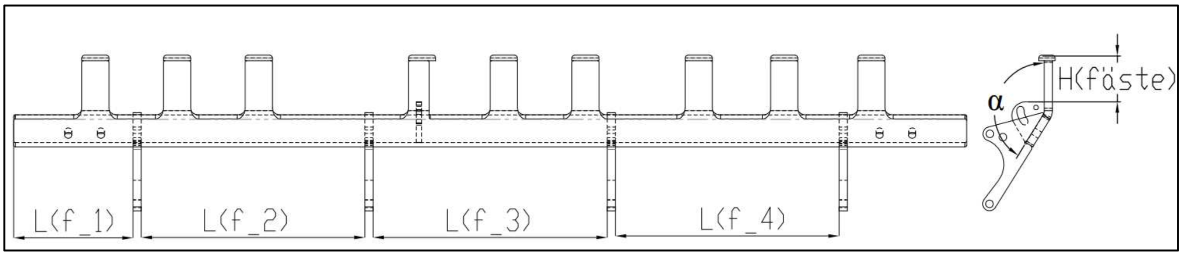


Figure 34 Common scheme for quality inspection of the comb

Mounting for PC2H adapter

The mounting for PC2H adapter is welded from two rectangular plates, used for installation and mounting adapters to sites of bin lift. PC2H adapter is necessary component that further would be replaced by the load weigh cells during final assembling in Finland. Weigh cells transmit information about the weight of containers to the refuse vehicle computer. Sizes of the part must meet the requirements according to the drawings. Since the installation of the adapters dependends on this components, and moreover it can affect the entire lift. Main dimensions are given in the *Figure 35*.

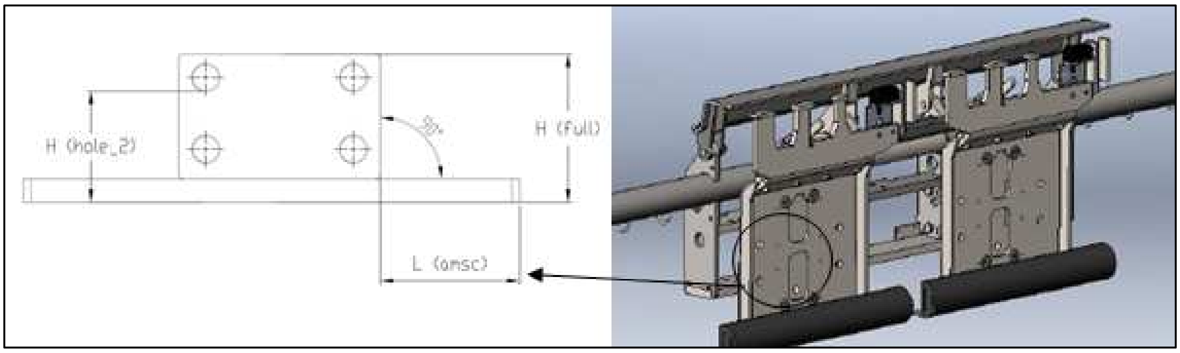


Figure 35 Mounting for PC2H adapter

Mounting for bin lift's arms

The arms (levers) that are shown on the picture (Figure 36) below are used for automatic waste container's top opening during the process of overturning. Dimensions showed in the scheme, are very important for correct installation of the arms. The arms should be set at the same level and have to move freely between the mounting plates. Deviation from tolerances entails problems of disclosure arms.

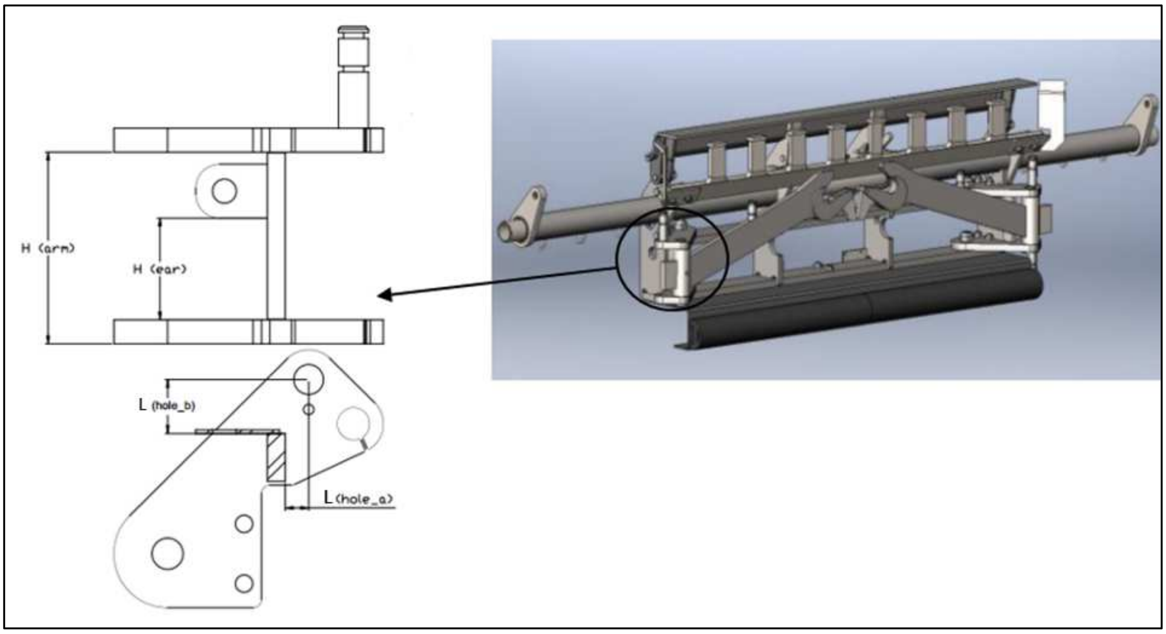


Figure 36 Mounting for bin lift's arms

3.6 Quality inspection of the assembled bin lift

Depending on the type of bin lift is necessary to measure various dimensions.

Standard-type bin lifts should be measured in the following areas to ensure that the lift is assembled correctly (Figure 36):

- Between clamping plate and comb – to ensure that bin lift can firmly hold the container. The average distance is 24 mm, it may differ depending on the design by 1-1.5 mm. (*H kamenhet-klämlåt*)
- Between comb and D-beam – to ensure that both comb D-beam are correctly installed. (*H kamenhet-gummi*)
- Between comb and side plate of the frame. This dimension guarantees the proper position of the comb on the frame. (*L kamenhet-ramjärn*)

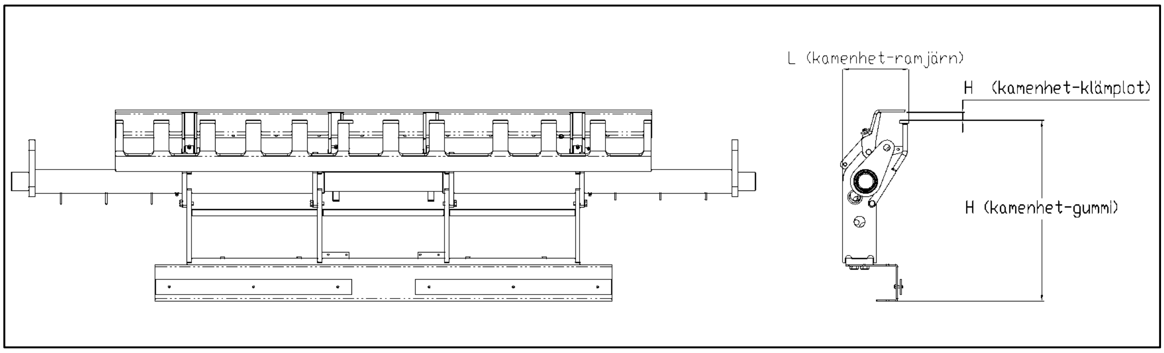


Figure 37 Common inspection scheme for standard-type bin lifts

Additionally to measures that are described above, *Armar-type* bin lifts should be measured in the following areas:

- Between ID antennas and clamping plate – to ensure that there is minimum distance (not more that 5 mm). The grips / handles for bins have rod diameter from 8 mm and too big clearance can cause that the bins will fall out. (*H kam.distance*)
- Between the arms of bin lift - to ensure that the arms are installed are correctly. (*L lyftarm*)
- Between upper side of lift's arm and D-beam- to ensure that bin lift's arm do not need additional adjustments

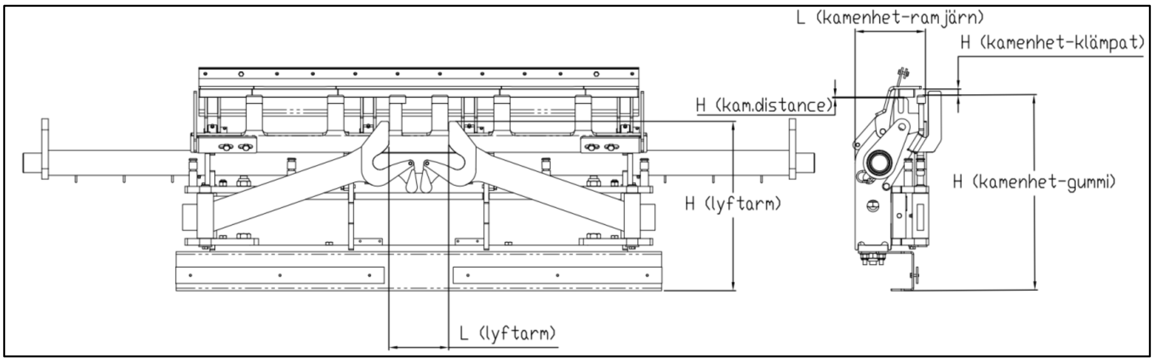


Figure 37 Common inspection scheme for "Armar"- type bin lifts

Hydrauliska-type bin lift with hydraulic arms has to be measure similarly to *Armar*-type:

- Has to be measured distance between hydraulic arms - to ensure that the arms are installed are correctly. (L hyd.arm)
- Has to be measure height of arms relative to D-beam.

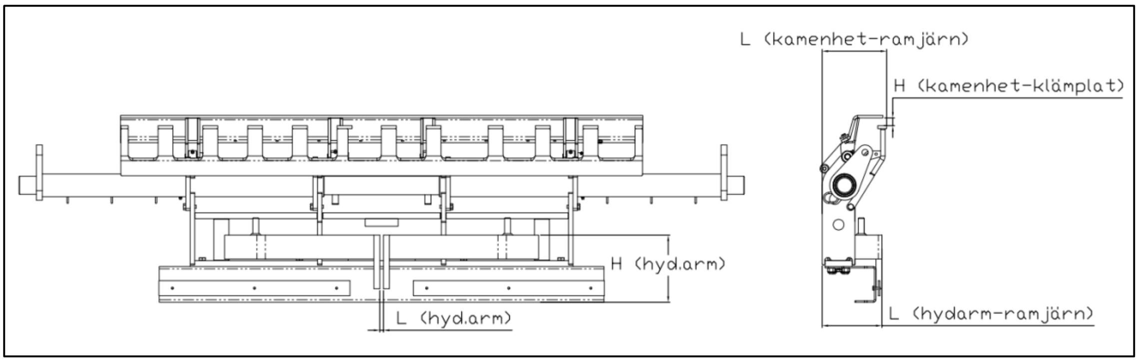


Figure 38 Common scheme for "Hydrauliska"-type bin lifts

4 ECONOMIC CALCULATIONS

4.1 Average time calculation for technical quality inspection

NTM Baltic Ltd produces only about 7 000 average- and small- size metal constructions per year, as well as in mass production the time spent on quality control and assurance is very important factor. In this part of the work describes the method of calculation the necessary time to perform quality control process.

The need for accurate, reasonable and effective technological preparation of technical quality control is comfimed by the practice of industrial enterprises. The most important point in the preparation process is not a description of control technology, but the necessity for its implementation. At the same time we must not lose sight of the fact that the control and inspection processes do not create value, but only assess the condition of the material values and their compliance with certain statutory requirements. *(V.N. Chupyrin, A.D Nikiforov, 1987)*

This chapter describes the standards for technical quality inspection based on materials taken from the handbook for designers, technologists and employees of Quality Department "Technical control in mechanical engineering", written under the general editorship of the engineer V.N. Chupyrin and Doctor of Technical Sciences A.D Nikiforov. Despite the fact that the handbook was written in 1987, it is still relevant in terms of current machine building.

Visual inspection and welds quality assurance

The inspection of the clamping plate and the comb performs manually as the weight of the heaviest part does not exceed 25 kilograms. The final assembly inspection and the frame inspection are carried out by using the telpher. Work done manually assumed that it is necessary to take or turn part (sub-assembly), check visually and to put it back. In case of bin lifts it is necessary to turn its subassembly 180 degrees. Using telpher, subassembly has be secured and picked up, checked visually, and then has to be put back in place.

Visual assurance assuames that if the weld looks good, it passess, but if not, it is rejected. This procedure is often mistakenly overloooked, when more complicated nondesructive assurance methods are used. If this procedure is carried out efficiently, it can reduce the finished weld rejection rate by more than 75%. Visual inspection can be easily used to check for fit up, interpass acceptance, welder technique, and other variables that will affect the weld quality. (L. Jeffus, L. Bower, 2010)

The requirement for controller is quite high. This procedure requires knowledge of weld drawings, procedures, joint design, standard and company internal requirements, and inspection and testing techniques. The welding inspector must be capable of identifying all of the different welding discontinuities during visual inspection. The inspector also must be able to evaluate, in terms of the relevant welding code or standard, the significance of identified discontinuities to determine whether to accept or reject them during testing and production. A welding inspector with good eyesight can be trained relatively quickly by a competent instructor and can prove to be a major asset to the welding quality system (good vision is obviously essential for visual inspection). *(T.Anderson, 2007)*

An engineer or technician who, by training or experience, or both, in metal fabrication, inspection and testing, is competent to perform inspection work. *(SAC Joint Venture, 2000)*

In case of manual, automatic and semi-automatic arc welding, time required for visual and measuring inspection of the weld seams consist of: a) time required for visual inspection of the entire length of the seam and; b) time required for measuring inspection of weld seam with gauge or vernier.

The quality of welds after manual gas welding is verified by visual inspection on the entire length of the weld as well as the quality of the edges after cutting. As we are dealing with small-sized products, it was decided to take the average time on the most common weld seam - vertical and horizontal T-joint. Time is calculated based on the total length of the seams on each subassembly.

The total length of the seams calculated on the basis of sub-assemblies of average complexity.

Frame – 4752 mm ≈4,8m

Clamping Plate – 1040 mm ≈1,0 m

Comb – 1290 mm ≈ 1,3 m

In the table below (Table 9) are given time norms for quality inspection of the weld seams that consist of: time for checking the entire length of the weld seam by visual inspection; and time for weld measurement with gauge or vernier.

Sub-assembly	**Time norm for QI of the weld seam, min/m**	**Installation and removal of parts (manually/telpher), min**	**Weld seams inspection, min**	**Total time for the QI of the weld seams, min**
Frame, 90-100 kg	0,507-0,634	0,44 (Turn 180°)	2,74	3,18
Clamping plate, 20-22 kg	0,210-0,262	0,096 (Turn 180°)	0,236	1,196
Comb, 19-20 kg	0,210-0,262	0,096 (Turn 180°)	0,307	0,403
Assembly<200kg	-	0,54	3	3,54

Table 8 Time calculations for visual quality inspection

Assembled bin lift is inspected visually for the presence of all necessary components, lubrication inside the tubes, fixtures, and also is checked how the clamping plate is closing and how inner tube scrolls inside the external tubes.

Workplace maintenance time, rest and personal needs

Additionally, is important to calculate time for maitanance, rest and personal need of quality inspector. Average percentage from total inspection time are given in *Table 10.* Time calculations of the additional time are gine in the end of this chapter.

Content	**Time, % from operational time**
Preparation and cleaning of measuring and control tools, technical documentation and the workplace at the beginning and end of the shift	2
Documentation for acceptance and accounting of suitable and defective products	3
Rest and personal needs in metalworking production	5

Table 9 Additional time calculations

Dimensional inspection of the subassemblies with different measuring tools

In the next tables (Table 11-14) are presented calculations of time, required to measure a products, according to the quality inspection schemes. Time depends on the lenght of critical dimensions and measurement accuracy.

1. Frame

Parameter/Average Lenght	Tool	Time required, min	Measurement accuracy, mm
H (ramjärn), 130-140 mm	Vernier	0,1	±1
L (ear), 2300-2350 mm	Metal measuring tape	0,185	±2
L (bushing), 1200-1300 mm		0,165	±2
L (klämplat), 150-350 mm	Vernier	0,1	±1
Bushings’ alignment (concentricity)	Alignment tool/Template	0,170	±1
Sidebars’ holes (concentricity)		0,120	±1
Crossbars’ holes alignment (concentricity)		0,110	±1
Crossbars are parallel	Setsquare/Template	0,1	±2
	Total	**1,05**	

Table 10 Time calculation for dimensional inspection of the frame

2. Clamping plate

Parameter/Average Lenght	Tool	Time required, min	Measurement accuracy, mm or °
L (arm_1), 20 mm	Vernier	0,08	±1
L (arm_2), 430 mm	Metal measuring tape	0,115	±1
L (arm_3), 495 mm		0,115	±1
L (arm), 48 mm	Vernier	0,08	±1
Alfa, 48°	angle gauge	0,1	±2
	Total	0,**49**	

Table 11 Time calculation for dimensional inspection of the clamping plate

3. Comb

Parameter/Average Lenght	Tool	Time required, min	Measurement accuracy, mm or °
L (fästplåt_1), 470 mm	Metal measuring tape	0,115	±1
L (fästplåt_2), 430 mm		0,115	±1
L (fästplåt_3), 430 mm		0,115	±1
H (fäste). 84 mm	Vernier	0,086	±1
Alfa, 148°	angle gauge	0,1	±2
	Total	**0,501**	

Table 12Time calculation for dimensional inspection of the comb

4. Assembled the bin lift

To calculate the time for dimensional inspection of the assembled bind lift it was decided to take the lift with the arms adapted for roller top vessel.

Parameter/Average Lenght	**Tool**	**Time required, min**	**Measurement accuracy, mm or °**
L (lyftarm), 200 mm	Vernier	0,122	±2
H (lyftarm), 800 mm	Metal measuring tape	0,135	±2
H (kamenhet-gummi), 850 mm		0,135	±2
H (kamenhet-klämplåt), 26 mm	Vernier	0,05	±2
L (kamenhet-ramjärn), 250 mm	Vernier	0,156	±2
`	Total	**0,598**	

Table 13Time calculation for dimensional inspection of the assembly

The calculation of the total time

Time calculations are based on the inspections of basic sub-assemblies with medium complexity. Total time is calculated by summation of the time for visual inspection and measurement control of the main dimensions. The data for calculations is taken from tables given above. In the end of calculations are added time for work place maintence, rest and personal needs. The time obtaine din calculation is average can vary, depending on the bin lift design complexity.

1. Frame:

Visual inspection 3,18 minutes + Dimensional inspection 1,05 minutes = 4,23 minutes

With adding the workplace maintenance time, time for inspectors rest and personal needs we get next total time: **4,65** minutes per frame

2. Clamping Plate:

Visual inspection 1,196 minutes + Dimensional inspection 0,49 minutes = 1,686 minutes

With adding the workplace maintenance time, time for inspectors rest and personal needs we get next total time: **1,83** minutes per clamping plate

3. Comb:

Visual inspection 0,403 minutes + Dimensional inspection 0,501 minutes = 0,904 minutes

With adding the workplace maintenance time, time for inspectors rest and personal needs we get next total time: **0,99** minutes per comb

4. Assembled bin lift:

Visual inspection 3,54 minutes + Dimensional inspection 0,598 minutes = 4,138 minutes

With adding the workplace maintenance time, time for inspectors rest and personal needs we get next total time: **4,55** minutes per assembled bin lift.

Time for quality inspection per one bin lift is ca' 12 minutes

Quality inspection time calculations are necessary for the costs estimation of the improved quality inspection processes. The improvement program has to be implemented cost-wise effectively. As the aim of developed quality inspection documents was rapid inspection proces, calculated time confirms convenience of this methods.

Knowing cost of quality, as well as cost of factors that influence quality, is crucially important for every organization.

4.2 Appraisal Costs

Appraisal Costs are costs associated with measuring, evaluating, audition products or services to assure conformance to quality standards and performance requirements: incoming inspection and costs associated with supplies and materials used. *(ASQ, 2013)*

To implement more precise quality inspection procedure, was hired additional full-time employee, whose responsibilities include inspection of incoming raw material and purchased goods, operational inspection and inspection of outgoing products to Finland. The average wage, taking into account all the costs associated with the employee, is taken 25 euros per hour. Thus, the annual cost associated with the additional employee is 48 000 euros. This sum will mean additional costs associated with improving the quality inspection process of welded contractions in NTM Baltic Ltd.

In the previous part of work, it was estimated the approximate time for quality inspection, using developed inspection documents. Knowing the time allocated for quality inspection process and the number of produced bin lifts we can calculate how much time was spent on the inspection in the last three years. We can also compare these numbers with the data obtained after improvements.

To verify the quality of one assembled bin lift was given 15 minutes (0,25 hour).

Year	**Sent bin lifts, pcs**	**Quality inspection, h**	**Inspection costs, €**	**Possible inspection time, h**	**Possible inspection costs, €**	**Additional appraisal costs, €**
2012	487	121,75	3 118,75	96,8	2 420	48 000
2013	513	128,25	3 206,26	102,6	2 565	48 000
2014	528	132,00	3 300,0	105,6	2 640	48 000

Table 14Comparison of current and possible inspection costs

As the costs associated with new employee (additional appraisal costs) are quite high in terms of small enterprise, it is necessary to prove the necessity of improvements and reveal potential economic benefit from reduction of productions losses.

4.3 Internal Failure Costs

Internal Failure Costs are costs occuring prior to delivery or dispatch of the products to the customer:costs of scrap, rework, re-inspection, material review, and downgrading.
(ASQ, 2013)
Developed model for the preparation of quality documents helps to identify defects at an early stage, thus the internal failure costs are relatively decreased. As well as documentation helps to monitor production and to make manufacturing operations more transparent. By using the program time spent on the preparation of documentation is minimal and its filling is not require much time, as there are listed all the main problem places and the possible appearance of defects. In the context of a small subsidiary company, the system can significantly increase the quality and have full accountability of actions before the parent company. If before improvements, defects were detected quite often during assembling, but now the time for assembling is reduced and the appearance of defects at this point is almost equal to zero.

The defected products are considered to be products, semi-finished product (assembly part), work that does not meet the quality standards or technical specifications. Defects include two major types of production loss: scrap and rework (Figure 38); as well as the fault of a third-party entity (a supplier with low-quality raw materials), the fault of the worker, due to technical or technological reasons (failure of technical equipment). *(J.J.Korinichev, 2010)*

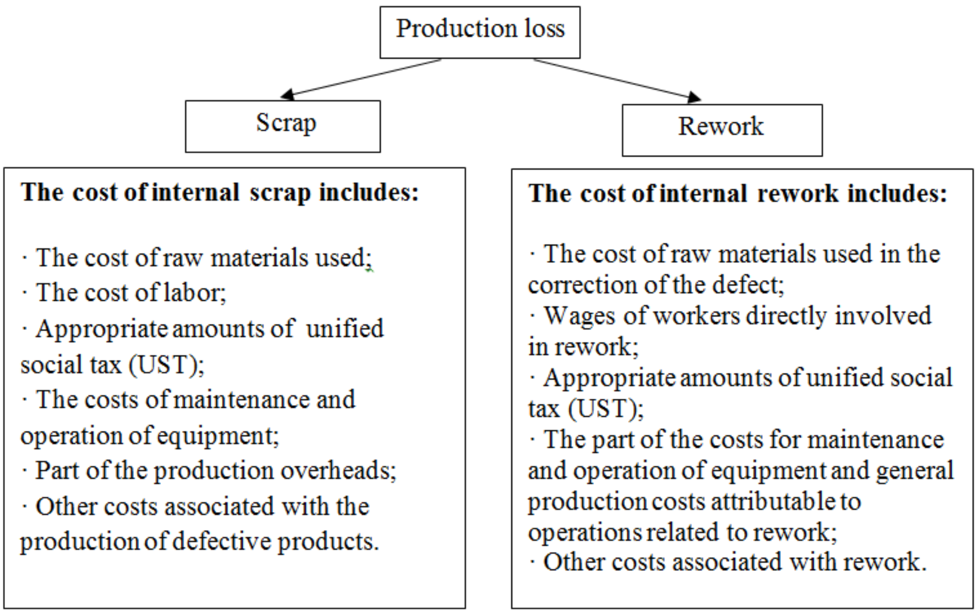


Figure 38 Two main types of production losses

Additionally to the defects described in the previous chapter, in this paper will be calculated the cost of rework and scrap, in case of discrepancy between measured dimensions and those that are indicated in the inspection card. For every new product production foremen in NTMB makes the calculation, which then is added to the accounting program Books. Besides calculations on the finished products, foremen makes the calculations for intermediate products/semi-finished products, where are identified used material and spent working time on it. This data from calculations is taken as a basis for calculation of internal failures in the present work.

4.4 Scrap and rework costs calculation (detection at early stage)

Cost of raw material/purchased components: these costs are associated with materials and/or components that are parts of the inspecting subassembly. These costs take place not only in case of irreparable defect (scrap) of the construction, but also in some cases of rework. During reworks can be cut/removed items, which are already unusable. The quality of such products suffers during their removal.

Auxiliary material: to calculate the auxiliary materials (for example, welding wire) that that were used to manufacture one unit of products, NTMB uses 10 percent of all spent materials on the product.

Spent working time: the time for making one unit of production.

Rework/new product: the time spent on rework or making a new unit of product. This time is cannot be calculated with 100% accuracy, because it depends on many factors. In the table below is being given average time, revealed experimentally.

Re-inspection: the time spent on reinspection of subassemblies. In the table below are used same values as in the previous chapter for inspection of different subassemblies.

Overhead expenses or manufacturing overhead: are factory-related costs. Overhead costs include items such as depreciation of factory building, property taxes and machinery repairs. NTMB uses ten percent from the total spent working time on the products and multiplied by the labor costs.

Defect code	**Produc-tion loss**	**Raw material, €**	**Auxiliary material, €**	**Spent work. time, h**	**Rework /new products, h**	**Re-inspection, h**	**Labor, €**	**Over-head, €**	**Total costs, €**
AF_01	scrap	140.3	14.03	3.98	4.66	0.08	25	21.6	**393.93**
AF_02	rework	4.26	0.43	0.1	0.16	0.08	25	0.66	**13.85**
AF_03	rework	0	0	0.12	0.5	0.08	25	1.55	**19.05**
AF_04	rework	0	0	0.13	0.22	0.08	25	0.88	**11.63**
AF_05	rework	9.98	1	0.33	0.45	0.08	25	1.95	**34.43**
AF_06	rework	0	0	0.4	0.23	0.08	25	1.58	**19.33**
AF_07	rework	0	0	0	1.5	0.08	25	3.75	**43.25**
CP_01	rework	0	0	0	0.3	0.03	25	0.75	**9**
CP_02	scrap	34.81	3.48	1.76	1.9	0.03	25	9.15	**139.69**
CP_03	rework	0	0	0.2	0.25	0.03	25	1.13	**13.13**
CO_01	rework	0	0	0.05	0.08	0.02	25	0.33	**4.08**
CO_02	rework	0	0	0	0.25	0.02	25	0.63	**7.38**
CO_03	rework	0	0	0	0.25	0.02	25	0.63	**7.38**
ALL_01	rework	0	0	0	1	0.04	25	2.5	**28.5**
H(ramj)	rework	0	0	0.13	0.22	0.08	25	0.88	**11.63**
L (ear)	scrap	140.3	14.03	3.98	4.66	0.08	25	21.6	**393.93**
L(bush.)	rework	4.26	0.43	0.05	0.1	0.08	25	0.38	**10.82**
L(kläm)	rework	3.50	0.35	0.38	0.45	0.08	25	2.08	**28.68**
L(arm_1)	scrap	34.81	3.48	1.76	1.9	0.03	25	9.15	**139.69**
L(arm_2)	scrap	34.81	3.48	1.76	1.9	0.03	25	9.15	**139.69**
L(arm_3)	scrap	34.81	3.48	1.76	1.9	0.03	25	9.15	**139.69**
L (arm)	scrap	34.81	3.48	1.76	1.9	0.03	25	9.15	**139.69**
L (f_1)	rework	9.4	0.94	0.08	0.13	0.02	25	0.53	**16.62**
L (f_2)	rework	9.4	0.94	0.08	0.13	0.02	25	0.53	**16.62**
L (ft_3)	rework	9.4	0.94	0.08	0.13	0.02	25	0.53	**16.62**
H(fäste)	rework	1.59	0.16	0.07	0.1	0.02	25	0.43	**6.93**
L(lyftar)	rework	0	0	0	0.45	0.08	25	1.13	**14.38**
H(lyft.)	rework	0	0	0	0.3	0.08	25	0.75	**10.25**
H (k-g)	rework	0	0	0	0.5	0.08	25	1.25	**15.75**
H (k-k)	rework	0	0	0	0.45	0.08	25	1.13	**14.38**
L (k-r)	rework	0	0	0	1.45	0.08	25	3.63	**41.88**

Table 15 Scrap and rework costs calculations

4.5 Scrap and rework costs calculation (at late stage)

Same defects that are being identified prior to dispatch would have additional time losses for disassembling and reassembling. It is at least two additional types of internal losses, Moreover, such defect detection on late production stages of the bin lift or other products often leads to delay of the execution of all works and getting the refuse collection vehicle to the customer.

The average time for bin lift disassembling and reassembling is 1.5 hour, as depending on the type of defect, it is often not necessary to disassemble the whole construction and at the same time, full disassembling mostly takes at least one and half time more than assembling. In addition, we have to take to account the additional time for priming of components that are given in the table below as a new column. Data given in the Table 16 are obtained experimentally and can be potentially higher, as it affects many different factors.

The data in column *Total costs of rework/scrap* are costs obtained in previous table (Table 16) by summarizing used materials and spent work on product manufacturing and correction. Cost for re-inspecton are sutracted.

Column *Total costs at late stage* means that sum of the all costs related to rework or scrap that were identified before improvements of quality inspection process.

Column *Re-inspection* contains time that was allocated for quality inspection of the assembled bin lift.

Last column *Difference* shows how much company loses each time, inspecting bin lift on the assembling stage.

Quality inspection was carried out at the final stage, as the company did not have enough resources for more accurate isnpection and preparation of the quality inspection documents.

Defect code	Produc-tion loss	Total costs of rework/scrap, €	Disassemble + Reassemble, h	Additional Priming, h	Re-inspection, h	Labor costs, €	Total costs at late stage, €	Difference, €
AF_01	scrap	391.93	1.50	0	0.25	25	**434.43**	40.5
AF_02	rework	11.96	1.00	0.08	0.25	25	**43.96**	30.11
AF_03	rework	17.05	1.50	0.08	0.25	25	**61.55**	42.5
AF_04	rework	9.63	1.50	0.1	0.25	25	**54.63**	43
AF_05	rework	32.43	1.50	0.15	0.25	25	**78.68**	44.25
AF_06	rework	17.33	1.00	0.5	0.25	25	**59.83**	40.5
AF_07	rework	41.25	1.50	0.5	0.25	25	**96.25**	53
CP_01	rework	8.25	0.50	0.08	0.25	25	**27.75**	18.75
CP_02	scrap	138.94	0.80	0	0.25	25	**163.94**	24.25
CP_03	rework	12.38	0.80	0	0.25	25	**37.38**	24.25
CO_01	rework	3.58	0.50	0.1	0.25	25	**23.58**	19.5
CO_02	rework	6.88	0.50	0.1	0.25	25	**26.88**	19.5
CO_03	rework	6.88	0.50	0.1	0.25	25	**26.88**	19.5
ALL_01	rework	27.5	1.50	1	0.25	25	**95**	66.5
H(ramjärn)	rework	9.63	0.80	0.1	0.25	25	**37.13**	25.5
L (ear)	scrap	391.93	1.50	0	0.25	25	**434.43**	40.5
L(bushing)	rework	8.87	1.00	0.1	0.25	25	**41.37**	30.55
L(klämplat)	rework	26.67	1.00	0.15	0.25	25	**60.42**	31.74
L (arm_1)	scrap	138.94	1.20	0	0.25	25	**173.94**	34.25
L (arm_2)	scrap	138.94	1.20	0	0.25	25	**173.94**	34.25
L (arm_3)	scrap	138.94	1.20	0	0.2	25	**173.94**	34.25
L (arm)	scrap	138.94	1.20	0	0.25	25	**173.94**	34.25
L (f_1)	rework	16.12	1.40	0.15	0.25	25	**59.87**	43.25
L (f_2)	rework	16.12	1.40	0.15	0.25	25	**59.87**	43.25
L (ft_3)	rework	16.12	1.40	0.15	0.25	25	**59.87**	43.25
H (fäste)	rework	6.42	1.00	0.15	0.25	25	**40.17**	33.24
L (lyftarm)	rework	12.38	1.20	0	0.25	25	**47.38**	33
H (lyftarm)	rework	8.25	1.50	0	0.25	25	**50.75**	40.5
H (k-g)	rework	13.75	1.50	0	0.25	25	**56.25**	40.5
H (k-k)	rework	12.38	1.50	0	0.25	25	**54.88**	40.5
L (k-r)	rework	39.88	1.50	0	0.25	25	**82.38**	40.5

Table 16 Scrap and rework costs calculation detected on late inspection stage

4.6 Results of improvements

Improved quality inspection process of welded construction cannot fully prevent the appearance of internal failures, but it eliminates dispatch of the defective product to parent company in Finland. Starting from January 2015 has not been received any complaint concerning bin lifts. The absence of complaints proves the effectiveness of improved quality inspection processes.

The most common bin lift defects for last three years were categorized with using developed defect codes and added to *Table 18*. This table does not consider absolutely all the defects of bin lifts during last threee year, but only a part of which information is remained. These amounts are not finite sums and do not show all losses, relate dto bin lift. Nevertheless, available data allows to compare current production losses and thereis possible reduction, in case of quality inspection process improvement.

The column *Late-stage inspection* shows the cost of production losses that were caused by scrap and rework, in case of quality inspection at late stage. Data in this column is taken from *Table 16*.

The column *Early-stage inspection* shows how these costs could be reduced, if quality inspection was performed between differet operations, avoiding appearane of defects on lates stages. Data is taken from *Table 16.*

Total, late stage inspection – shows how much was spent on rework and scrap during last three years. *Total, ealry stage inspection* shows how much could be spent, if quality inspection process was improved. (Table 18)

Despite the fact that the losses in the Table 18 are quite small, in a small subsidicary company even amount of 12 000 and 7000 euros have great importance. Especially, considering the fact that bin lifts represent 19 percent of total sales,

	Occurrence of defects per year, pieces			Total costs of rework or scrap	
Defect code	**Year 2012**	**Year 2013**	**Year 2014**	**Late-stage inspection, €**	**Early-stage inspection, €**
AF_01	2	4	5	**434.43**	**393.93**
AF_02	2	2	2	**43.96**	**13.85**
AF_03	5	4	5	**61.55**	**19.05**
AF_04	3	3	4	**54.63**	**11.63**
AF_05	3	3	4	**78.68**	**34.43**
AF_06	2	4	5	**59.83**	**19.33**
AF_07	2	2	3	**96.25**	**43.25**
CP_01	3	4	6	**27.75**	**9.0**
CP_02	4	2	3	**163.94**	**139.69**
CP_03	4	2	3	**37.38**	**13.13**
CO_01	3	2	4	**23.58**	**4.08**
CO_02	4	2	7	**26.88**	**7.38**
CO_03	2	2	3	**26.88**	**7.38**
ALL_01	23	22	22	**95**	**28.5**
H (ramjärn)	3	2	3	**37.13**	**11.63**
L (ear)	3	7	2	**434.43**	**393.93**
L (bushing)	3	2	3	**41.37**	**10.82**
L (klämplat)	4	2	5	**60.42**	**28.68**
L (arm_1)	2	2	3	**173.94**	**139.69**
L (arm_2)	4	3	3	**173.94**	**139.69**
L (arm_3)	7	2	4	**173.94**	**139.69**
L (arm)	3	2	6	**173.94**	**139.69**
L (f_1)	6	6	6	**59.87**	**16.62**
L (f_2)	2	7	3	**59.87**	**16.62**
L (ft_3)	4	4	2	**59.87**	**16.62**
H (fäste)	5	8	2	**40.17**	**6.93**
L (lyftarm)	6	4	5	**47.38**	**14.38**
H (lyftarm)	3	4	3	**50.75**	**10.25**
H (k-g)	5	3	4	**56.25**	**15.75**
H (k-k)	9	3	3	**54.88**	**14.38**
L (k-r)	8	2	2	**82.38**	**41.88**
Total, late stage inspection	**12635.71**	**12776.04**	**12784.5**		
Total, early stage inspection	**7017.7**	**7715.6**	**7455.7**		
Difference	**40%**	**42%**	**40%**		

Table 17 Comparison of the internal failure costs

The result of calculations shows that interoperable monitoring as well as quality inspection in the early stages is required. Production losses of the most common and frequently met defects during last free years have been analyzed and compared with possible losses after changes in quality inspection procedures. Production losses could be reduced by almost 40%.

Year	Sent bin lifts, pcs	Proceeds, €	Production losses, €	Production losses with improved quality inspection, €
2012	487	287 330	12 635, 71	7 017,7
2013	513	307 800	12 776, 04	7 715, 6
2014	528	327 360	12 784,50	7 455, 7

Table 18 Forecasting of possible reduction of internal production losses

For quality inspection processes modelling and documents development was used CASE software *AllFusion Process Modeler r7* with student license. New name of this program is CA ERwin Data Modeler. Price of this software vary fro 3 000 to 3 500 euros, depending on the number of users or can be done a licencing agreement for two-three years with monthly payments. And as was mentioned above, will be hired worker additional full-time worker. Thus, improved quality inspection process will not bring immediate profits and a sharp reduction in losses. Nevertheless, when such investments may provide additional long-term economic benefits with no additional up-fron costs, the th investments can be judged as a rational expenditure of resources.

4.7 Future work

The most important task in the future is to make analysis of the defects in other product groups in NTM Baltic Ltd. Fortunately other products not have so many different models and their analysis will take less time, than analysis of bin lifts. The data obtained will be processed in the same way as described in the work: critical dimensions will be elaborated and common defects will be divided into groups. Then, based on the created model, separate model will be made for each product group, in order to create quality inspection documents.

CONCLUSION

The present Master's Thesis was aimed at the analysis and improvement of quality inspection processes at NTM Baltic Ltd. In order to achieve a stated aim, it was necessary to perform next tasks: to identify defect causal factors of steel constructions, using Cause-and-Effect analysis; to develop guidelines for improved incoming/inter-operational/outgoing quality inspection procedures; and to develop functional model using IDEF0 method for rapid and flexible quality inspection. The work consists of four main chapter.

The first chapter gives an overview of NTM Baltic Ltd, its Finnish parent company NTM and main product groups. Besides that, during this chapter explains the choice of the object of study – bin lifts of refuse collection vehicles. It was selected the largest and the most problematic group of products, to justify the need for improved quality inspection on the example of specific defects of the bin lifts. Additionally, this chapter gives an overview of the current quality inspection process and its weaknesses.

The second chapter describes different defect causal factors of steel construction and as a basis for analysis were taken the most frequently met defects of bin lifts. Main causes are presented as a Ishikawa diagram. By a group of four members was determide the relative importance of the defect causing factors of the steel products. Further quality inspection improvements relate mainly to selected causes.

The third chapter of this work is dedicated to the quality inspection procedures improvement. To reduce different kinds of production losses, during this works two main options are considered - the increasing of quality inspection stages and the improvement of existing ones. As main production operation is welding at NTM Baltic Ltd, the first part of this chapter was aimed at the development of regulatory documents for quality inspection of welded joints. These documents set the improved control methods by visual inspection and measurement control of the steel welding joints that are made by MIG/MAG welding methods. Incoming inspection of raw material and purchased components has to be also improved to prevent substandard goods from entering the production. Furthermore, additionally to incoming inspection the inter-operational inspection has to be performed, to avoid defective semi-finished products after sheet metal processing. It also eliminates the situations where a welder discovered that the semi-finished goods are not properly processed during the welding.

Since NTM Baltic Ltd produces at least ten different bin lift weekly additionally to other twenty product groups, the time for inspection is limited. In order to make quality inspection more accurate and rapid, during this work general dimensions for the measurement were developed. Despite the external similarity of bin lifts, each model has its own characteristics, therefore universal schemes have been developed for inspection of the different sub-assemblies, without using a large number of drawings. The schmenes will include critical dimensions that have to be measured. For each dimension is given special character. As a basis for quality inspection documents development was used AllFusion Process Modeler programe that is based on IDEF0 method. The developed block diagram contains detailed information concerning quality inspection process, as well as the numerical value for each critical dimension and possible defects of bin lifts. All the required references on standards, measurement tools and drawing numbers have been also given in the model.

The fourth chapter reveals the economic benefit of the improved quality inspection process. Despite the fact that the number of control operations is increased, due to the use of developed inspection documents the time for quality inspection per one bin lifts is minimal and even less than the time allocated for inspection of assembled bin lift. Calculations of the average inspection time for one bin lift is based on the time norms for visual weld inspection and measurement control of different sub-assemblies. Knowing cost of quality is crucially important for every organization. Therefore, in the end of this work is given economic overview of the possible defects, or rather of resulting from defects different production losses. Improved quality inspection process of welded construction cannot fully prevent the appearance of internal failures, but it eliminates dispatch of the defective product to parent company in Finland. The present work demonstrated the economic benefit for the company of the additional quality inspection operations. Due to the offered improvements, it is possible to reduce the production losses for rework or scrap at almost 50%. Furthermore, developed function model reduces the time for preparation of quality inspection documents and the need for a large number of technical drawings.

KOKKUVÕTE

Tiheda tööstuse konkurentsi tingimustes maailmaturul ettevõtted on suunitud optimeerima oma tootmis protsesse ja alandama kulusid. Tänapäeval kvaliteetse toote valmistamine, kvaliteetse töö tegemine ja kliendi rahulolu tagamine kõrgel tasemel ei ole piisavalt. Nende eesmärkide saavutamisega seotud kulusid peavad olema kontrollitavad ja tuvastatavad, et pikaajaline efekt ettevõttele oleks nagu me soovime. Pidevalt kasvavad tootmismahud ja sagedased muudatused joonistes põhjustavad suured tootmiskulusid ettevõttes NTM Baltic OÜ – Soome ettevõtte tütarfirma, mis tegeleb metallkonstruktsioonide valmistamisega.

Käesoleva magistritöö eesmärgiks on keevituskonstruktsioonide kvaliteedi inspekteerimise protsessi analüüs ja parendamine NTM Baltic OÜ jaoks. Püstitatud eesmarkide saavutamiseks oli vaja teostada järgmised ülesanded: tuvastada teraskonstruktsioonide defektide põhjuslikud tegurid, kasutades *Põhjus-Tagajärg-analüüsi*; töötada välja juhised paranenud sisemise/ operatsioonide vahelise / välise kvaliteedi inspekteerimise protseduride jaoks; ja arendada funktsionaalse mudeli kasutades IDEF0 meetodi kiire ja paindliku kvaliteedi inpekteerimiseks. Töö koosneb neljast peamisest peatükis**.**

Esimene peatükk annab ülevaate ettevõttest NTM Baltic OÜ, Soome emafirmast NTM ja peamistest tootegruppidest. Lisaks sellele selgitatakse peatükis välja uurimisobjekt - prügiveoki prügikonteineri tõstuk**.** Kõige suurem ja probleemsem tootegrupp oli valitud selleks, et põhjendada vajadust parema kvaliteedi inspekteerimise protsessi saavutamiseks prügikonteineri tõstuki defektide näitel. Lisaks annab see peatükk ülevaate praegusest kvaliteedi inspekteerimisest ja selle nõrkustest. Üheks peamiseks põhjuseks, miks tõstukite tootmine põhjustab suuri tootmiskulusid, on puudulik kvaliteedi inpekteerimine, mis sageli toimub viimasel tootmise etapil enne kauba saatmist. Juhul kui avastatakse, et sel etapil toote kvaliteet ei küüni kavandatud kvaliteedistandardite tasemeni, siis defektide korrigeerimine või praagi likvideerimine põhjustavad ettenägematuid takistusi ja märkimisväärset ajakadu. Defektide likvideerimine viimasel etapil tähendab konstruktsiooni demontaaži, korduvat pinnakäsitlust, kruntimist ja montaaži, misjärel toode on vaja uuesti konrollida.

Teises peatükis kirjeldatakse erinevate tegurite poolt põhjustatud defekte teraskonstruktsioonidel. Analüüsi aluseks võeti kõige sagedamini korduvad defektid prügikonteineri tõstukitel. Peamised põhjused on esitatud *Põhjus-Tagajärg-diagrammis*; mida tuntakse ka Ishikawa diagrammi nime all (selle looja järgi), millised näidatakse sildistatud nooltena ja mis sisenevad peamist põhjust kujutavasse noolde. Toodete kvaliteeti mõjutavad mitmed tegurid, kuid peamiseks eesmärgiks piiratud ressursside olukorras siiski on see, et on vaja keskenduda konkreetsetele teguritele. Seetõttu tootejuhtide korraldusel indentifiseeriti tähtsamad:

1. Kvaliteedi inspekteerimine erinevate operatsioonide vahel (peale lehtmetalli töötlemist; enne pinnakäsitlust ja enne kruntvärvimist);
2. Sissetulevate metalli ja ostutoodete inspektsioon;
3. Kasutatud tehnoloogilised meetodid keevitamisel, painutamisel ja lõikamisel;
4. Tähtsamate parameetrite mõõtmine (kriitilised mõõtmed, kasutatud mõõtmisvahendid, kulunud aeg).

Käesoleva töö kolmas peatükk on pühendatud kvaliteedi inspekteerimise protsessi parendamisele. Sihtväärtustele vastava kvaliteedi ja toimivuse saavutamiseks peetakse kvaliteedi inspekteerimise etappide arvu suurendamist ja olemasolevate protsesside täiustamist ning parendamist. Kuna üks peamisi tootmisprotsesse ettevõttes NTM Baltic on keevitamine, siis käesoleva peatüki esimese osa eesmärgiks oli keevituse kvaliteedikontrolli reguleerivate dokumentide loomine. Loodud dokumendid kehtestavad eeskirjad keevisliidete visuaalse kontrolli ja mõõtmise kohta, mis on tehtud MIG -/ MAG-keevituse meetodiga. Metalli ja ostutoodangu sisemine kontroll nõuab samuti olulisi muudatusi, et vältida mittekvaliteetse materjali kasutamist tootmises. Lisaks ettevõtte sisemisele inspekteerimisele on tarvis läbi viia operatsioonide vahelist inspektsiooni, mille eesmärk on defektsete pooltoodete likvideerimine peale lehtmetalli töötlust. Niisugune inspektsioon välistab olukorra, kus pooltoodete halb kvaliteet avastatakse alles kontruktsiooni keevitamise ajal.

Kuna NTM Baltic toodab igal nädalal lisaks ***prügikonteineri tõstukitele veel*** kakskümmend eri toodet, mistõttu kvaliteedi inpekteerimise aeg on piiratud. Nädalas valmistatakse kuni kümme erinevat tõstukit, mis raskendab inspekteerimist, sest see nõuab tööd paljude tootejoonistega. Selleks, et teha kvaliteedikontolli täpsemaks, kiiremaks ja paindlikumaks kriitiliste mõõtude mõõtmisel, on välja töötatud universaalsed skeemid mõõtude tähestikuliste tähistega. Erinevad mudelid on analüüsitud ja jagatud alamkoostejoonisteks.

Hoolimata välisest sarnasusest on tõstukite tootmise tehnoloogia väga erinev. Seetõttu oli vaja luua mudel paindliku kasutajaliidesega. Mudeli loomiseks, kvaliteedi inpekteerimise protsesside modelleerimiseks ja inspekteerimise dokumentide loomiseks kasutati programmi *AllFusion Protsess Modeler*. Programm põhineb IDEF0 modelleerimiskeelel, mis koosneb hierarhilisest diagrammide jadast, tekstist ja sõnastikust, mis ristviitavad üksteisele ristkülikute ja noolte kaudu. Kasutades *AllFusioni* kasutaja määratletud omadusi on võimalik kiiresti sisestada või muuta kvaliteedi inpekteerimise andmeid, samuti luua dokumente, mille järgi teostatakse inspekteerimist. Arenenud plokkskeem sisaldab arvväärtusi iga kriitilise mõõtme jaoks ja võimalike vigade definitsioone alamkoostejoonistel. Kõik vajalikud viited standarditele, mõõtmisvahenditele ja jooniste numbritele on ka mudelil esitatud. Kvaliteedi inspekteerimise käigus peab inspektor mõõtma määratletud dokumendis esitatud mõõtmed ja kirjutama sinna saadud andmed.

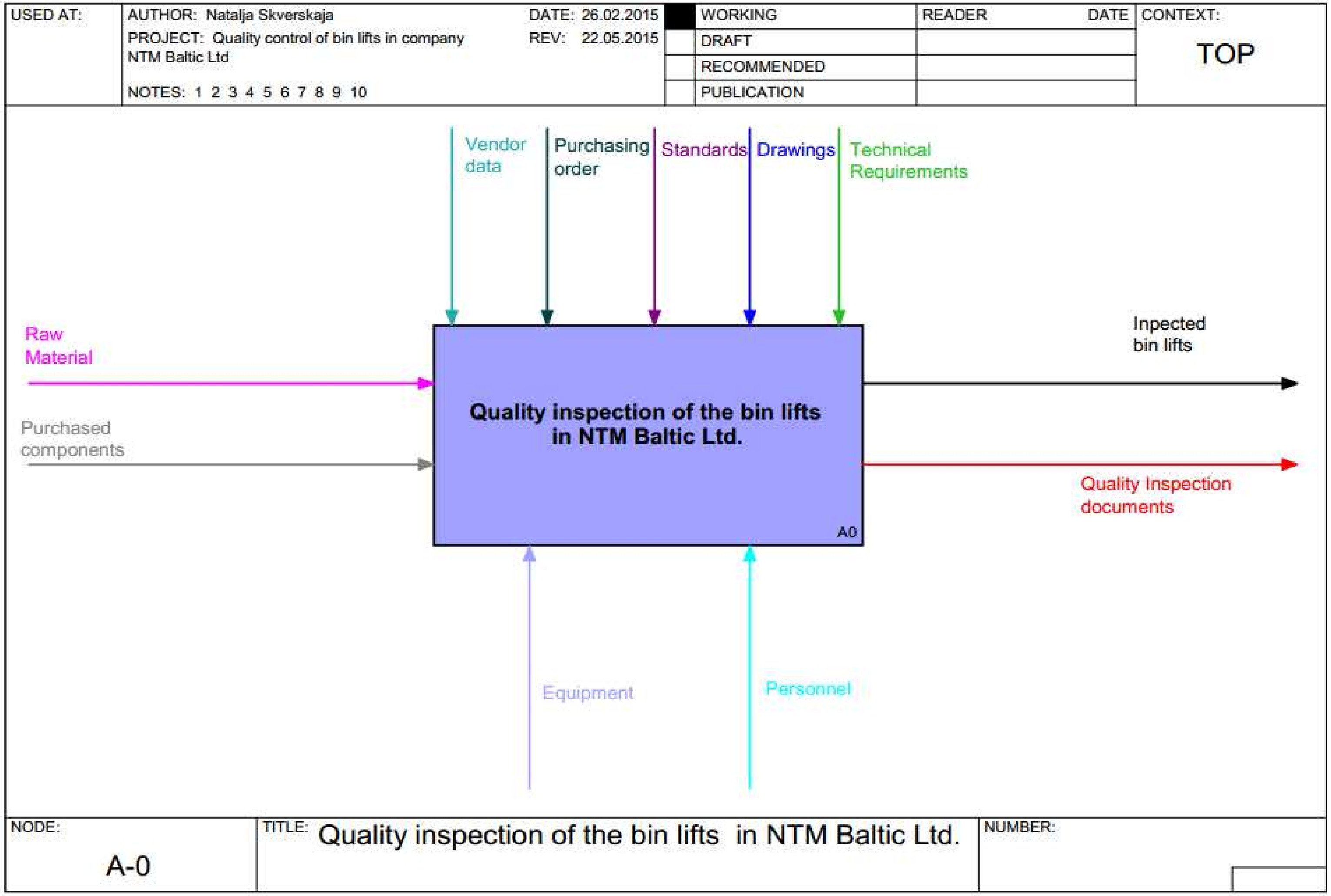
Neljandas peatükis on välja toodud erinevate inspekteerimise protsesside parendatud kvaliteedi majanduslik kasu . Vaatamata sellele, et kontrolli etappide arv on suurenenud, jäi kvaliteedikontolli aeg peaaegu endiseks. Aeg on minimaalne tänu sellele, et inspekteerimise ajal kasutatakse väljatöötatud kontrollidokumente. Keskmise kontolli aja arvutused ühe tõstuki kohta põhinevad visuaalsel kontollil ja erinevate sõlmede mõõtmisel. Igas organisatsioonis on äärmiselt oluline teada kvaliteedi maksumust. Seega selles peatükis on välja toodud võimalike defektide ja nendest tulenevate kulude majanduslik ülevaade. Parema kvaliteedi inspekteerimise protsessiga ei ole võimalik täielikult vältida sisemisi defekte ja praaki, kuid see likvideerib defektsete toodete lähetamise Soome omanikettevõtesse. Käesolev töö näitab ettevõtte majanduslikku kasu täiendavatest kvaliteedi kontrolli toimingutest. Tänu pakutud lahendustele on võimalik vähendada tootmisega seotud kulusid ümbertegemiseks ja vigade parandamiseks peaaegu viiskümmend protsenti. Lisaks võimaldab väljaarendatud funktsiooni mudel organisatsioonis paremini uurida ja käsitleda vigu ning defekte, mis võivad anda väärtuslikku infot vigade vältimiseks. Seda mudelit saab ka kopeerida ja kohandada teiste tootegruppide inpekteerimiseks.

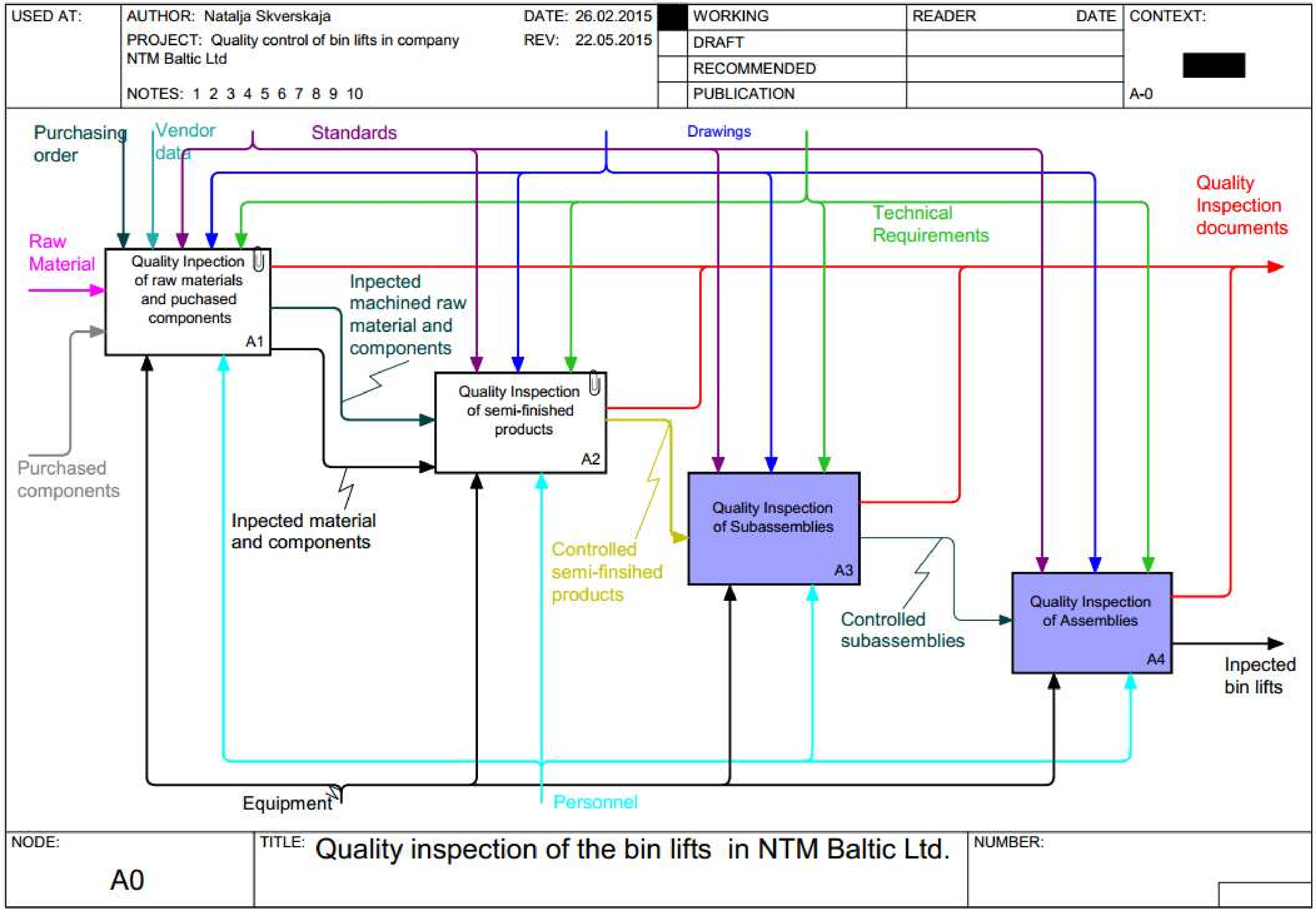
References:

- Advantages and disadvantages of plasma cutting (http://metalurg.su/preimushhestva-i-nedostatki-plazmennoj-rezki.html), March 2012
- ASQ – American Society for Quality, Principles of Quality Costs, Fourth Edition: Financial Measures for Strategic Implementation of Quality Management., USA, 2013. Available: https://books.google.ee/books/about/FCS_Welding_L3.html?id=nY0dRNVPvVIC&hl=en
- By L. Jeffus, L. Bower, Welding Skills, Processes and Practices for Entry-Level Welders:, Book , USA, 2010. Available:
- C.G.Feldmann,The practical guide to business process reengineering using IDEF0, USA, 1998
- CA- Computer Associates International, Inc., AllFusion™ Process Modeler , USA, 2002, Available: http://www.virginia.edu/crmes/stip/BPwin4MG.pdf
- Definition of term Incoming Goods Inspection (http://www.isixsigma.com/dictionary/incoming-goods-inspection/), May 2015
- E.W. McAllister, Pipeline Rules of Thumb Handbook: A Manual of Quick, Accurate Solutions to everyday pipeline engineering problems, UK, 2014
- EN 17637 - Non-destructive testing of welds. General rules for metallic materials
- J.G.Bollinger, Committee on Welding Controls, Control of Welding Processes: Report of the Tekijät National Research Council (U.S.). USA, 1987, Available: https://books.google.ee/books?id=6pIrAAAAYAAJ
- J.J.Korinichev, Audit orhganizacii razlichnyh vidov dejateljnosti, Russia, 2010
- Kita-Shinagawa, Shinagawa-Ku, *Weld Imperfections and Preventive Measures* , Japan, 2015 Available:
- Measuring gauges - http://www.galgage.com/measuring_gauges.html, May 2015
- N.B.Dahotre, S.P.Harimkar, Laser Fabrication and Machining of Materials,USA, 2008,
- NTM-About the company, (www.ntm.fi), May 2015
- R. K.Mobley, Root Cause Failure Analysis , USA, 1999, Available: https://books.google.ee/books?isbn=0750671580
- R. L.Weil, M.W. Maher, Handbook of Cost Management , Canada, 2005,
- R. Wild, Essentials of Operations Management, UK , 2015

- R.Creese, Introduction to Manufacturing Processes and Materials, USA, 1999, Available: https://books.google.ee/books?isbn=0824799143
- R.Mohler, Practical Welding Technology , USA, 1983 Available: https://books.google.ee/books?isbn=0831111437
- S. Mukherjee, Metal Fabrication Technology , New Delphi, 2011
- SAC Joint Venture. Guidelines Development Committee, Recommended Specifications and Quality Assurance Guidelines for Steel Moment, USA, 2000.
- SIS - Swedish Standards Institute (www.sis.se) , May 2015
- T. Swift, FCS Welding L3, Pearson South Africa, 2009
- T.Anderson, Ensuring a topnotch weld inspection program. TPJ – The tube and pipe journal, USA, 2007. Available: (http://www.thefabricator.com/article/testingmeasuring/quality-inspections)
- UNCHS - United Nations Centre for human settlements, Refuse Collection Vehicles for Developing Countries, Habitat, 1988, Available: https://books.google.ee/books?isbn=9211310660
- V.M Baryshev, V.F Belyayev, R.G. Gubaidulin, Production and quality control of steel structures, Russia, 1999
- V.N. Chupyrin, A.D Nikiforov, Handbook for designers, technologists and employees of Quality Department "Technical control in mechanical engineering", Russia, 1987

Appendix 1. Functional model of quality inspection processes, created in AllFusion Process Modeler

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PUBLICATION
READER
DATE
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Purchasing order
Vendor data
Standards
Drawings
Technical Requirements
Quality Inspection documents
Raw Material
Purchased components
Quality Inpection of raw materials and puchased components
A1
Inpected machined raw material and components
Quality Inspection of semi-finished products
A2
Inpected material and components
Controlled semi-finsihed products
Quality Inspection of Subassemblies
A3
Controlled subassemblies
Quality Inspection of Assemblies
A4
Inpected bin lifts
Equipment
Personnel
NODE:
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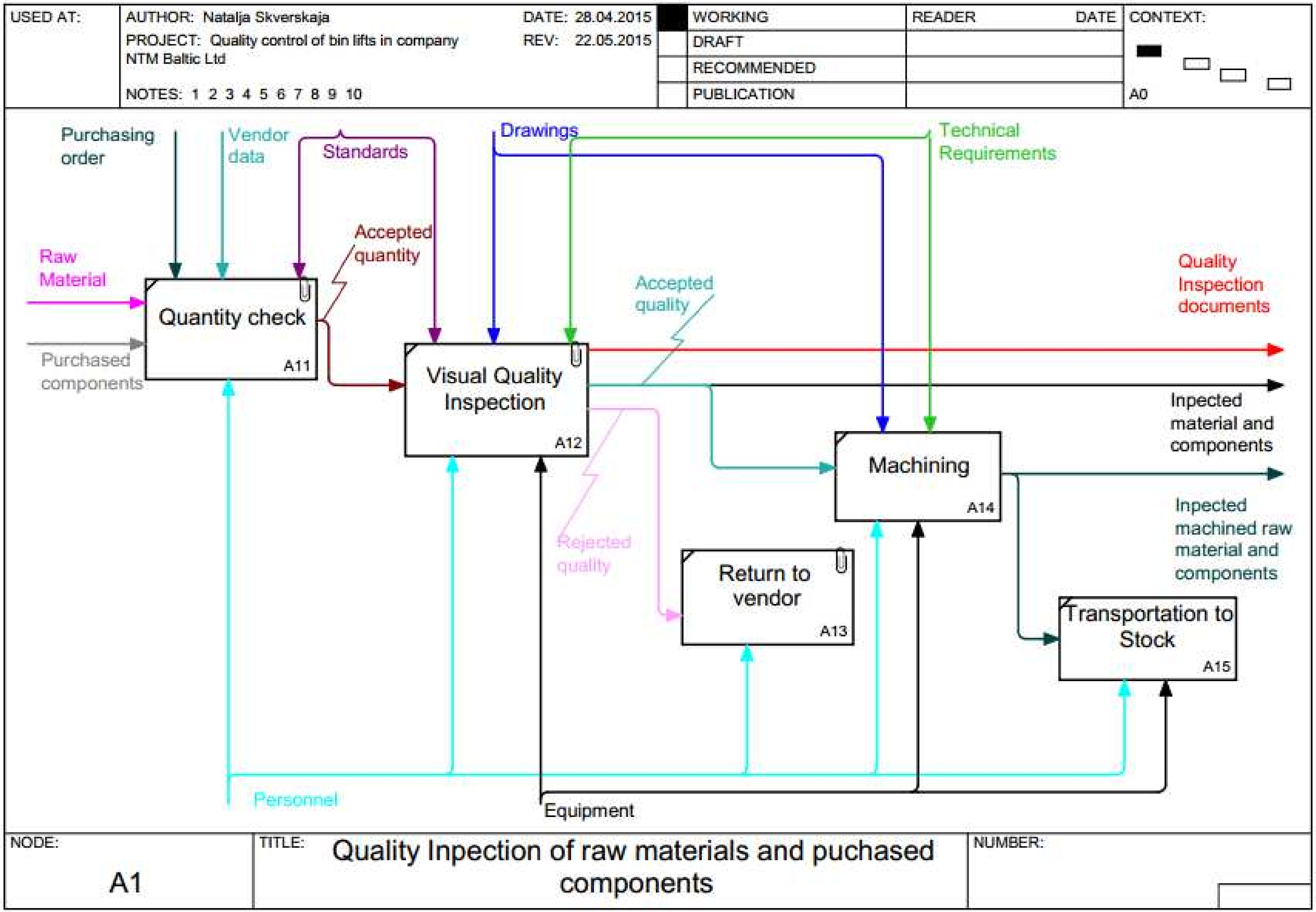
NUMBER: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DATE
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Purchasing order
Vendor data
Standards
Drawings
Technical Requirements
Raw Material
Purchased components
Accepted quantity
Quantity check
A11
Visual Quality Inspection
A12
Accepted quality
Quality Inspection documents
Inpected material and components
Machining
A14
Inpected machined raw material and components
Rejected quality
Return to vendor
A13
Transportation to Stock
A15
Personnel
Equipment
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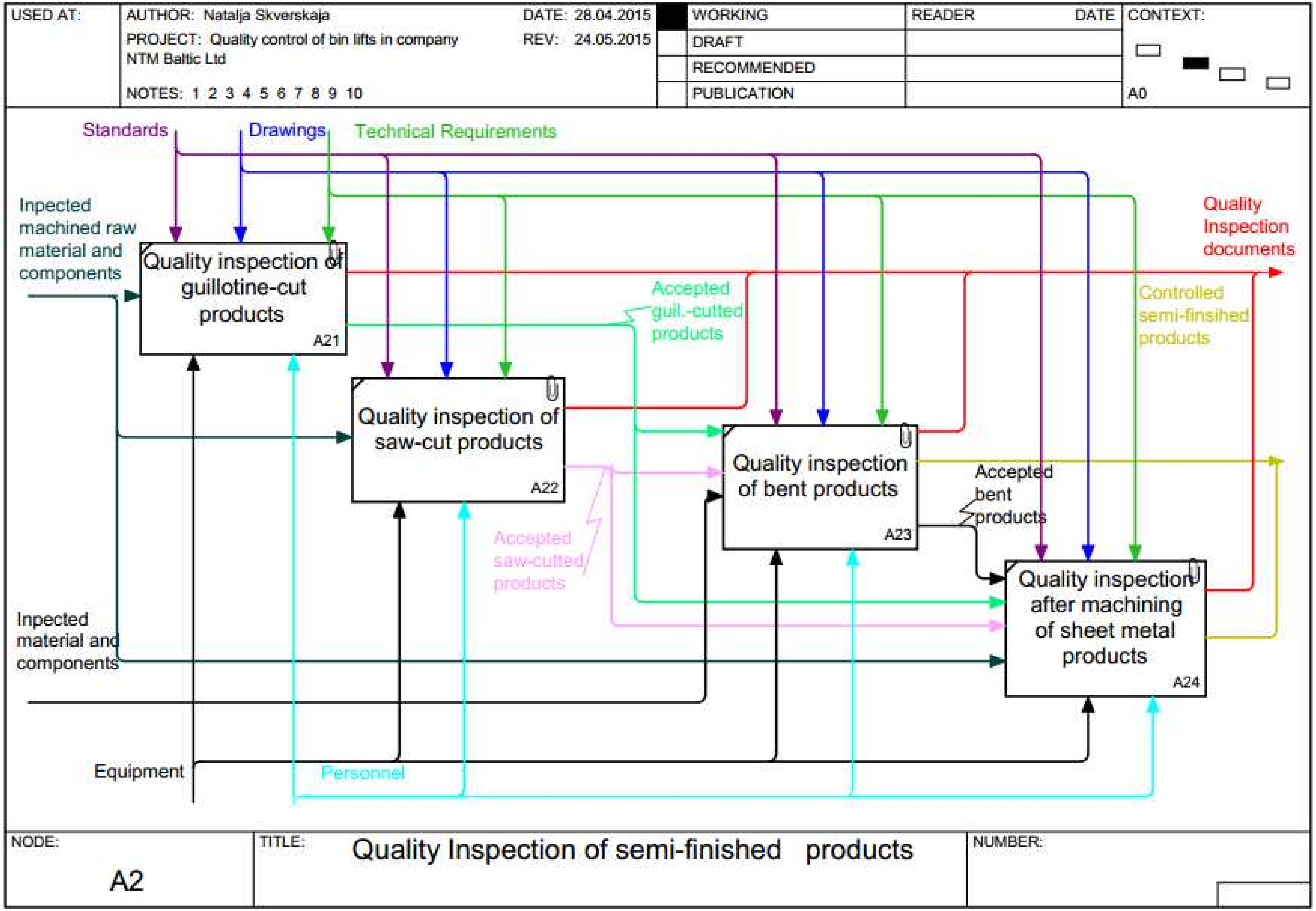
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PUBLICATION
READER
DATE
CONTEXT:
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Standards
Drawings
Technical Requirements
Inpected machined raw material and components
Quality inspection of guillotine-cut products
A21
Quality inspection of saw-cut products
A22
Quality inspection of bent products
A23
Quality inspection after machining of sheet metal products
A24
Accepted guil.-cutted products
Accepted saw-cutted products
Accepted bent products
Controlled semi-finsihed products
Quality Inspection documents
Inpected material and components
Equipment
Personnel
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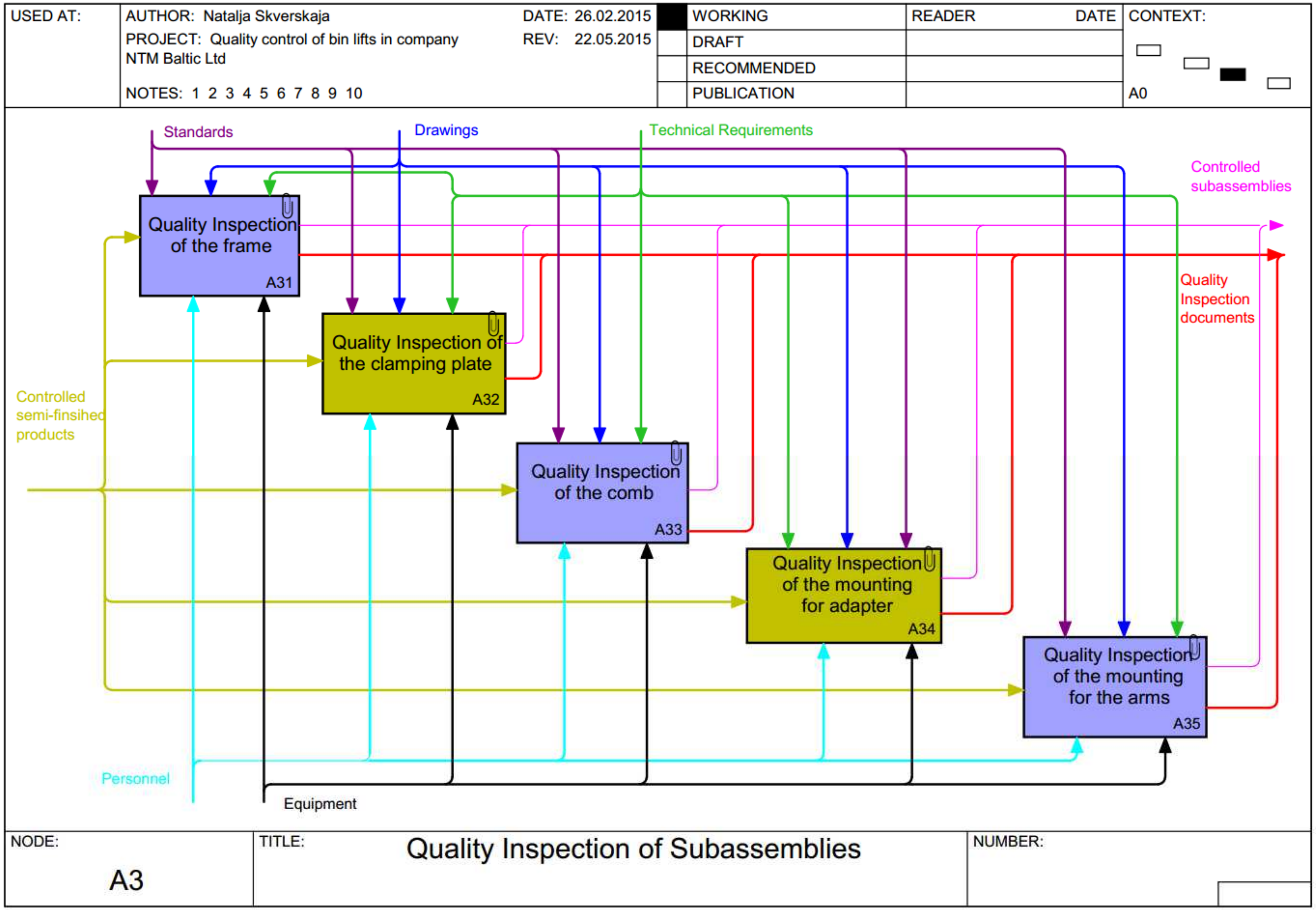
NUMBER: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Drawings
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Controlled subassemblies
Quality Inspection documents
Controlled semi-finsihed products
Quality Inspection of the frame
A31
Quality Inspection of the clamping plate
A32
Quality Inspection of the comb
A33
Quality Inspection of the mounting for adapter
A34
Quality Inspection of the mounting for the arms
A35
Personnel
Equipment
NODE:
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TITLE:
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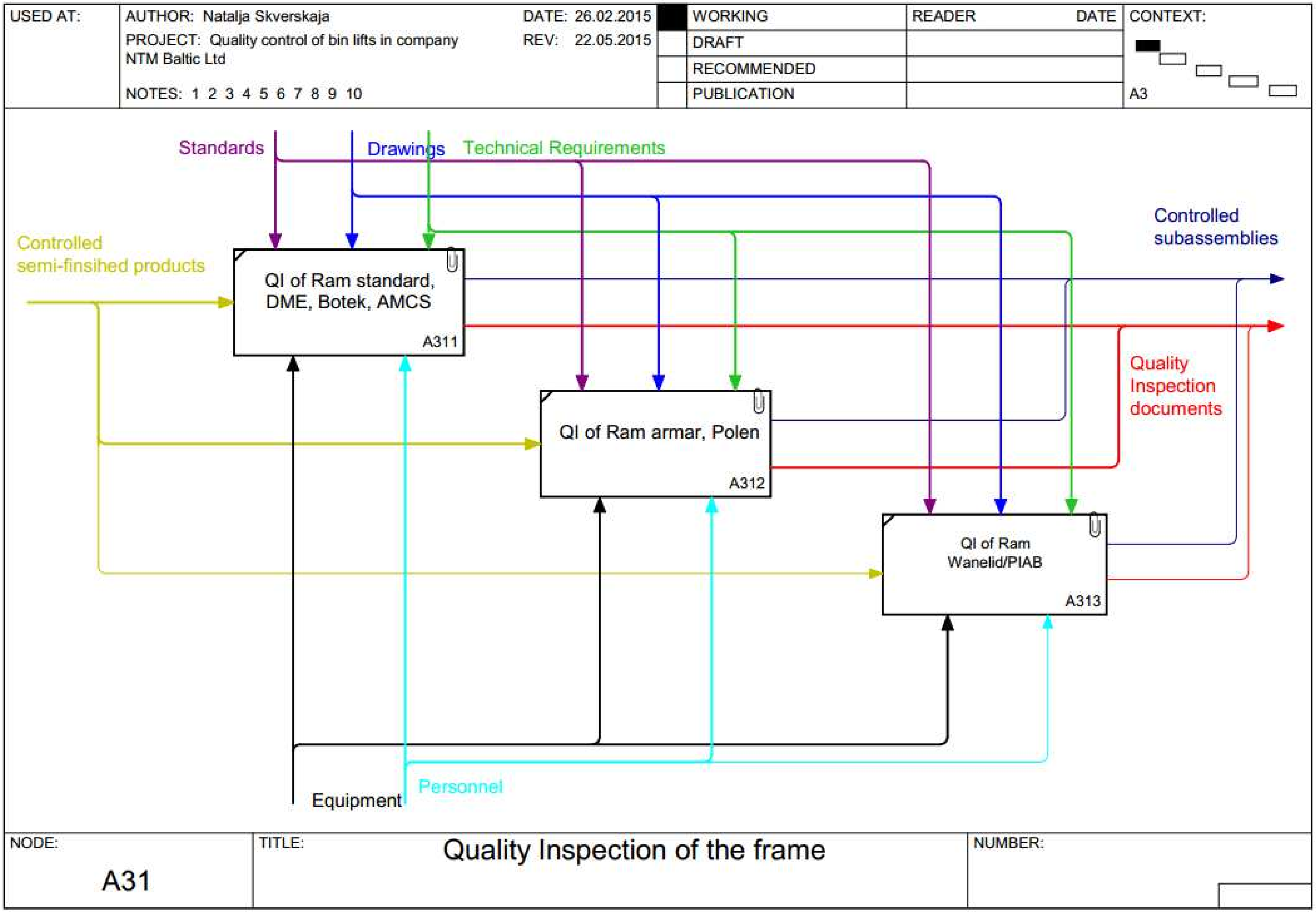
NUMBER: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Drawings
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QI of Ram standard, DME, Botek, AMCS
A311
QI of Ram armar, Polen
A312
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A313
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Equipment
Personnel
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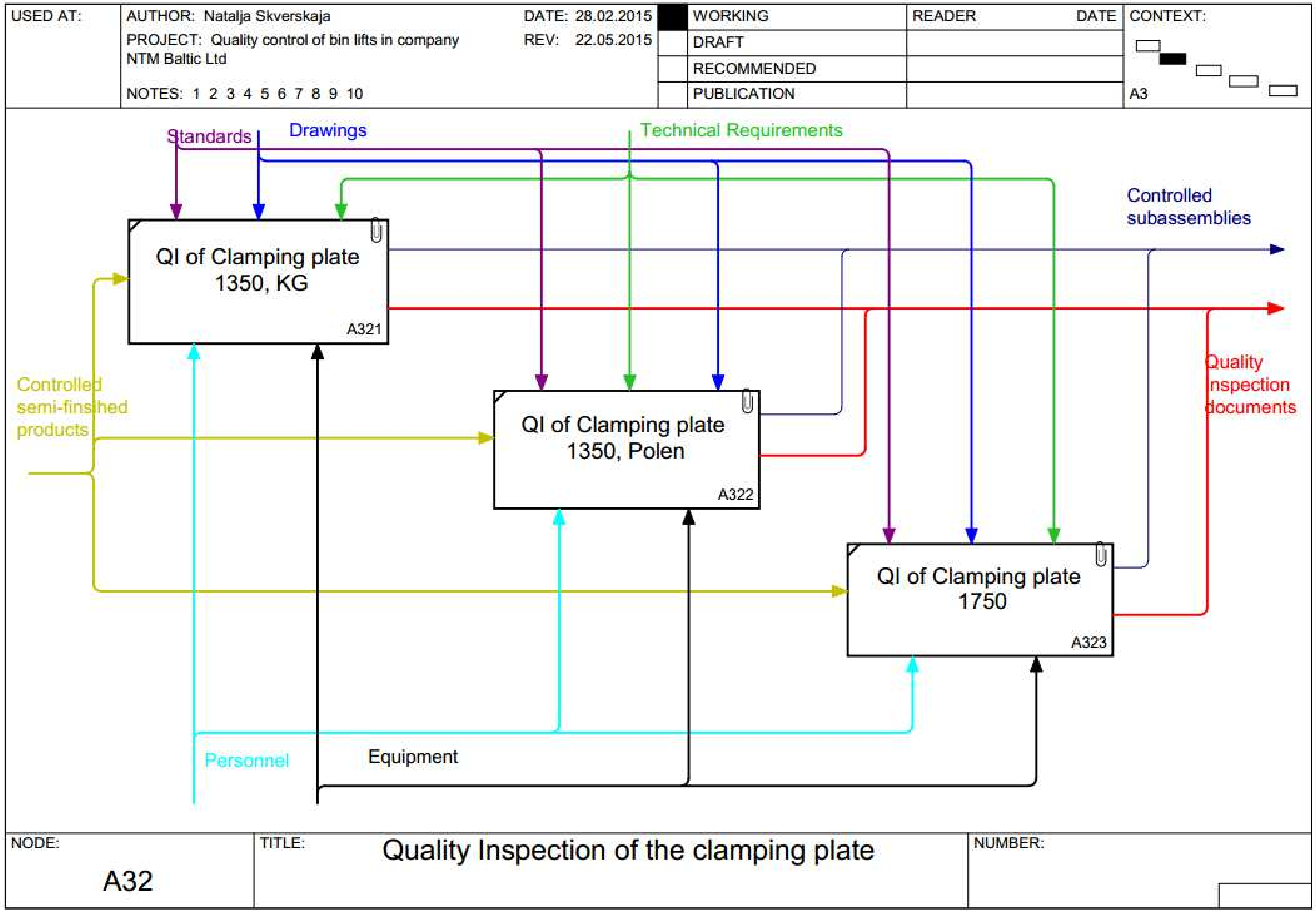
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Standards
Drawings
Technical Requirements
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QI of Clamping plate 1350, KG
A321
Controlled semi-finished products
QI of Clamping plate 1350, Polen
A322
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QI of Clamping plate 1750
A323
Personnel
Equipment
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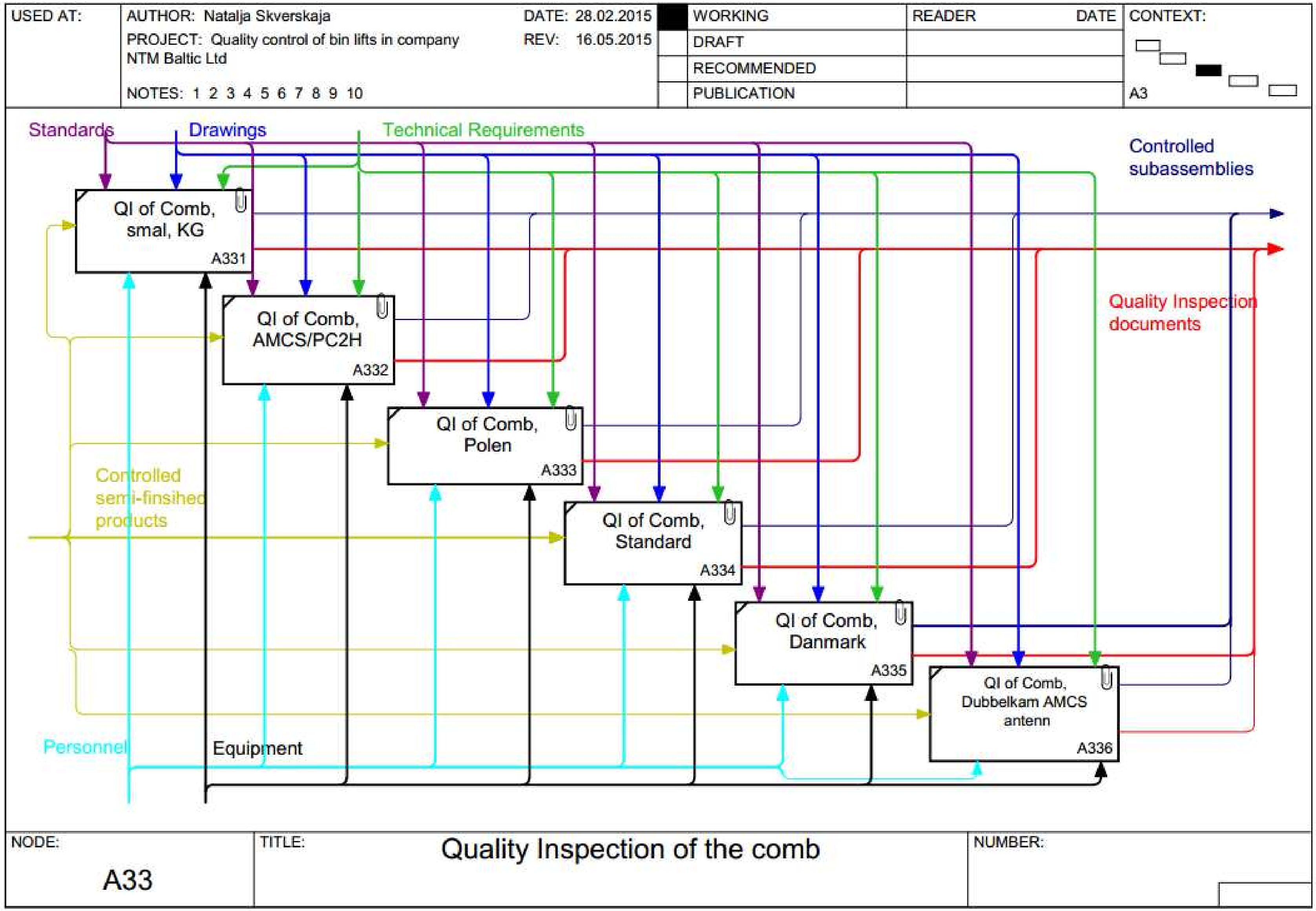
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Standards
Drawings
Technical Requirements
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QI of Comb, smal, KG
A331
QI of Comb, AMCS/PC2H
A332
QI of Comb, Polen
A333
QI of Comb, Standard
A334
QI of Comb, Danmark
A335
QI of Comb, Dubbelkam AMCS antenn
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Personnel
Equipment
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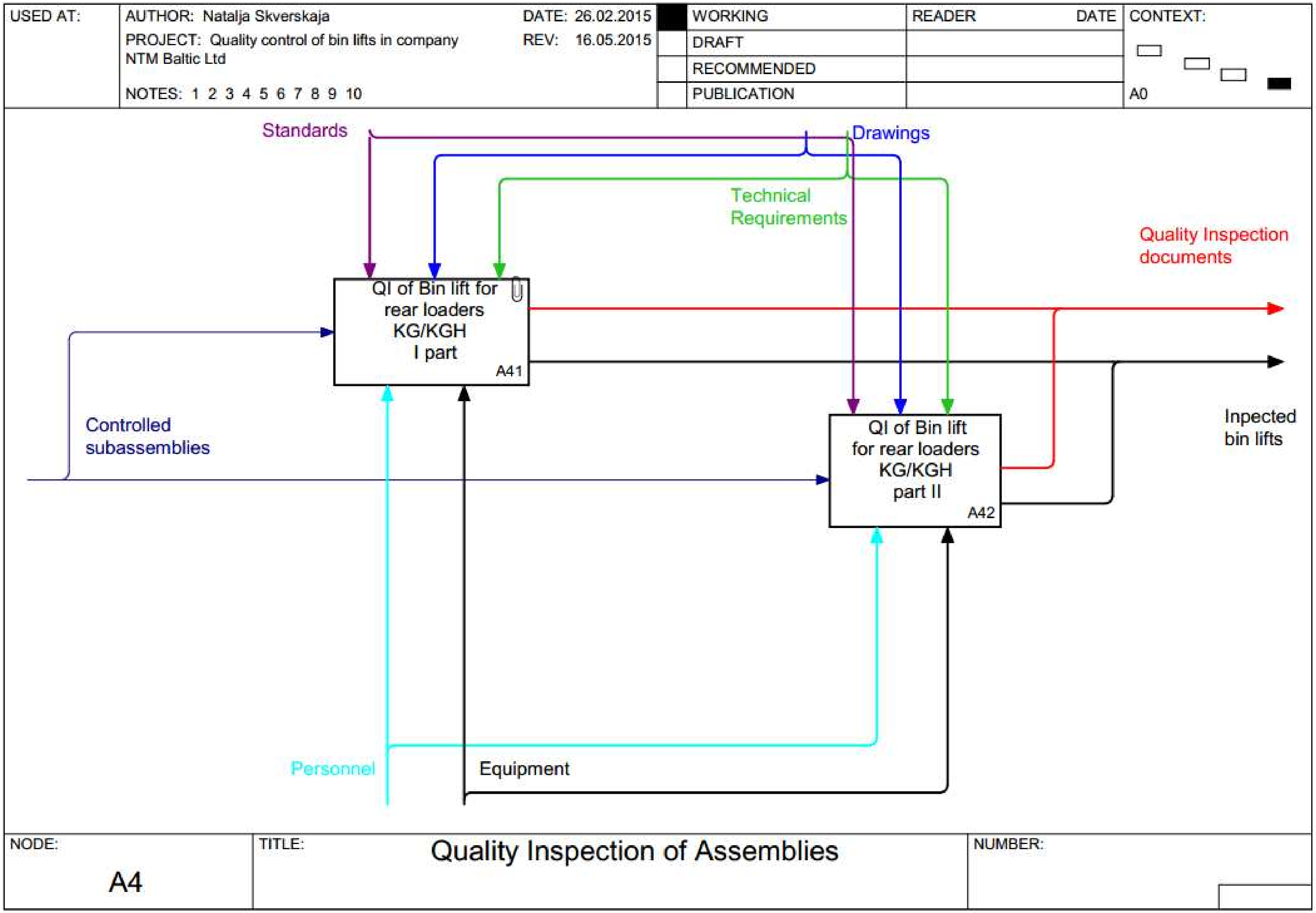
Quality Inspection of the comb
NUMBER: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DRAFT
RECOMMENDED
PUBLICATION
READER
DATE
CONTEXT:
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Standards
Drawings
Technical Requirements
Quality Inspection documents
QI of Bin lift for rear loaders KG/KGH I part
A41
Controlled subassemblies
Inpected bin lifts
QI of Bin lift for rear loaders KG/KGH part II
A42
Personnel
Equipment
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A4
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Quality Inspection of Assemblies
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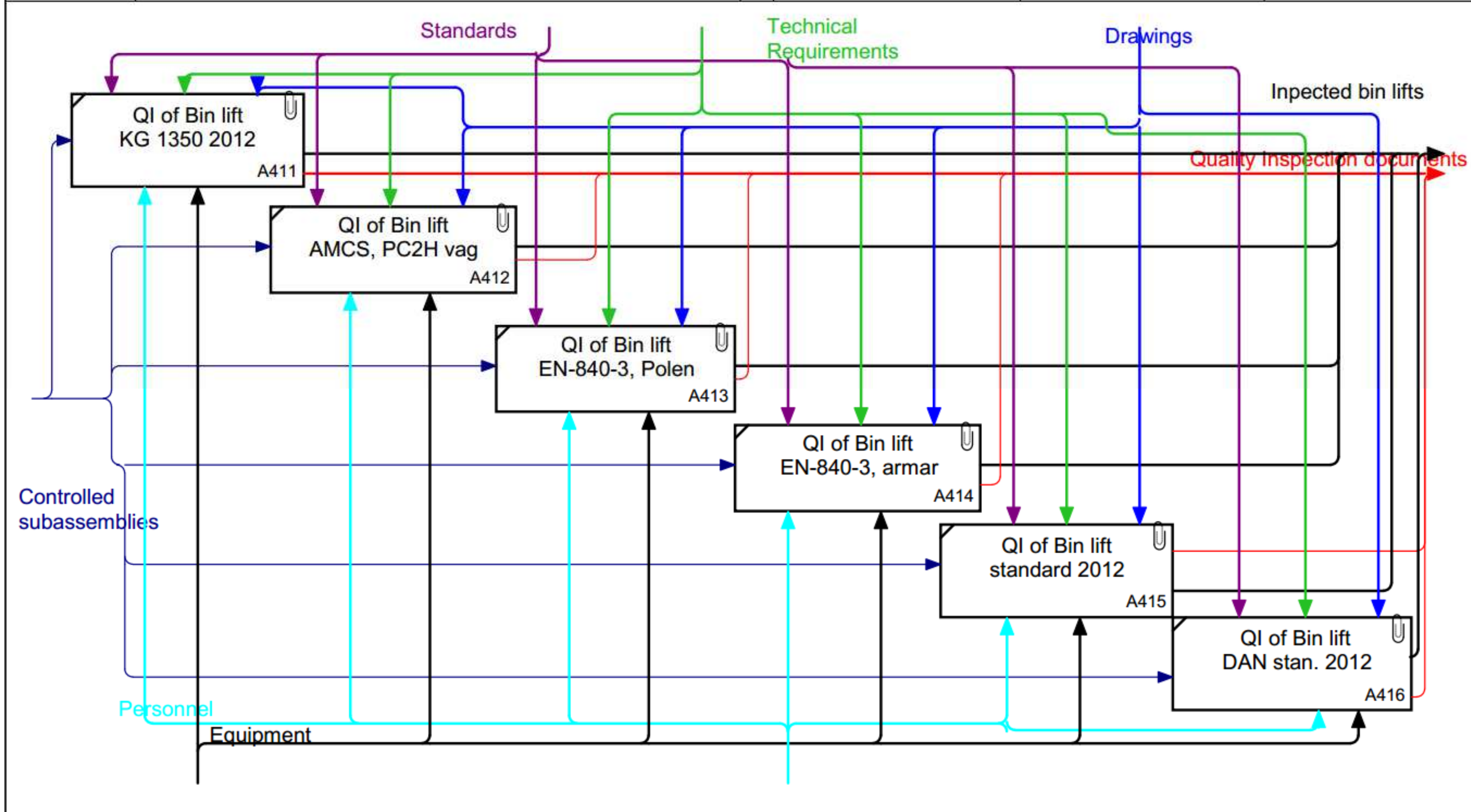

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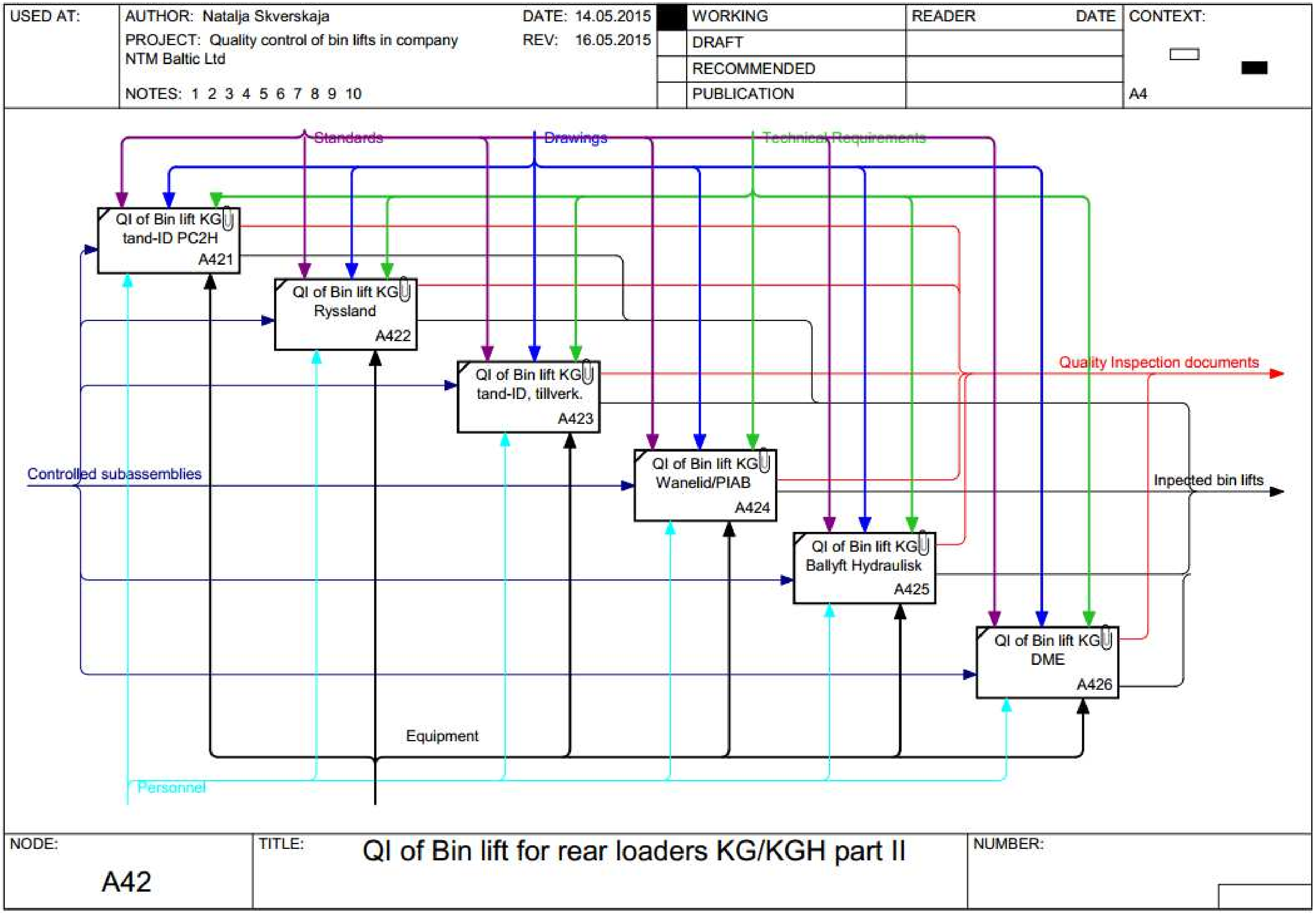
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WORKING
DRAFT
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PUBLICATION
READER
DATE
CONTEXT:
A4
Standards
Drawings
Technical Requirements
QI of Bin lift KG tand-ID PC2H
A421
QI of Bin lift KG Ryssland
A422
QI of Bin lift KG tand-ID, tillverk.
A423
QI of Bin lift KG Wanelid/PIAB
A424
QI of Bin lift KG Ballyft Hydraulisk
A425
QI of Bin lift KG DME
A426
Quality Inspection documents
Controlled subassemblies
Inpected bin lifts
Equipment
Personnel
NODE:
A42
TITLE:
QI of Bin lift for rear loaders KG/KGH part II
NUMBER:

Appendix 2. Developed quality inspection documents

Quality Inspection Documents for Bin Lift Devices
(Rear Loaders, KG/KGH/KGLS group)

Activity

Activity		
Number	**Name**	**Duration**
A0	Quality inspection of the bin lifts in NTM Baltic Ltd.	383,01
A1	Quality Inspection of raw materials and purchased components	245,00
A11	Quantity check	15,00
A12	Visual Quality Inspection	30,00
A13	Return to vendor	60,00
A14	Machining	120,00
A15	Transportation to Stock	20,00
A2	Quality Inspection of semi-finished products	55,00
A21	Quality inspection of guillotine-cutted products	15,00
A22	Quality inspection of saw-cutted products	10,00
A23	Quality inspection of bent products	10,00
A24	Quality inspection after machining of sheet metal products	20,00
A3	Quality Inspection of Subassemblies	25,38
A31	Quality Inspection of the frame	13,95
A311	QI of Ram standard, DME, Botek, AMCS	4,65
A312	QI of Ram armar, Polen	4,65
A313	QI of Ram Wanelid/PIAB	4,65
A32	Quality Inspection of the clamping plate	5,49
A321	QI of Clamping plate 1350, KG	1,83
A322	QI of Clamping plate 1350, Polen	1,83
A323	QI of Clamping plate 1750	1,83
A33	Quality Inspection of the comb	5,94
A331	QI of Comb, smal, KG	0,99
A332	QI of Comb, AMCS/PC2H	0,99
A333	QI of Comb, Polen	0,99
A334	QI of Comb, Standard	0,99
A335	QI of Comb, Danmark	0,99
A336	QI of Comb, Dubbelkam AMCS antenn	0,99
A34	Quality Inspection of the mounting for adapter	0,00
A35	Quality Inspection of the mounting for the arms	0,00
A4	Quality Inspection of Assemblies	57,63
A41	QI of Bin lift for rear loaders KG/KGH I part	29,00
A411	QI of Bin lift KG 1350 2012	4,55
A412	QI of Bin lift AMCS, PC2H vag	4,55
A413	QI of Bin lift EN-840-3, Polen	5,40
A414	QI of Bin lift EN-840-3, armar	5,40
A415	QI of Bin lift standard 2012	4,55
A416	QI of Bin lift DAN stan. 2012	4,55
A42	QI of Bin lift for rear loaders KG/KGH part II	28,63
A421	QI of Bin lift KG tand-ID PC2H	4,55
A422	QI of Bin lift KG Ryssland	4,55
A423	QI of Bin lift KG tand-ID, tillverk.	4,55
A424	QI of Bin lift KG Wanelid/PIAB	5,23
A425	QI of Bin lift KG Ballyft Hydraulisk	5,20
A426	QI of Bin lift KG DME	4,55

UDP(s) of "Quality Inspection of raw materials and purchased components" Activity	
Definition	**Note**
During metal receiving process next requirements have to be checked: 1) Amount by theoretical weight, gauge and steel grades by the purchase orders, stampings/brandings and tags of the supplier; 2) There have to be no visible bundles, cracks, shells, dents and general deformations that exceed the permissible relevant standards and specifications. **During receiving process of purchased products next requirements have to be checked or measured:** 1) The number of parts should be compared with the delivery note, and then with the number in the order 2) That products do not have any striations (periodic pattern on the cut edge), dross, heat-affected zones. 3) If product has holes, they have to be measured with a vernier and compared with the drawings 4) If visual and quantitative inspections satisfy requirements, products can be added to the bookkeeping program	EN 10163-3-2004 Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections Tolerances - ISO 2768-mK-E

UDP(s) of "Quantity check" Activity
Definition
Quantity check of raw materials: The amount has to be checked by theoretical weight with the delivery note **Quantity check of purchased components:** The number of parts should be compared with the delivery note, and then with the number in the purchasing order. In case of incoming goods batch size over 300 pieces and weight lower that 0,1 kg, products can be checked by total weight To verify packaging and labelling

UDP(s) of "Visual Quality Inspection" Activity	
Definition	**Note**
Quality inspection of steel sheet metals, tubes, bars: 1)Checking the availability of supporting documentation for the products that certifies the quality and completeness of production; 2) There have to be no visible bundles, cracks, shells, dents and general deformations that exceed the permissible relevant standards and specifications **Quality inspection of the purchased steel components**: 1) Products must not have any striations, dross, heat-affected zones. 3) If product has holes, they have to be measured with a vernier and compared with drawings 4) If visual and quantitative inspections satify requirements, products can be added to the bookkeeping program According to the results of incoming inspection compile a report on the conformity of production and fill the log book of the results of the incoming inspection	EN 10163-3-2004 Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections Tolerances - ISO 2768-mK-E

UDP(s) of "Return to vendor" Activity
Definition
All rejected product have to be returned to the vendor or utilized, if vendor is refused to take back defected products. The complaint must be made out according to the incoming inspection report and sent to the vendor.

UDP(s) of "Quality Inspection of semi-finished products" Activity	
Definition	**Note**
Quality inspection of semi-finished products according to the drawings that has to be attached to the pallet. **Guillotine cutting:** The edges of the part after cutting with guillotine shears should not have cracks, bundles, burrs and debris greater than 1 mm. The edges that do not meet the requirements have to be machined. Tolerance ± 2 mm. **Saw-cutting:** All edges have to be checked. In the case of burrs, edges should be machined with abrasive disk. Sheet metal die bending: Deviation of the bending line from the stated in drawing has to be lower than 2 mm.	Tolerances - ISO 2768-mK-E

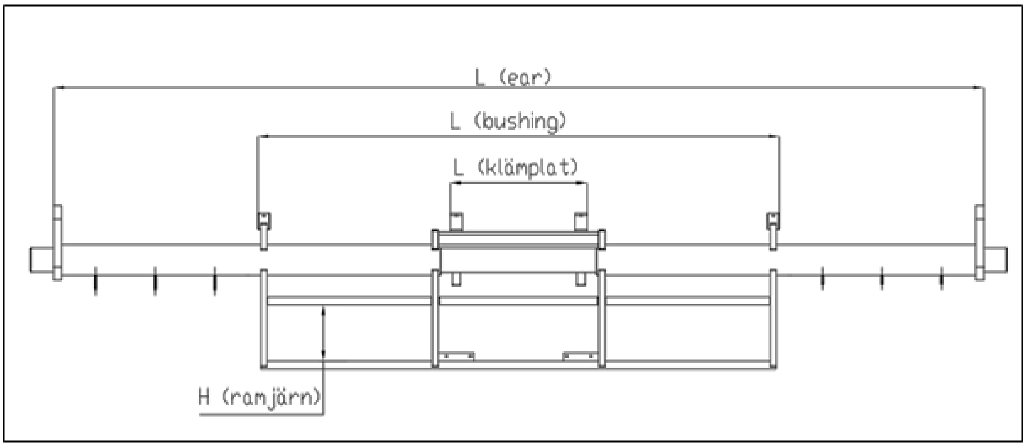
UDP(s) of "Quality inspection of guillotine-cut products" Activity	
Definition	**Note**
Cutting with guillotine shears of the manufacturing part should not be performed in case: -Steel yield strength is greater than 350 MPa -Part with thickness more than 16 mm from steel with a yield strength from 285 MPa to 350 MPa The edges of the part after cutting with guillotine shears should not have cracks, bundles, burrs and debris greater than 1 mm. The edges that do not meet the requirements have to be machined.	Tolerances - ISO 2768-mK-E

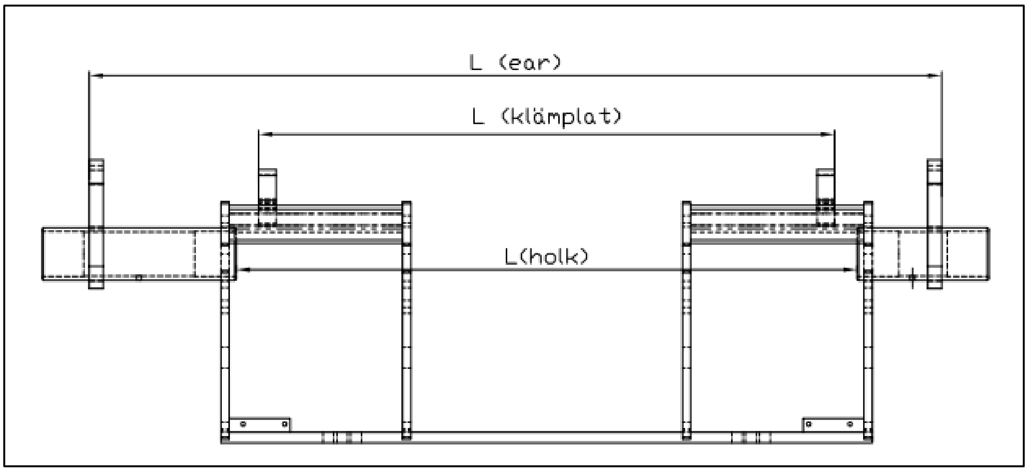
UDP(s) of "Quality inspection of saw-cut products" Activity	
Definition	**Note**
After saw-cutting of the steel product on the semiautomatic saw is necessary to measure the dimensions of work pieces and compare them with the drawing. Additionally, all edges have to be checked. In the case of burrs, edges should be machined with abrasive disk.	Tolerances - ISO 2768-mK-E

UDP(s) of "Quality inspection of bent products" Activity	
Definition	**Note**
Sheet metal bending procedure is performed on CNC controlled bending machine. Bent parts must meet the following requirements: -Displacement of the edges of cross-sectional profile parts shall not exceed the triple value of the maximum tolerance for the type of metal; -Deviation of the bending line from the stated in the drawing have to be lower than 2 mm. -Tanget of the bending angle should not differ from the stated in the drawing more than 0.01. -Verification of the geometric dimensions of components is carried out by measuring tool and with a set of gauges, designed to evaluate radius of convex and concave surfaces.	Tolerances - ISO 2768-mK-E

UDP(s) of "Quality inspection after machining of sheet metal products" Activity	
Definition	**Note**
Components have to be compared with drawings. Verification of the geometric dimensions of components is carried out by measuring tool (vernier)	Tolerances - ISO 2768-mK-E

UDP(s) of "Quality Inspection of the frame" Activity			
Unit nr/ Drawing nr	**Definition**	**Note**	**Comment**
1000032614 1000036425	During quality inspection of the frame additionally to dimensional and visual inspection next element have to be controlled/measured: 1. Internal tube freely rotates (scrolls) inside frame external tubes (AF_01) 2. Holes in side bushings for clamping plate installation are concentric (AF_02) 3.Holes in central sidebars of the frame are concentric (AF_03) 4. Crossbars are parallel (AF_04) 5. Holes in the crossbars are concentric(AF_05) 6. 2B Frame- External tubes are concentricl (2B_01) 7. Priming of the frame (AF_06) 8. Visual inspection and measurement check of the welds (AF_07)	Tools: Alignment tools, concentric tool, steel set square, digital/Bridge cam welding gage, vernier, metal measuring tape Standards: 1) Variations on dimensions without tolerance values are according to EN ISO 13920 A&E (welded constructions) 2) Limiting values for weld seam defects according to EN 25817	-



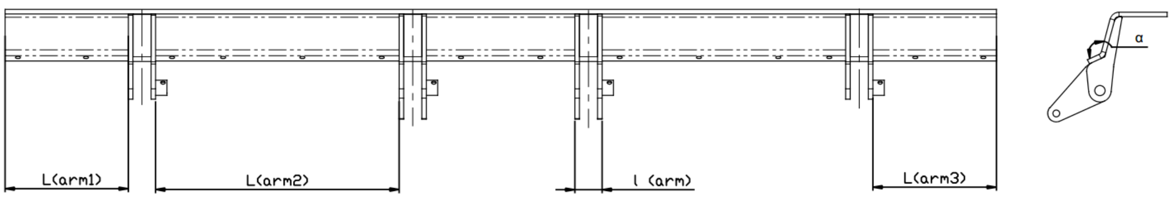


UDP(s) of "QI of Ram standard, DME, Botek, AMCS" Activity					
Unit nr/ Drawing nr	**Dimensions, Frame**	**Inspected; Frame**	**Definition**	**Note**	**Comment**
1000032614	H(ramjarn)=140 mm L (bushing)=1297 mm L (ear)=2314 mm L (klamplot)= 340 mm	H (ramjarn)= L (bushing)= L (ear)= L (klamplot)=	Tolerances for H (ramjarn), L (klamplat) are ±1 mm	EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Ram armar, Polen" Activity					
Unit nr/ Drawing nr	**Dimensions, Frame**	**Inspected; Comb**	**Definition**	**Note**	**Comment**
1000036425	H(ramjarn)=140 mm L (bushing)=1297 mm L (ear)=2314 mm L (klamplot)= 340 mm	Alfa= H (faste) L (f_1)= L (f_2)=	Tolerances for H (ramjarn), L (klamplat) are ±1 mm	EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Ram Wanelid/PIAB" Activity					
Unit nr/ Drawing nr	**Dimensions, Frame**	**Inspected; Frame**	**Definition**	**Note**	**Comment**
1000044685	H (ramjarn)= 180 mm L (bushing)= 1295 mm L (ear)=2314 mm L (klamplot)= 340 mm	H (ramjarn)= L (bushing)= L (ear)= L (klamplot)=	Tolerances for H (ramjarn), L (klamplat) are ±1 mm	EN ISO 13920 A&E EN 25817	-

UDP(s) of "Quality Inspection of the clamping plate " Activity		
Unit nr/ Drawing nr	**Definition**	**Note**
1000033173 1000033179 1000033187	Tolerances for L (arm_1), L (arm_2), L (arm_3), L (arm) are ±1 mm During quality inspection of the clamping plate, additionally to dimensional and visual inspection, next element have to be controlled/measured: 1. Cracks on the outer surface of the bend (CP_01) 2. Holes in welded parts are concentricl (CP_02)	Tools: Alignment tools, concentric tool, steel set square, digital/Bridge cam welding gage, vernier, metal measuring tape Standards: 1) Variations on dimensions without tolerance values are according to EN ISO 13920 A&E (welded constructions) 2) Limiting values for weld seam defects according to EN 25817

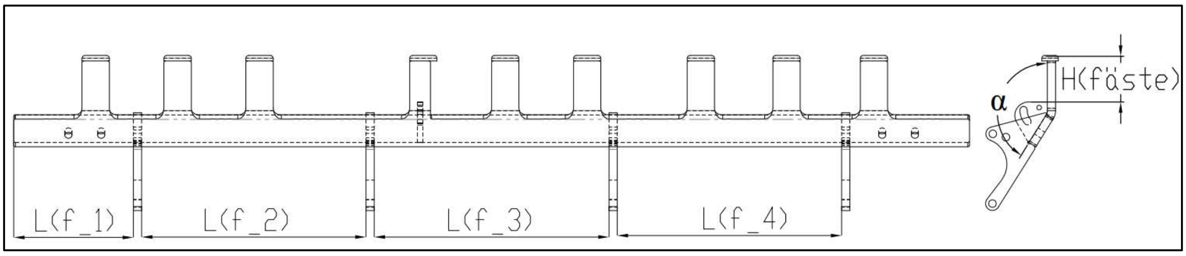


UDP(s) of "QI of Clamping plate 1350, KG" Activity					
Unit nr/ Drawing nr	**Dimensions, CP**	**Inspected; CP**	**Definition**	**Note**	**Comment**
1000033173	Alfa= 130 deg L (arm)= 48mm L (arm_1)= 18 mm L (arm_2)= 430 mm L (arm_3)= 496 mm	Alfa= L (arm)= L (arm_1)= L (arm_2)= L (arm_3)=	Tolerances for L (arm_1), L (arm_2), L (arm_3), L (arm) are ±1 mm	EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Clamping plate 1350, Polen" Activity					
Unit nr/ Drawing nr	**Dimensions, CP**	**Inspected; CP**	**Definition**	**Note**	**Comment**
1000033187	Alfa= 130 deg L (arm)= 48mm L (arm_2)= 430 mm L (arm_3)=18 mm	Alfa= L (arm)= L (arm_1)= L (arm_2)= L (arm_3)=	Tolerances for L (arm_1), L (arm_2), L (arm_3), L (arm) are ±1 mm	EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Clamping plate 1750" Activity					
Unit nr/ Drawing nr	**Dimensions, CP**	**Inspected; CP**	**Definition**	**Note**	**Comment**
1000033179	Alfa= 130 deg L (arm)= 48mm L (arm_1)=215 mm L (arm_2)= 430 mm L (arm_3)=218 mm	Alfa= L (arm)= L (arm_1)= L (arm_2)= L (arm_3)=	Tolerances for L (arm_1), L (arm_2), L (arm_3), L (arm) are ±1 mm	EN ISO 13920 A&E EN 25817	-

UDP(s) of "Quality Inspection of the comb " Activity		
Unit nr/ Drawing nr	**Definition**	**Note**
1000036173 1000042918 1000042920 1000042924 1000057232	Tolerances for L (fastplat_1), L (fastplat_2), L (fastplat_3), H (faste) are ±1 mm During quality inspection of the comb, additionally to dimensional and visual inspections next elements have to be controlled/measured: 1. Comb's "teeth" are welded from all sides (CO_01) 2. No cracks on the outer surface of bend (CO_02) 3. No corrosion in the corners of welded parts (CO_03)	Tools: Alignment tools, concentric tool, steel set square, digital/Bridge cam welding gage, vernier, metal measuring tape Standards: 1) Variations on dimensions without tolerance values are according to EN ISO 13920 A&E (welded constructions) 2) Limiting values for weld seam defects according to EN 25817



UDP(s) of "QI of Comb, smal, KG" Activity					
Unit nr/ Drawing nr	**Dimensions, Comb**	**Inspected; Comb**	**Definition**	**Note**	**Comment**
1000042924	Alfa= 148 deg H (faste)= 84 mm L (f_1)= 470 mm L (f_2)= 430 mm L (f_3)= 430 mm L (f_4)= 411 mm	Alfa= H (faste) L (f_1)= L (f_2)= L (f_3)= L (f_4)=	Tolerances for L (fastplat_1), L (fastplat_2), L (fastplat_3), H (faste) are ±1 mm	EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Comb, AMCS/PC2H" Activity					
Unit nr/ Drawing nr	**Dimensions, Comb**	**Inspected; Comb**	**Definition**	**Note**	**Comment**
1000057232	Alfa= 148 deg H (faste)= 85 mm	Alfa= H (faste) L (f_1)= L (f_2)= L (f_3)= L (f_4)=	Tolerances for L (fastplat_1), L (fastplat_2), L (fastplat_3), H (faste) are ±1 mm	EN ISO 13920 A&E EN 25817	-

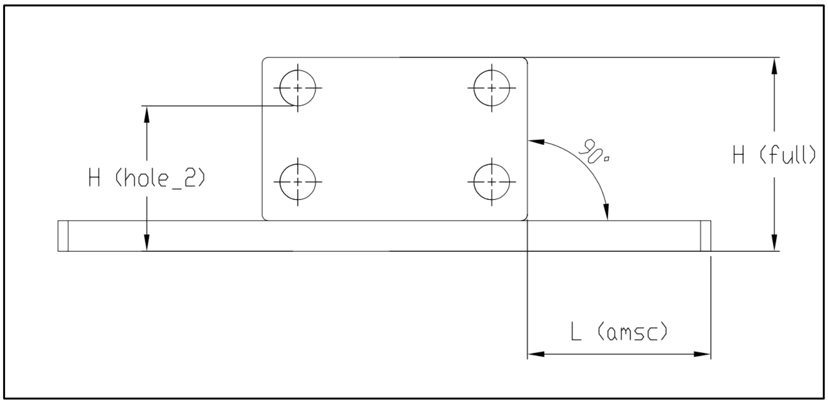
UDP(s) of "QI of Comb, Polen" Activity					
Unit nr/ Drawing nr	**Dimensions, Comb**	**Inspected; Comb**	**Definition**	**Note**	**Comment**
1000042918	Alfa= 148 deg H (faste)= 84 mm L (f_1)= 44 mm L (f_2)=411 mm L (f_3)= 430 mm	Alfa= H (faste) L (f_1)= L (f_2)= L (f_3)= L (f_4)=	Tolerances for L (fastplat_1), L (fastplat_2), L (fastplat_3), H (faste) are ±1 mm	EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Comb, Standard" Activity					
Unit nr/ Drawing nr	**Dimensions, Comb**	**Inspected; Comb**	**Definition**	**Note**	**Comment**
1000042920	Alfa= 148 deg H (faste)=84,7 mm L (f_2)=411 mm L (f_4)= 218 mm	Alfa= H (faste) L (f_1)= L (f_2)= L (f_3)= L (f_4)=	Tolerances for L (fastplat_1), L (fastplat_2), L (fastplat_3), H (faste) are ±1 mm	EN ISO 13920 A&E EN 25817	-

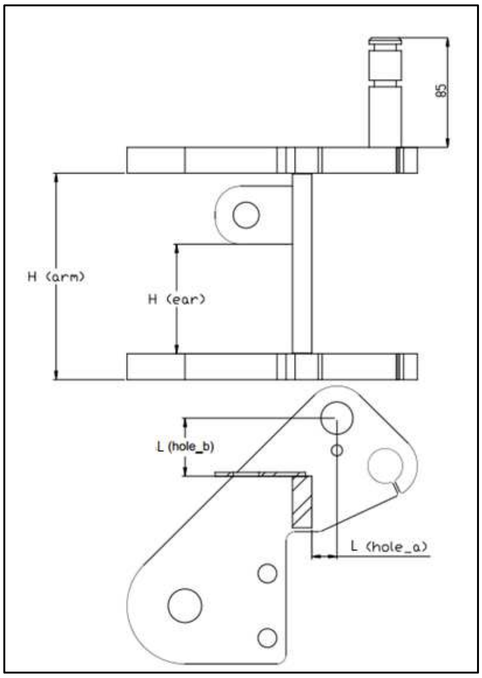
UDP(s) of "QI of Comb, Danmark" Activity					
Unit nr/ Drawing nr	**Dimensions, Comb**	**Inspected; Comb**	**Definition**	**Note**	**Comment**
1000036173	Alfa= 148 deg H (faste)=85,3 mm L (f_1)=219 mm L (f_2)= 430 mm L (f_2)=411 mm	Alfa= H (faste) L (f_1)= L (f_2)= L (f_3)= L (f_4)=	Tolerances for L (fastplat_1), L (fastplat_2), L (fastplat_3), H (faste) are ±1 mm	EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Comb, Dubbelkam AMCS antenn" Activity					
Unit nr/ Drawing nr	**Dimensions, Comb**	**Inspected; Comb**	**Definition**	**Note**	**Comment**
-35509/-35526	Alfa= 125 deg H (faste)= 85 mm	Alfa= H (faste)	Tolerances for L (fastplat_1), L (fastplat_2), L (fastplat_3), H (faste) are ±1 mm	EN ISO 13920 A&E EN 25817	-

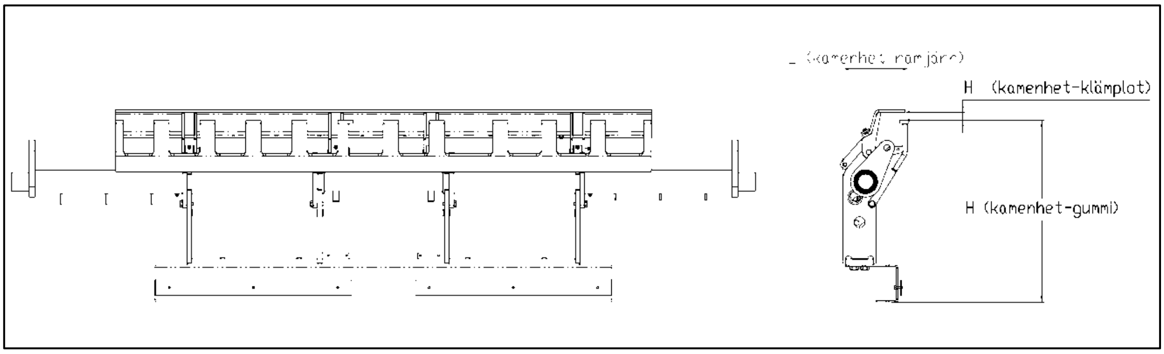
UDP(s) of "Quality Inspection of the mounting for adapter" Activity					
Unit nr/ Drawing nr	**Dimensions, Mountings**	**Inspected; Adapter**	**Definition**	**Note**	**Comment**
1000033429	H (full)= 95 mm H (hole_2)= 122 mm L (amcs)= 89 mm	H (full)= H (hole_2)= L (amcs)=	Quality control of dimensions and surface finishing.	Tools: Alignment tools, concentric tool, steel set square, digital/Bridge cam welding gage, vernier, metal measuring tape Standards: 1) Variations on dimensions without tolerance values are according to EN ISO 13920 A&E (welded constructions) 2) Limiting values for weld seam defects according to EN 25817	-

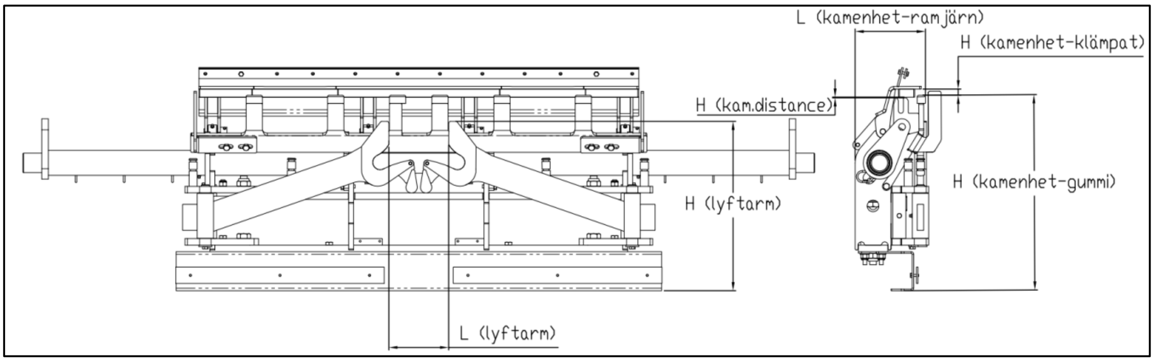


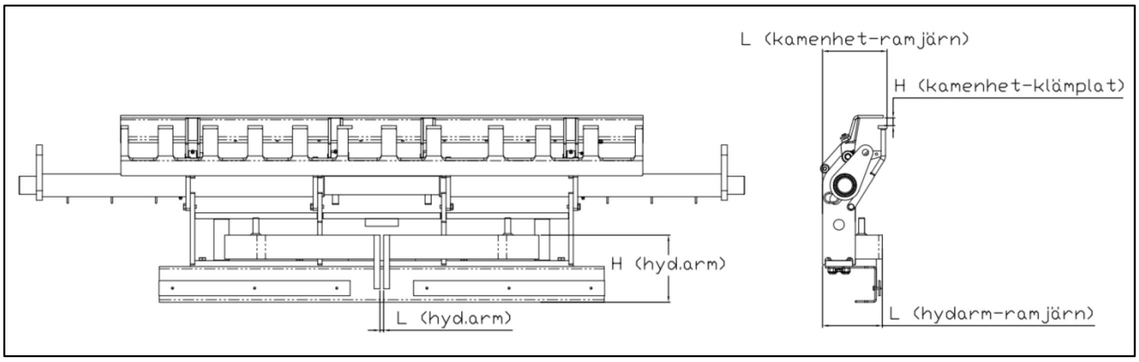
UDP(s) of "Quality Inspection of the mounting for the arms" Activity				
Unit nr /Drawing nr	**Dimensions, Mountings**	**Inspected; Arms**	**Definition**	**Note**
1000043232 1000044911	H (arm)= 160 mm H (ear)= 85 mm H (full)= 95 mm L (hole_a)= 19,5 mm L (hole_b)= 45 mm	H (arm)= H (ear)= L (hole_a)= L (hole_b)=	Tolerances: L (hole_b)/ L(hole_a) +0.5 -0.0 mm. For other dimensions ± 1 mm	Tools: Alignment tools, concentric tool, steel set square, digital/Bridge cam welding gage, vernier, metal measuring tape Standards: 1) Variations on dimensions without tolerance values are according to EN ISO 13920 A&E (welded constructions) 2) Limiting values for weld seam defects according to EN 25817



UDP(s) of "Quality Inspection of Assemblies" Activity	
Definition	**Note**
Assembled bin lift has to be inspected visually and with using of measuring tool. After performed inspection, filled document has to be tranferred to foreman.	Tools: Steel set square, digital/Bridge cam welding gage, vernier, metal measuring tape Standards: 1) Variations on dimensions without tolerance values are according to EN ISO 13920 A&E (welded constructions) 2) Limiting values for weld seam defects according to EN 25817







UDP(s) of "QI of Bin lift KG 1350 2012" Activity					
Unit nr/ Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000044282	H (k-g)= 592 mm H (k-k)= 26 mm L (k-r)= 216 mm	H (k-g)= H (k-k)= L (k-r)=	Frame: drawing nr 1000032614 Clamping plate: drawing nr 1000033179 Comb: 1000042924	Tolerances: H (kamenhet-klamplot) +0/-3 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift AMCS, PC2H vag" Activity					
Unit nr /Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000057217	H (k-g)= 612 mm H (k-k)= 22 mm L (k-r)= 215 mm	H (k-g)= H (k-k)= L (k-r)=	Frame: drawing nr 1000032614 Clamping plate: 1000033173 Comb: 1000057232	Tolerances: H (kamenhet-klamplot) +0/-3 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift EN-840-3, Polen" Activity					
Unit nr /Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000044883	H (k-g)= 600 mm H (k-k)= 19 mm H (kam.distance)= 3mm H (lyftarm)= 519 mm L (k-r)= 215 mm L (lyftarm)= 184 mm	H (k-g)= H (k-k)= H (kam.distance)= H (lyftarm)= L (k-r)= L (lyftarm)=	Frame: drawing nr 1000036425 Clamping plate: drawing nr 1000033187 Comb: drawing nr 1000042918 Mounting for arms: -43232/-44911	Tolerances: H (kam.distance) +2/-1 H (kamenhet-klamplot) +1/-0 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift EN-840-3, armar" Activity					
Unit nr/ Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000044000	H (k-g)= 600 mm H (k-k)= 24 mm H (lyftarm)= 519 mm L (lyftarm)= 184 mm	H (k-g)= H (k-k)= H (lyftarm)= L (k-r)= L (lyftarm)=	iFrame: drawing nr 1000036425 Clamping plate: drawing nr 1000033173 Comb: drawing nr 1000042924 Mounting for arms: -43232/-44911	Tolerances: H (kamenhet-klamplot) +0/-3 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift standard 2012" Activity					
Unit nr/ Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000044279	H (k-g)= 592 mm H (k-k)= 26 mm L (k-r)= 216 mm	H (k-g)= H (k-k)= L (k-r)=	Frame: drawing nr 1000036414 Clamping plate: drawing nr 1000033179 Comb: drawing nr 1000032614	Tolerances: H (kamenhet-klamplot) +0/-3 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift DAN stan. 2012" Activity					
Unit nr/ Drawing nr	**Dimensions, Comb**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000042892	L (f_1)= 470 mm L (f_2)= 430 mm L (f_3)= 430 mm	H (k-g)= H (k-k)= L (k-r)=	Frame: drawing nr 1000032614 Clamping plate: drawing nr 1000033179 Comb: drawing nr 1000036173	Tolerances: H (kamenhet-klamplot) +0/-3 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift KG tand-ID PC2H" Activity					
Unit nr/ Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000033433	H (k-g)=611,2 H (k-k)= 22,8 mm L (k-r)= 213,8 mm	H (k-g)= H (k-k)= L (k-r)=	Frame: drawing nr 1000032614 Clamping plate: drawing nr 1000033173 Comb: -35509/-35526 Mounting for adapter: 1000033431	Tolerances: H (kamenhet-klamplot) +0/-3 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift KG Ryssland" Activity					
Unit nr/ Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000103821	H (k-g)= 592,5 mm H (k-k)= 25,6 mm L (k-r)= 215 mm	H (k-g)= H (k-k)= L (k-r)=	Frame: drawing nr 1000036425 Clamping plate: drawing nr 1000033179 Comb: 1000042920	Tolerances: H (kamenhet-klamplot) +0/-3 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift KG tand-ID, tillverk." Activity					
Unit nr/ Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000100683	H (k-g)= 592,5 mm H (k-k)= 25,6 mm L (k-r)= 215 mm	H (k-g)= H (k-k)= L (k-r)=	Frame: drawing nr 1000032614 Clamping plate: drawing nr 1000033179 Comb: 1000036384	Tolerances: H (kamenhet-klamplot) +0/-3 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift KG Wanelid/PIAB " Activity					
Unit nr/ Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000100028	H (k-g)= 610 mm H (k-k)= 24 mm	H (k-g)= H (k-k)=	Frame: drawing nr 1000044685	Tolerances: H (kamenhet-	-

UDP(s) of "QI of Bin lift KG Wanelid/PIAB " Activity					
Unit nr/ Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
	L (k-r)= 213 mm	H (lyftarm)=	Clamping plate: drawing nr 1000033173 Comb: 1000057232 Mounting for adapter: 1000067732	klamplot) +0/-3 EN ISO 13920 A&E EN 25817	

UDP(s) of "QI of Bin lift KG Ballyft Hydraulisk" Activity					
Unit nr/ Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000045867	H (hyd.arm)= 225 mm H (k-g)= 592 mm H (k-k)= 26 mm H (lyftarm)= 519 mm L (h-r)= 200 mm L (hyd.arm)= 12,5 mm L (k-r)= 216 mm	H (hyd.arm)= H (k-g)= H (k-k)= L (h-r)= L (hyd.arm)= L (k-r)=	Frame: drawing nr 1000036425 Clamping plate: drawing nr 1000033179 Comb: 1000042920	Tolerances: H (kamenhet-klamplot) +0/-3 EN ISO 13920 A&E EN 25817	-

UDP(s) of "QI of Bin lift KG DME" Activity					
Unit nr /Drawing nr	**Dimensions, Assembly**	**Inspected; Assembly**	**Definition**	**Note**	**Comment**
1000099621	H (k-k)= 26 mm L (k-r)= 216 mm	H (k-k)= L (k-r)=	Frame: drawing nr 1000032614 Clamping plate: drawing nr 1000033173 Comb: -55641/-55640	Tolerances: H (kamenhet-klamplot) +0/-3	-