



# **Quality Assurance Methods in Hose Assembly Production**

**Parker Hannifin Ylöjärvi**

Jari Sarkonen

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## TIIVISTELMÄ

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Parker Hannifin Ylöjärvi

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Tässä opinnäytetyössä perehdytään Parker Hannifinin Ylöjärven tehtaan uudistetun ja noin kaksi vuotta toiminnassa olleen tuotantoprosessin laadunvarmistusmetodeihin ja niiden tehokkuuteen sekä tarkastellaan erilaisia kehitysmahdollisuuksia. Tutkimuksessa avataan laadunvarmistuksen tapoja ja työkaluja, joita Parker Ylöjärvellä on käytössä, sekä käydään läpi menetelmiä, joilla asiakkaille voidaan varmistaa tuotteiden korkea laatu. Työn tavoitteena oli varmistaa, että laadunvarmistusmenetelmät ovat käytössä, kuten on suunniteltu, sekä implementoida mahdollisesti uusia tai parantaa jo käytössä olevia käytäntöjä. Näin voitiin taata, että tuotannon laatu saadaan pysymään nykyisten ja muuttuvien vaatimusten asettamalla tasolla. Käytettyjä metodeja ja niiden tuomia hyötyjä tarkastellaan teoreettisesti, mutta lisäksi arvioidaan niiden toimivuutta Parker Hannifinin Ylöjärven tehtaalla letkuasennelmien tuotannossa

Laadunvarmistusmenetelmiin perehtymisen tuloksena todettiin, että tehtaan tuotannon laadullista tasoa mitattiin tehokkaasti. Työkalut, jotka oli suunniteltu otettavan käyttöön, myös olivat käytössä muutamin poikkeuksin. Oman tuotannon laadullisesta tasosta olttiin tietoisia ja korjausliikkeitä pystyttiin tarvittaessa tekemään, sekä varmistumaan niiden vaikutuksista laatuun. Uusia käytäntöjä ja laadunvarmistuksen työkaluja päädyttiin kuitenkin implementoimaan opinnäytetyöprosessin yhteydessä käyttöön.

Parker Hannifin Ylöjärven laadunvarmistus tutkittiin ja saatiin hyvä käsitys sen nykytilasta ja mahdollisista puutteista. Tutkimuksen perusteella voi todeta, että tuotantotehtaan muuton yhteydessä uudelleen suunnitellun tuotantoprosessin laatu oli tavoitellulla tasolla. Tähän oli päästy käytetyillä laadunvarmistusmetodeilla, jotka toimivat tehokkaasti ja kuten oli alun perin suunniteltu. Tämä opinnäytetyö antaa Parkerille vahvistuksen siitä, että uuden tuotantoprosessin suunnittelussa oli onnistuttu laadun näkökulmasta hyvin.

## **ABSTRACT**

Tampere University of Applied Sciences  
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This thesis concentrates on the quality assurance methods, their effectiveness and possible scope for improvements at Parker Hannifin's hydraulic hose assembly factory in Ylöjärvi. The manufacturing facility is new and the production process has been in operation for approximately two years. This research examines the quality assurance methods and tools, which are in use in Parker's process, and the ways in which customers can be assured of getting high quality products. The objective of this thesis was to ensure that the quality assurance methods are being used as planned, and that they are working properly. The other goal was to implement new methods and improve ones already in use if deemed necessary. In these ways it can be ensured that the quality level of the process is meeting the current and possibly changing requirements. The methods in use and their benefits are explained in theory, together with further details of how they actually work in Parker Hannifin's assembly manufacturing process in Ylöjärvi.

On the basis of the inspection of the quality assurance methods, it can be affirmed that the production's quality level is being monitored effectively. Most of the tools that had been planned to be taken into operation had in fact been deployed, with some exceptions. Parker is well aware of the quality capability of its production, and corrective actions can be made effectively if required. However, during the research for this thesis, it was decided to implement some new quality assurance methods.

For this thesis the quality assurance system of Parker Hannifin's production was studied and a clear picture was obtained of its current state and weaknesses. It can be stated as a final conclusion that the newly designed manufacturing process's quality is at the desired level. This was made possible by the effective utilization of the selected methods. The result of this thesis gives Parker a confirmation that the new design of the manufacturing process was successful from the quality point of view.

Key words: quality, quality assurance, quality tools

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## ABBREVIATIONS AND TERMS

Assembly	complete hydraulic hose
Breadman	Parker's service where products are carried straight to customer shelves by Parker
Kitting	Parker's service where desired assemblies are packed together for easier unpacking at customer's location
APQP	Advanced Product Quality Plan
C <sub>pk</sub>	process capability measuring tool
FIFO	First in – First out method for material flow
FMEA	Failure Mode and Effect Analysis
GAGE R&R	process's Reproducibility and Repeatability measuring tool
ISIR	Initial Sample Inspection Report
PPAP	Product Part Approval Process
SIPOC	a high level process map, which includes <b>S</b> uppliers, <b>I</b> nputs, <b>P</b> rocesses, <b>O</b> utputs and <b>C</b> ustomers
TPM	Total Preventative Maintenance

## 1 INTRODUCTION

Parker Hannifin is a global manufacturer of motion and control technologies and systems, and it has a manufacturing facility in Ylöjärvi which makes hydraulic hose assemblies. This Parker's factory in Ylöjärvi has moved there from Tampere in March 2012, and had been in operation about two years at the time when this thesis was made. When Parker decided to move their factory from Tampere to a new location and a bigger space, it gave an opportunity to redesign their manufacturing process for improved productivity. This new production process needed also effective quality assurance methods to confirm that the assemblies produced are at high quality level, which is one of Parker's assets at its market area.

This thesis studies Parker's quality assurance methods in hose assembly production at Ylöjärvi. The object is to make sure that the quality tools are well and truly in use, which were originally planned to take in operation in pursuance of the new manufacturing process design. The used methods and their results from the production are introduced and analyzed, and the assessments of the need of quality assurance improvements are based on these results. It came out during the research that all the planned quality assurance methods were not implemented properly to meet the today's requirements and corrective actions were made.

This thesis gives an impression which issues are important in quality assurance. It also clarifies how certain quality tools are used and what benefits they can bring out. Many of the introduced quality assurance methods are important to the production itself, but their other also very important task is to convince the customer that the products they receive are at the required quality level. The reader of this thesis receives a practical advice of what it takes to properly track and measure the quality of a production process and how a supplier is able to convince its customer that it offers high quality products.

## **2 PARKER HANNIFIN**

Parker Hannifin creates solutions for motion control for very wide range of customers. Parker designs, manufactures and delivers products from simple components to complete systems and the main target is to increase customers' productivity and profitability. Parker Hannifin has made "The Win Strategy" in year 2001 which is a business strategy that is still in use. It has helped Parker to change and improve their functions worldwide since the strategy was established, and now they have achieved their vision: to be world's leading manufacturer of motion control technologies and systems. (Parker The Win Strategy)

Parker has technical competence in 9 different areas which are listed below:

- Aerospace
- Climate control
- Electro mechanics
- Filtration
- Fluid and gas handling
- Hydraulics
- Pneumatics
- Process control
- Sealing and shielding

(Parker The Win Strategy)

### **2.1 Parker's history**

Arthur Parker established Parker Alliance Corporation in 1918, which was originally specialized in making of break lines for heavy vehicles. Parker bought Hannifin Corporation in year 1957 and so the Parker Hannifin was born. Today Parker has approximately 60 000 employees in 50 countries and their areas of expertise have increased to 9 different segments which all contain about one million products combined. Parker delivers these products to their 500 000 customers. (Parker Hannifin website, read 15.1.2014)

## **2.2 Parker in Finland**

In Finland Parker Hannifin employs 470 people in 7 places of business. These places are Ylöjärvi, Tampere, Forssa, Joensuu and Vantaa. Each of them focuses on different segments. Ylöjärvi manufactures hose and tubing assemblies, Tampere manufactures valve blocks, Forssa manufactures electronic systems, Joensuu has concentrated on breadman services, Urjala manufactures filtration products and in Vantaa Parker have the sales company headquarters of Finland and also the facility in Vantaa manufactures valve blocks. The sales of the sales company of Finland was 110 million euros in 2013. (Parker Hannifin website, read 15.1.2014)

## **2.3 Parker Ylöjärvi**

Parker Hannifin manufactures hose and tubing (HTA) assemblies at Ylöjärvi and it is one of Parker's the four HTA assembling facilities in Europe. Parker's factory at Ylöjärvi has floor surface area approximately 2200 m<sup>2</sup>, which includes an office, production area, meeting room, locker rooms and recreation room. The annual production rate is around 500 000 hydraulic and pneumatic assemblies. Assembly refers a single, measured and cut hose where have been pressed fitting in one, or both ends. (Parker, 2014)

All operations are specifically designed through lean thinking and all working methods are continuously observed and improved if necessary. The production is certified to meet quality management standard ISO 9001:2008. All the produced hoses fulfill cleanliness standards ISO 4405, 4406 and 4407. Parker Ylöjärvi also provide kitting- and breadman services. Breadman service contains order deliveries straight to customer's shelves without, that customer needs to do anything. This means that Parker takes care of the whole supply chain management from the beginning to the end. Kitting service offers customers a possibility to have their order delivered and sorted the way the customer requires. This way all the right hoses end up to the right places where they are needed at customers production facility and customers' workers do not have to search or collect them from shelves. (Parker, 2014)

Parker moved their HTA manufacturing plant from Tampere to Ylöjärvi in March 2012, and the layout (*figure 1*) was completely rebuilt and new stages came part of the manufacturing process. Formerly same worker picked the right fittings and hose according to the work order and after that, cut the hose and pressed the fittings to produce the complete assembly. The new layout at Ylöjärvi was made to increase production rate by dividing these tasks to two different parts, which both were taken care of by different workers. The idea was to give assembly producers peace to concentrate only on cutting the hoses and pressing the fittings. The task of collecting the right products from shelves was given to specific collectors, whose responsibility was to feed all the cells and keep production flowing. Kitting was also put into operation as a new service at Ylöjärvi. (Parker, 2014)

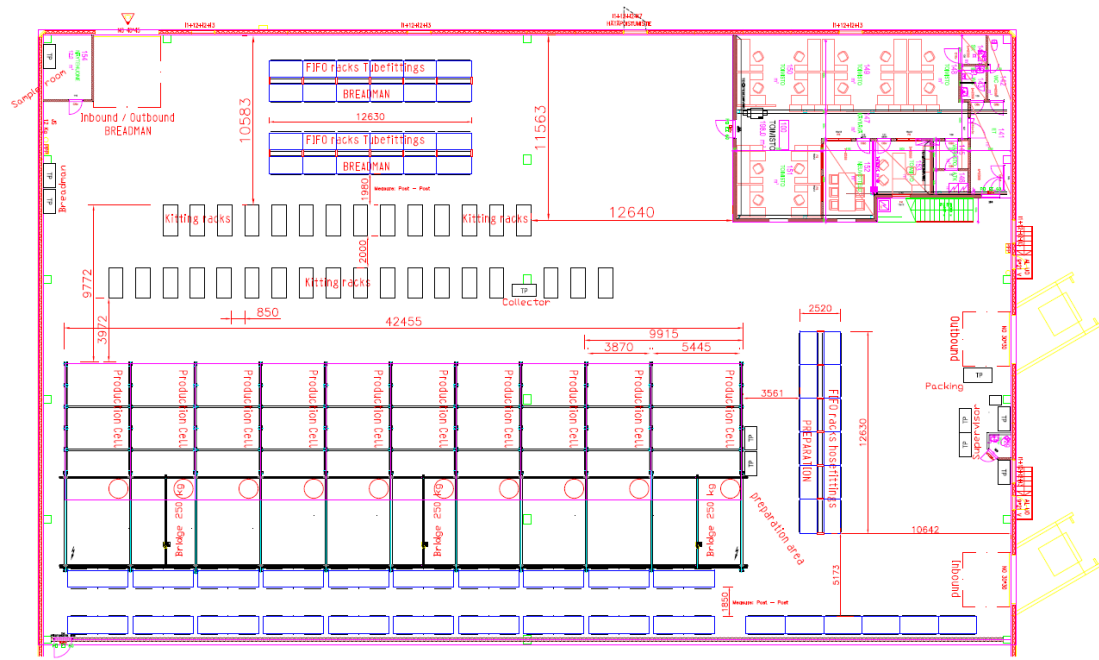


Figure 1. Parker Ylöjärvi layout (Parker, 2014)

Parker follows FIFO (first in – first out) thinking on material flow. This means that all the materials that come in to the factory, pulls out at the same order. All the components are tagged by the month as they come in, before they go into Parkers stocks. This way it is easy to ensure that nothing is left unused on the shelves and utilization rates for different products can be seen visually. FIFO method is proved to be an effective tool for optimizing stocks and production.

### 3 QUALITY JOURNEY TRACKING CENTER

Quality journey tracking center is a physical board that should be located at some centered place where everyone is able to see it. Its purpose is to visually demonstrate how well quality targets are reached and what are future plans, and this way it supports Parker's quality strategy. The quality tracking center also defines "what does good look like" for each of the quality supporting elements. Figure 2 shows the appearance of the Parker's quality journey tracking center. This was one of the quality tools that were implemented during the thesis research. (Parker, 2014)

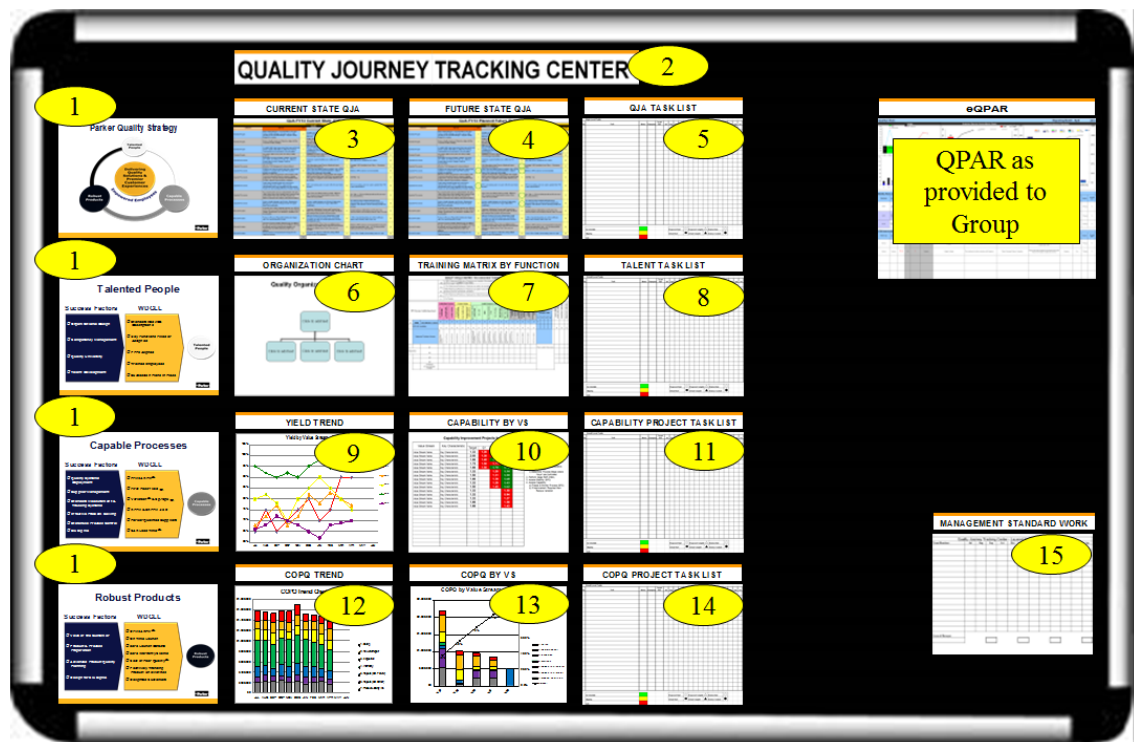


Figure 2. Parkers Quality Journey Trackin Center (Parker, 2014)

#### 3.1 Quality strategy row

Parker offers the quality tracking center in the local language, so everyone is able to read the charts and get an understanding of current and future states of the quality. The first row of the quality journey tracking center basically shows how good quality current process is capable to produce and which sections are planned for implementations in the future. The last sheet of the quality strategy row (figure 2, number 5) is for a high level

task list, from which can be seen what actions are put into operation, if the level of quality is not acceptable on some of the subjects. (Parker, 2014)

### **3.2 Talented people row**

First sheet on the second row determines Parker's ideology what is needed for talented people. The recipe is fairly clear and simple. Parker believes that when employees and their resources are efficiently placed and managed, talented people are created. At the same row can be seen organizational chart which also shows any open quality positions. This helps everyone, especially the employees, to keep on track of the responsibility fields and the form of the organization above them. Last sheet in the second row is again the task list, but more detailed. It shows educational needs and plans for employees. (Parker, 2014)

### **3.3 Capable process row**

Capable process row identifies quality assurance methods which are in use, and which make the process reliably producing the desired quality. Value streams are individually tracked, but the second sheet (*figure 2*, number 9) sums them up for whole site comparison. This gives a good overview what are the quality levels in different tasks, and what areas need improvement the most. Regular quality measurements are listed on the last task sheet to help managing the continuous tracking of quality. (Parker, 2014)

### **3.4 Robust products row**

The last row of the quality journey tracking center specifies what Parker's ideologies for creating a good product are. It mentions as the success factors the importance of voice of the customer and the usage of Advanced Product Quality Planning (APQP) and SIX SIGMA methods. The charts on this row (*figure 2*, numbers 12 and 13) show the monthly amount of the cost of poor quality, and divide it on 7 different categories. This way it can be easily seen where the costs are forming. (Parker, 2014)

## 4 SIPOC

SIPOC is a high level process map, which includes **S**uppliers, **I**nputs, **P**rocesses, **O**utputs and **C**ustomers. SIPOC is used to document the observed process at high level and to present the process as a simple, visual diagram starting from a supplier and ending to a customer. With this tool, it can be seen very simply and easily what happens to the product between those two stages. Quality is defined from the output of the process. The quality of output can be improved by analyzing inputs and process variables. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

SIPOC is a very effective communication tool. It ensures that everyone sees the process in the same way and misunderstandings can be avoided. SIPOC helps people to see business from a process perspective. It also informs management precisely and straightly what the team is doing. For this reason, SIPOC should be done in very early stages of the project creation. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

SIPOC identifies and presents both interfaces and junctions of the process, and also customers and suppliers. SIPOC helps to indicate data gathering points. In this method the process is presented on high level, so all the process phases are not meant to be presented in detail, but only the main stages. Customers, outputs, inputs and suppliers are identified, after the process is properly described. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

### 4.1 Components of SIPOC

**Process presentation** is explanation of the process which produces outputs, that satisfies customer's needs. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

**Input and output interfaces** define the starting and ending points of the process. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

**Output** is the outcome of the process. It is important to take notice how these outputs regard customer's wishes and are they satisfying their requirements, when defined. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

**Customers** are people who receive outputs and set the requirements for them. Customers can be either internal or external. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

**Customer requirements and measurements** are quantitative expectations for process outputs. Outputs must be measured and compared to the customer's requirements, to find out customer satisfaction. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

**Inputs** are all those things what process needs to function. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

**Input requirements and measurements** are quantitative expectations for the inputs that are put to the process. Process inputs must meet the requirements in order for process to produce outputs that meet customer requirements. SIPOC has to document what requirements are set to the inputs before the process is launched. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

**Suppliers** produce requisite inputs for the process. SIPOC should define supplier information as accurately as possible. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

## 4.2 How SIPOC is created

Eight steps to create SIPOC

1. Identify and describe presented process.
2. Define the dimensions of the process. Clarify starting and ending points.
3. List all the important outputs.
  - The requirements for outputs must be listed, and also how these requirements are measured
4. Determine customer for every output.
5. Document customer requirements for every output. Define which outputs features are critical for customer, and what are essential requirements for inputs.
6. List all the inputs that the process needs and how they are measured.
7. List suppliers. Quantity requirements must also be mentioned.
8. Identify, define and name all the key phases of the process.

(Tanja Karjalainen, Eero E. Karjalainen, 2002, s.100-102)

## 4.3 Parker's SIPOC

Parker's SIPOC is fairly detailed, because it divides the manufacturing process in 13 different components between start and end. It specifies the areas of responsibility for every type of worker in the process and determines all the required resources that the process needs to work properly. Desired outputs for every activity are also described.

SIPOC's benefits appear when something goes wrong with the process. After these problems are identified, SIPOC can be used as a tool to evaluate which other factors could be affected. In some cases the cause of the problem can easily be seen from a SIPOC, if the problem is diagnosed to be as a result of process's input or output component. In general SIPOC shows what is being done, and by who, and also how different processes are linked between each other. In other words, what some specific process need to function and what this process produce.

See Parker's SIPOC from attachment 1.

#### **4.4 Parker's hose assembling process map**

Process map is based on SIPOC, but it is more detailed. Its purpose is to be a device for visualizing a process as means of improving it. Every detail or an individual task is more or less affected by every other component of the process. Therefore the entire process must be presented in a form, where it can be seen all at once, before any changes are made in any of its components. This way the effects of the change for the rest of the process can be pictured more easily and everything is taken under consideration more surely. Process map can also be used when employees are trained to their tasks. It gives clear description of the responsibility fields.

(Parker, 2014)

Parker's process map starts from customer forecast and ends to the point when product leaves from the factory. The whole manufacturing process is divided in 6 different phases. Every possible work phase or action is described, what different kinds of hose assemblies may need. This map gives a full picture how Parker handles incoming orders and how a hose assembly is precisely made from the very beginning till it is finished. See Parker's Process map from the attachment 2.

## 5 ADVANCED PRODUCT QUALITY PLAN

### 5.1 Fundamentals of APQP

*“Advanced Product Quality Planning is a structured method of defining and establishing the steps necessary to assure that a product satisfies the customer. The goal of product quality planning is to facilitate communication with everyone involved to assure that all required steps are completed on time. Effective product quality planning depends on a company’s top management commitment to the effort required in achieving customer satisfaction. Some of the benefits of Product Quality Planning are:*

- *To direct resources to satisfy the customer.*
- *To promote early identification of required changes.*
- *To avoid late changes.*
- *To provide a quality product on time at the lowest cost.”*

(APQP reference manual)

APQP’s ideology on product quality planning is presented in the figure 3.

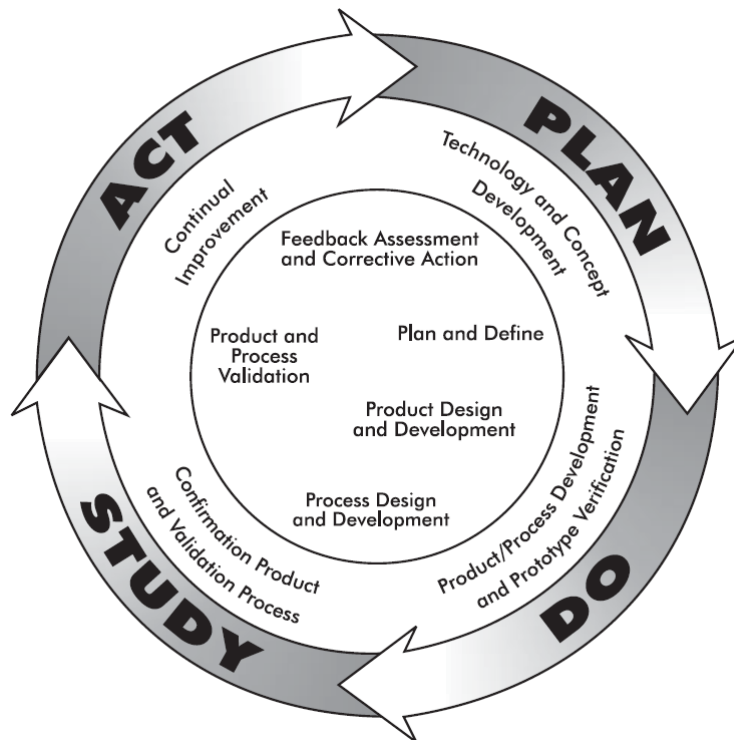


Figure 3. Product quality planning cycle (APQP reference manual)

## 5.2 Advanced Product Quality Planning in progress

The supplier should understand that when APQP is put into practice, it is not a subject just for the highest management, but the whole organization has to be dedicated on it. Although the APQP refers to quality planning, its effective using requires the involvement of more than just the quality department in the APQP team. (APQP reference manual)

The first important task for the product quality planning team is to define customers' needs, expectations and requirements. The team also has to decide if they need any external specialist help, and is the current process capable to produce the product that customer has ordered. The process costs and timing are also significant issues to determine for picturing the boundaries of the whole process. (APQP reference manual)

Because the Advanced Product Quality Planning requires the involvement of the whole organization, it is important to agree and establish communication ways and routines between other customer and supplier teams. This may lead to regular meetings in order for continuous communication, including subcontractors and material providers. (APQP reference manual)

APQP team can speed up the introduction of a new product by taking care of simultaneous engineering. This means that all the teams involve, work for the same goal simultaneously and do not wait for results from previous departments to examine and advance the project step by step. Developing process has many phases that can be started at the same time, or at least, the next step can begin before the previous is completely finished (*figure 4*). (APQP reference manual)

Creation of control plans is one of Advanced Product Quality Plan team tasks. This written description shows how parts and processes are controlled, and it is made for three distinct phases: prototype, pre-launch and production. These control plans describe dimensional measurements of material and performance tests during every phase, and make comprehensive documentation of them. Problems with design or processing are sometimes revealed due to accurate control plans. According to APQP, these prob-

Items should be documented and assigned to responsibility persons with timing targets. (APQP reference manual)

One of the first and the most important assignments for the APQP team is to produce timing table for every phase and task of the design and developing processes of the product. All team members must agree every event, action and the timing for them. A good timing plan contains exact “start” and “complete” dates for every team’s every task, and it also determines review dates for tracking the process. (APQP reference manual)

A process is considered successful when it produces quality product that meets customer requirements and expectations in given time and with reasonable costs. In addition the APQP team must concentrate its efforts on preventing any defects when designing or manufacturing the product, as the Quality Planning Cycle describes (*figure 3*). This target can be reached by simultaneous engineering of the product and manufacturing teams that work concurrently. Teams involved in the process must be prepared to make changes to the product quality plans to meet customer expectations. To fulfill customer requirements completely means that the APQP team also assures that the timing of the process meets or even exceeds the customer timing plan. (APQP reference manual)

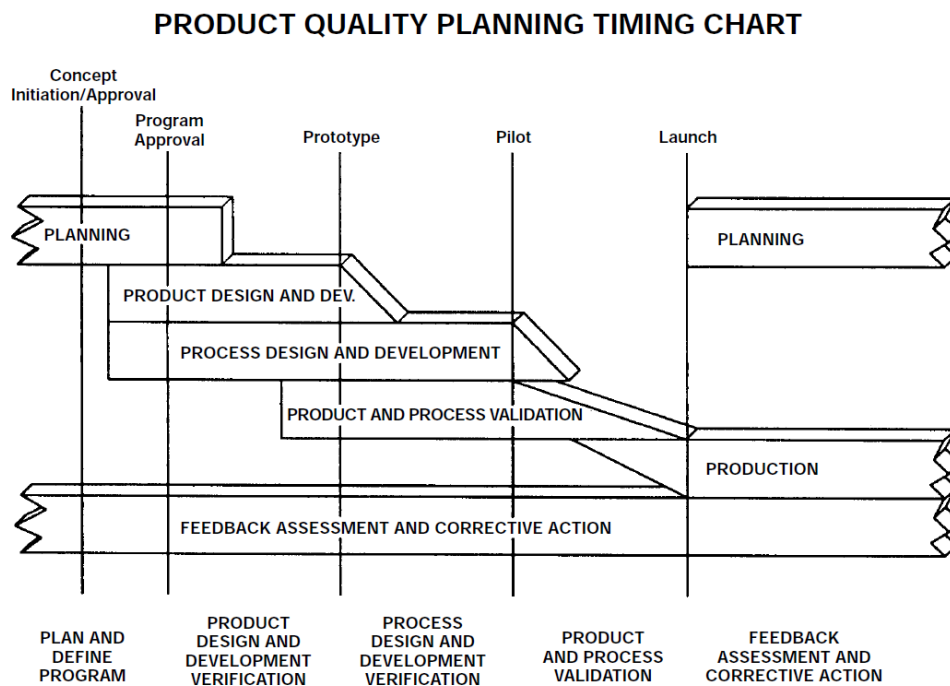


Figure 4. Product Quality Planning Timing Chart (APQP reference manual)

### **5.3 Failure Mode and Effect Analysis (FMEA)**

FMEA is a risk analysis and part of the APQP, which was born in the mid-1960s by aviation industry, and it is formerly further improved for safety and reliability analysis for space- and nuclear engineering. FMEA is a key method in product- and process planning and it is considered as one of the few preventative methods of quality control techniques. Its purpose is to detect possible errors and failures from either products or processes at early stage of designing. Quality risks can be minimized beforehand and with low cost. Failure Mode presents defect conditions when the product, service or process does not meet customer requirements. Effect Analysis inspects the effects of the defects. FMEA focuses on increasing product quality, but the actual FMEA is made either for product designing (DFMEA) or a process (PFMEA). (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.168-169)

FMEA is a systematic method to detect, analyze and prioritize defects and their effects for any system, product or process. It shows critical product features and process variables, and organizes product and process errors by importance. FMEA makes it possible to evaluate the risk and it also helps to determinate which actions should be taken to minimize it. FMEA is a detailed document or chart, which identifies the ways how products or processes are able to fail to fulfill the critical customer demands. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.168-169)

#### **5.3.1 FMEA benefits**

FMEA increases quality, reliability and the safety of the products. Customer satisfaction is also better when supplier has well-made FMEA in use, because in that situation the customer can be confirmed that every safety aspect is taken into consideration and the product does not have any unexpected hazards. Designing time and costs will also get lower due to a proper FMEA because possible errors can be foreseen and everything does not have to be learned by trial and error. This way the need of reproducing or repairing the products decreases, and less material goes to scrap. FMEA traces and documents all actions that are being made, and prioritizes defects. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.168-169)

FMEA is always more effective when it is taken into use at early stages of design or process. It is a changing document that lists all the possible causes for defects, and based on that list, a process- or design managing plan can be created. It gathers thoughts about risks to a customer if some critical process variable fails. FMEA also includes recommended and already carried out methods to minimize the risks, and that is why it must be updated every time when the process is changed somehow. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.168-169)

FMEA is usually launched at measuring phase and it is continued at analyzing and managing stages, and it can offer the team some recommended methods for minimizing any risks. This way it can be assured that evaluating criteria, (severity, manifestation, and observing) and causations are updated by the conclusions based on measured data. At the managing stage FMEA must be updated to describe the processes final state. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.168-169)

### 5.3.2 Parker's PFMEA

Parker has made a Process Failure Mode and Effect Analysis chart for their HTA production, where they have identified every possible failure that can occur during the production. Those failure modes are described in detail and the consequences on customer are also defined. Potential failure effects are rated by occurrence from 1 in 1,500,000 to >1 in 2 and severity from none or very minor to hazardous. Every failure effect is classified in three different categories:

- **Critical:** Could cause major injury/loss of life, legal requirement, would cause potential costs of over £200K.
- **Major:** Could cause injury (loss of =< 5 working days), would disrupt customer build, less than 200K cost.
- **Key:** Could cause minor injury (no lost working days), part would not assemble, or minor disruptions to customer build.

(PFMEA, Parker)

PFMEA points out potential causes for these failures, and also specifies what actions can be made to prevent these failures. It identifies how and in which phases these process failures are detected, and what is the probability to notice them. Finally PFMEA

gives out a Risk Priority Number (RPN) which is calculated by multiplying ratings for severity x occurrence x detection rankings. According to APQP's principles, a higher number than 40 is not recommended. "*Organizations should be working the highest priority risks regardless of the rating criteria or values. High Severity ratings should always be addressed.*" (www.aiag.org, pdf). The higher the RPN number is, the more severe is the risk.

See Parker's PFMEA document from attachment 3.

## **5.4 PPAP**

### **5.4.1 Purpose of PPAP**

The main purpose of a Product Part Approval Process (PPAP) is to improve the component supply chain for both the supplier and the customer. PPAP is basically a series of agreements which all must be signed by both the supplier and the customer. These documents provide written evidence that the supplier has understood the customer requirements and specifications, and the supplier is capable to produce desired products with desired quality and quantity in the given time frame. (www.smallbusiness.chron.com, read 29.1.2014)

*PPAP highlights the proof or evidence collected through APQP and validated with results from the first trial run. The trial run cannot be a prototype. This trial must represent the production environment, with correct tools, machines, processes, personnel and conditions that may affect part quality.* (<http://quality-one.com/apqp/>, read 29.1.2014)

PPAP is connected to APQP, as PPAP documents are the results of APQP. PPAP contains proof that APQP has been successfully performed. If the sample is rejected, can it be attributed to poor APQP. (<http://quality-one.com/apqp/>, read 29.1.2014)

### **5.4.2 When is PPAP required**

- New part
- Engineering changes
- Tooling: transfer, replacements, refurbishment or adding
- Correction of discrepancy
- Tooling inactive more than one year
- Change to optional construction or material
- Sub-supplier or material source change
- Change in part processing
- Parts produced at a new or additional location

(Cooper industries PPAP manual, 2009)

Basically PPAP is needed every time a new product is ordered from a supplier, or when supplier's procedures are being changed in any way at ongoing production. This way the customer can be sure that these changes do not affect the quality or the safety of the ordered product. If the supplier is new to the customer, PPAP is a tool for the supplier to confirm the customer that they are capable to satisfy the customer and their needs. By PPAP the supplier also ensures that all the subcontractors and material sources they use are at the required quality level.

### **5.4.3 Content of PPAP**

PPAP contains series of documents related to the product, its performance and the process how it is made. Overall there are 18 different documents that can be included in PPAP, but all of them are not always requested. Here is listed what a full PPAP can include:

1. Design records
2. Authorized engineering change documents
3. Customer engineering approval, if required
4. Design failure mode and effects analysis (DFMEA)
5. Process flow diagram
6. Process failure and effects analysis (PFMEA)
7. Control plan

8. Measurement system analysis
9. Dimensional results
10. Records of material / performance test results
11. Initial process studies
12. Qualified laboratory documentation
13. Appearance approval report (AAR)
14. Sample production part
15. Master sample
16. Checking aids
17. Customer-specific requirements
18. Part Submission Warrant

(NCR supplier PPAP training presentation, PowerPoint, read 30.1.2014)

The most critical elements of PPAP are Product Design Drawings, Design- and Process FMEA and Sample Production Part. These documents confirm that the product is dimensionally as desired, the safety of the product is inspected and approved, and the final product is actually managed to produce by the supplier's production process. Part Submission Warrant (PSW) is certain kind of summary of the PPAP and when it is inspected and approved by both sides, it is confirmed that the supplier and the customer are both satisfied to the product and its producing process and the mass production can be launched.

## **5.5 ISIR**

Initial Sample Inspection Report (ISIR) is a document which confirms that all the measures and actions are made to the product as agreed between the customer and the supplier. Initial sample which is inspected must be produced exactly by the same process which is going to produce the product at the mass production phase. All the materials, and the sources of them, must also be the same as the final products. ISIR can be seen as part of PPAP, because PPAP cannot be confirmed without Part Submission Warrant (PSW) which sums up the PPAP, and ISIR which verifies the products performance. (Production part approval process manual, MS Word document, Parker.)

Parker delivers ISIR when it is requested. Initial sample is made before prototype and it runs through series of tests where the results are recorded by detail to the ISIR. With ISIR, Parker is able to confirm their customers that the product delivered is as requested. (Production part approval process manual, MS Word document, Parker,)

## 5.6 Control plan

Control plan is a written document that describes what actions are required and currently made to ensure that the process is able to stay at a high and desired level of quality. Control plan gives instructions on what should be inspected and how frequently, how these inspections should be made and also who is responsible of these process control actions during the manufacturing process. The purpose of these actions is to minimize variations in the production process, and through that, the final product is able to sustain a high level of quality. Control plan is not meant to be the same for very long periods of time, because it is evolving document that changes with the process and the requirements of the product. Parker Ylöjärvi control plan is showed below (figure 5). (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.176-178)

Parker		TUOTANNON TARKASTUSSUUNNITELMA					Versio: 06
Päivä: 16.12.2013							
Tuotantopaikka: Parker Hannifin Oy Lomake: No. 12 Tarkastussuunnitelma		Paikka: Asennelmien tuotanto Tuotanto: Letkuasennelmat					
Asennelmien tuotanto	Materiaali, tarkastuskohdat	Pääkohdat tarkastettavaksi	Prosessi, tarkastusväli	Tarkastusmetodi	Vastuuhenkilöt	Jäljitys, tilastoinnit ja säilytysaika	Toiminta ongelmatilanteissa
Letku	Collector taidista letkuttäpän kasälyvaiheesta	Jokainen esä taidistetaan	Työohje	Visuaalinen taidistus	Collector, asentaja	Jäljitys tiedot löyryttävä letkusta	Taidista koko esä ja lajittele 100 % epäksäntti, huom toimitusvarmuus
Liittimet	Collector taidista: Osannumero, määsä, valmistusesi	Jokainen esä taidistetaan	1 kpl minimi	Visuaalinen taidistus	Collector, asentaja	Säätänumero WO:lle aina	Taidista koko esä ja lajittele 100 % epäksäntti, huom toimitusvarmuus
Merkkaus	Asiakkaan numero, Valmistuspäivä ja asennustunnus	Ennen sajan tuotantos	1 kpl minimi	Visuaalinen taidistus	Asentaja, työnohjaaja	WO-lista, säilytys puolivuotta	Hävitetään ja poistetaan tuotannosta
Ensimmäisen letkun valmistus	L-pitus, puistutusmitat, visuaalinen taidistus	Ennen sajan tuotantos	1 kpl minimi	Mittojen tarkistus	Asentaja	Tiedot WO:lle aina (oputettuihin päällystämiseen WO:loon tiedot)	Hävitetään ja poistetaan tuotannosta
Letkun katkaisu	Oikea letku ja -katkaisupöitus	Jokainen esä taidistetaan	Työohje	Visuaalinen taidistus	Asentaja, työnohjaaja	WO ja työohje	Taidista koko esä ja lajittele 100 % epäksäntti, koeksä prosessi
Kuorinta (tarvittaessa)	Kuorintapöitus	Jokainen esä taidistetaan	Työohje	Visuaalinen taidistus	Asentaja	Työohje	Taidista koko esä ja lajittele 100 % epäksäntti, koeksä prosessi
Letkun harjaus	Kommanlin päin harjaus	Jokainen esä taidistetaan	Työohje	Visuaalinen taidistus	Asentaja	Työohje	-
Asennuksen syvyysmerkkäus	Käytä oikeasä asennussyvyttä	Jokainen esä taidistetaan	Työohje	Visuaalinen taidistus	Asentaja	Työohje	-
Letkun tulppapuhdistus	Puhdistusöljyä ammotaan letkun läpi molemmista päistä, lähyt ilmapöuhäus tulppauksen jälkeen, taidista työohje	Jokainen esä taidistetaan	Työohje	Visuaalinen taidistus	Asentaja	Työohje	Taidista letku, poista tulokset ja puhdistä uudelleen
Liittimien asennus	Asennussyvytys, oikea liitin, kolmen asento, kolonaspöitus, ölym pöitus	Jokainen esä taidistetaan	Työohje	Visuaalinen taidistus	Asentaja	Työohje	Taidista koko esä ja lajittele 100 % epäksäntti, koeksä prosessi
Letkunpuristus	Puistutusmitat, oikea letku, oikea liitin, kolonaspöitus	Jokainen esä taidistetaan	Säätötuotannossa enimmäksäinen, taidistusraportti	Kätkö tarkistusraportti	Asentaja, työnohjaaja	Työohje	Taidista koko esä ja lajittele 100 % epäksäntti, koeksä prosessi
Kutistesukat	Tarkista, että suojat on ehjä	Jokainen letku taidistetaan	100 %	Visuaalinen taidistus	Asentaja	Työohje	Tarkista koko esä ja koeksä prosessi
Puhtausraportti	Puhtaustaso sovitettujen arvojen mukaan	Joka päivä	Minimi 2 kpl vuokssa	Tarkistus partikkeläksänsäällä ja mikroskoeksäällä	Asentaja, Service Center, Manager, Tönohjaaja	Tarkistusraportti puhtaudesta, säilytys vesäkkölelyllä	Koko esä puhdistetaan uudelleen, koeksä prosessi
Lopputarkistus & siirto lähetysalueelle	Määksä tarkistus WO:n mukaan, visuaalinen taidistus	Joka esä	Työohje	Ristiintarkistus collector taidista, visuaalinen taidistus	Asentaja, collector	Asennelman valmistuspäivä asiakkaan koodi, WO- työnumero, liittimien bath numero, säilytys puoli vuotta	Taidista koko esä ja lajittele 100 % epäksäntti, koeksä prosessi
Pakkaus	Asennelmat, lähetysluettelo, oikea pakkaus tapa	Joka kolla	100 %	Visuaalinen taidistus	Vasätoimies, vasätoimies	Lähetysluettelo, tuotteet	Uudelleenmääksä
Lähetys	Rähtäksä, oikea lähetystapa	6 kpl väksä prosessin taidistus	100 %	Visuaalinen taidistus	Vasätoimies, vasätoimies	Lähetysluettelo	Tarkistus 100 %, koeksä prosessi

**AVAINTEKIJÄT: PURISTUSMITAT, ASENNELMAN L-PITUUS JA PUHTAUSTASO**

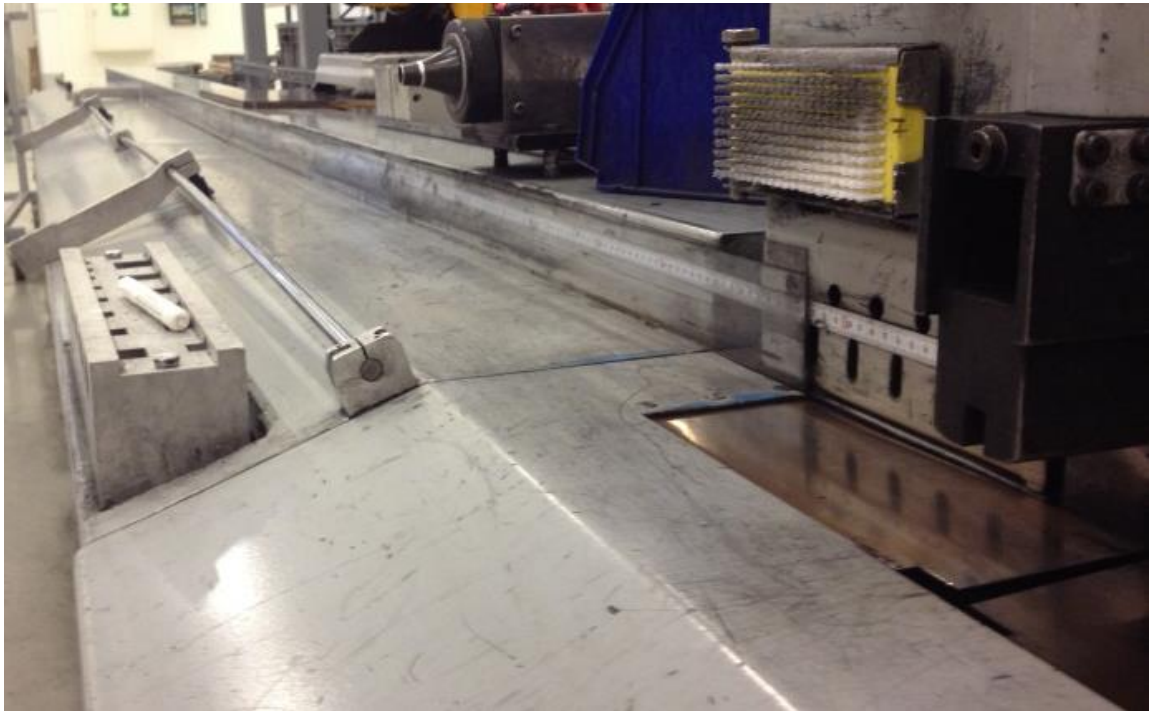
Figure 5. Parker's Control Plan (Parker, 2014)

### 5.6.1 Benefits of a Control Plan

Control plan can be described as an agreement between the company and its workers. It explains how different quality ensuring tasks must be performed, and at the same time it is a guarantee to the customer that the quality level will maintain. Parker Ylöjärvi has placed one control plan to each manufacturing cell for employees to follow up every stage of the productions quality inspections. It helps especially new employees, because with current control plan in sight, they can make sure that every inspection phase is carried out properly, whether they remembered all of them or not. Control plan also identifies possible failure risks of the production and provides straightforward and unquestionable solutions to remove them. If the manufacturing process is being performed strictly by the control plan, the final product's quality level will be as wanted. This way the supplier and the customer can rely on that the products delivered are consistently at the same quality.

### 5.6.2 Parker's quality key factors

Parker's control plan (*figure 5*) points out the three critical key factors, which determine if the end product is at high quality level or not. These factors are proper crimping of the fittings, accurate length of the complete assembly and the cleanliness level of the hose. Every quality assurance action is dedicated for one of these three aspects. Parker's primary tools for ensuring the key factors are hoses length measuring tables (*figure 6*), calibrated crimping machines (*figure 7*) and the cleanliness level testing room with its equipment (*figure 10*, page 36). Cleanliness tests obviously only confirm the cleanliness levels of the hoses, but the actual hose cleaning is done by brushing the cut hose from both ends, and by blowing a foam plug also from both ends before the fittings are crimped.



*Figure 6. Hose's cutting length measuring table*



*Figure 7. Crimping machine*

## 6 SIX SIGMA

SIX SIGMA can be considered as a vision or an ideology, which goal is to find a way to produce nearly flawless products or services to customers. In this case nearly flawless means 0,002 errors per million error possibilities. SIX SIGMA is a customer orientated way of thinking, and the improvements for the process must be based on measured data. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s. 14)

SIX SIGMA offers tools for example problem solving, staff organizing and measuring or visualizing process attributes. Parker Ylöjärvi operates by SIX SIGMA thinking and according to its methods in different phases of the hose manufacturing process. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s. 14)

### 6.1 $C_{pk}$ process capability

Process capability defines how capable the process is to consistently produce products or services that meet the customer requirements. To be precise,  $C_{pk}$  is an index for short-term process capability and long-term index is called  $P_{pk}$ . Capability index is used to predict process performance by comparing its variations to given tolerances. Process capability can be observed and measured from variable or quality point of view. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s. 145)

$C_{pk}$  is ratio between processes median, nearest tolerance limit and three standard variations in short-term inspection. Because  $C_{pk}$  takes into consideration where data median is located between tolerance limits, it can be seen as an accurate and reliable measuring method.  $C_{pk}$  value is calculated for upper guideline and lower guideline, see formula 1 and 2. Figure 8 shows example how short- and long term process variations could be compared to tolerance limits. This type of diagram can point out if the process has variations that do not stay between upper and lower capability guidelines.

Short term process capability  $C_{pk}$  for upper guideline:

$$C_{pk(USL)} = \frac{(USL - \bar{x})}{3\sigma_{st}} \quad (1)$$

$USL$  = upper tolerance limit

$\bar{x}$  = process median

$3\sigma_{st}$  = 3 standard variations in short term

(Tanja Karjalainen, Eero E. Karjalainen, 2002, s.146)

Short term process capability  $C_{pk}$  for lower guideline:

$$C_{pk(LSL)} = \frac{(\bar{x} - LSL)}{3\sigma_{st}} \quad (2)$$

$LSL$  = lower tolerance limit

$\bar{x}$  = process median

$3\sigma_{st}$  = 3 standard variations in short term

(Tanja Karjalainen, Eero E. Karjalainen, 2002, s.146)

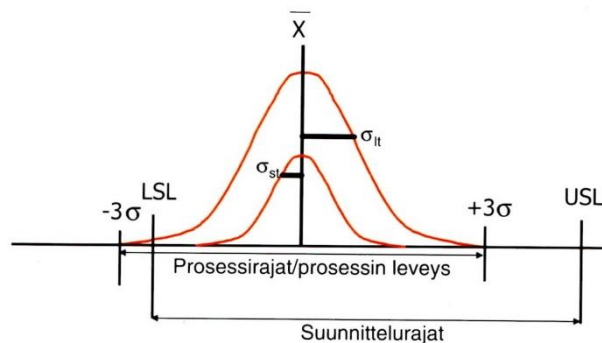


Figure 8. Short- and long term process variations compared to tolerance limits (Tanja Karjalainen, Eero E. Karjalainen, 2002, s.146)

Process capability measurement is important part of Parkers efforts to maintain high quality level on the first of its key factors, proper crimping of fittings. The crimping machines must be in the best possible condition at all times and Parker makes sure of that by performing  $C_{pk}$  measurements. The frequency of these measurements is determined by the previous results. Parker's goal is to achieve  $C_{pk}$  value that is higher than 1,66 because then corrective actions are not needed. See table 1, where  $C_{mk}$  value is equivalent to  $C_{pk}$  value.

Table 1. Frequency of the Cpk measurements (Parker, 2014)

C <sub>mk</sub> value	Process capability calculations required	Corrective actions
C <sub>mk</sub> < 1,33	1 x per week	Corrective actions needed
C <sub>mk</sub> > 1,33	1 x per month / 3 months	Recommended
C <sub>mk</sub> > 1,66	every 6 months	No requirements
C <sub>mk</sub> > 2,00	1x per year	No requirements

Parker crimping devices are calibrated annually, this service is provided by the device manufacturer. Service and calibration certificates are available at location.

## 6.2 GAGE R&R

GAGE R&R is a SIX SIGMA's measuring tool for identifying variable sources that affect to the used measuring system. Measuring system includes the equipment, operators and factors that normally are part of the measuring process. Calibrating and GAGE R&R should not be transposed, because by calibration, it is not possible to affect to the accurate repeating of the measuring system, contrary to GAGE R&R. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s. 145)

GAGE R&R comes from the words reproducibility and repeatability. Reproducibility stands for the variations of the measured value medians, when different operators use the same measuring device to measure identical features from the same objects. Repeatability means the detected variations in the measuring results, when the same operator repeats the same measurement with the same device. GAGE R&R research should be done when new devices are introduced, when comparing measuring devices that are already in use, when evaluating a suspected measuring device or when defining true process variation. So basically the GAGE measurement is done only once, and there are no continuous follow up with this tool. (Tanja Karjalainen, Eero E. Karjalainen, 2002, s. 145)

Parker Ylöjärvi uses GAGE R&R measurement method to ensure the second key factor: accurate assembly lengths. It starts by selecting three operators from production, and the quality engineer who prepares the GAGE measurement cuts five hoses, which are approximately the same length. The quality engineer who is the director of the whole

operation must stay on count which hose is which, but the operators must not know which hose they are measuring at any time. Every operator measures every hose three times and the results are written down and analyzed with Minitab. The final outcome shows visually by diagrams the variations of the measurements and it also gives a precise numeric data to observe. From figure 9 can be seen, how for example the section “Xbar Chart by operator” indicates that additional measuring education could be appropriate for operators one and two, whose measuring results went over or under the tolerance limits

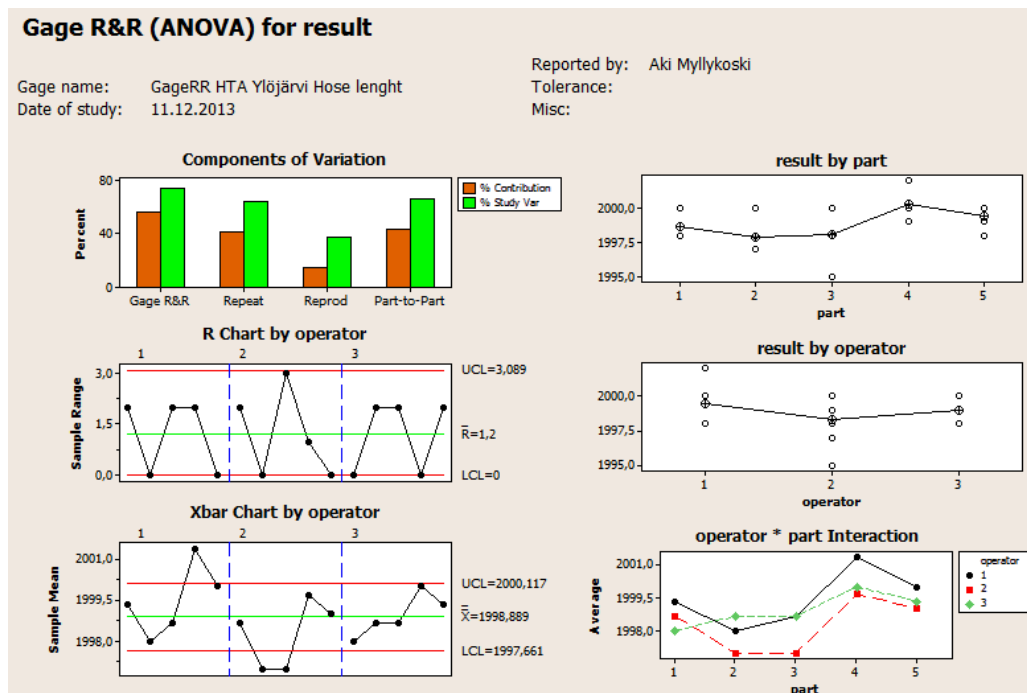


Figure 9. Minitab results from GAGE R&R measurements (Parker, 2014)

GAGE R&R measurements are Parker’s tool and information source when evaluating if any corrective actions are needed for the hose’s length measuring system. When Parker Ylöjärvi was choosing its measuring system, which is the measuring table using attached tape ruler, the GAGE R&R was made for it. This way Parker could made sure that the measuring system it picked, was capable to produce results accurate enough.

### **6.3 Quality maintaining**

SIX SIGMA's tools can point out if the used manufacturing devices or methods are not accurate enough, but they do not tell if the device itself is on good condition and as accurate as possible. That can be confirmed only by continuous calibration, which also gives guarantee to the customer that Parker's production is in its best condition and quality products can be produced.

#### **6.3.1 Calibration**

Parker's crimping machine supplier performs annual maintenance service to the crimping machines. This is important relative to SIX SIGMA, because when implementing its methods, the first assumption is that the machines which are in use work as they are meant to work. If the measuring, or in this case the crimping systems, do not work properly and the productions quality gets poorer, it affects to the production capability. The variation that impairs the quality can be caused by measuring process, and consequently the production might reject the good units and accept the bad ones without knowing the true state of the situation. It is even more severe if the variation is thought to come from the process itself, and in truth it is being caused by the measuring process.

#### **6.3.2 Validate**

Device manufacturer provides service report which from can be seen what operations were made by whom and when. Other document that Parker receives is a maintenance certificate. It shows calibrated machines test results compared to real values. This certificate is again part of Parker's proof to its customers that the production is in good condition and capable to produce high quality products. See service report and maintenance certificate from attachment 4 and 5.

### 6.3.3 Total Preventative Maintenance

TPM is systematic way to prevent any possible problems with working equipment, such as breakdowns or unnecessary delays. Parker uses this TPM method to prevent any machine- or other equipment damages in advance. TPM ensures that the process produces continuously high quality products, which both supplier and customer can rely. Any unexpected quality variations caused by broken equipment are minimized. It can be seen as a kind of a common sense quality assurance method where working tool are maintained regularly, so that repairing them would not be necessary. (Parker, 2014)

From quality point of view at Parker Ylöjärvi, TPM program involves three main objects: oil sponges, brushes and hose cutting blades. The oil sponges which are being used in production cells to lubricate fittings before pressing and crimping them on the hose, are observed daily and changed at least once every week. This action prevents dirt to enter into the hose at the crimping phase and improves final assembly's cleanliness. (Parker, 2014)

Brushes are being used to remove any particles from the cutting surfaces after cutting. By changing them when necessary, it can be made sure that the brushing is consistently effective and the largest possible quantity of the particles can be removed with every brushing action. This also improves the final cleanliness level of the assembly. (Parker, 2014)

A broken cutting blade can cause a rough cutting surface to the hose and eventually inflict improper crimping of fittings. This can reduce assembly's durability and make it even dangerous if the fitting pops out from the hose under high pressure. Broken cutting blade can also produce large particles which can get into the hose and lower the cleanliness level of the final assembly. These large particles can block hydraulic systems at worst. Cutting blades are being changed for new or sharpened ones every month. (Parker, 2014)

## 7 CLEANLINESS QUALITY CONTROL

Parker's final key factor is the cleanliness level of the hose assemblies. Parker uses certain tools, like brushing the hose ends and blowing foam plug through the hose with compressed air, to secure this feature. The final cleanliness quality control method is cleanliness testing. The main idea is to run one cleanliness test two times a week for randomly picked assembly from production. With this approach Parker is able to monitor the quality level of their production and is also able to create documents which from can be seen if there are any deviations in the quality of the assemblies. Another benefit from the cleanliness testing is that Parker can also deliver a cleanliness certificate to a customer if requested.

In November 2013 Parker Ylöjärvi changed their principle on which assemblies they run the cleanliness tests. Formerly there was only one customer and their subcontractors whose assemblies were tested. Therefore hose ends were brushed after cutting only for them, which was necessary if the test was going to be made. According to the new instructions for production, all hoses for every customer must be brushed for now on. After these new instructions the cleanliness test could have been made for any assembly from production. The Parkers cleanliness test is based on ISO 4406 method for coding the level of contamination by solid particles.

### 7.1 ISO Cleanliness Code 4406:1999

The International Organization for Standardization created the cleanliness code 4406:1999 to quantify particulate contamination levels per milliliter of fluid at three sizes: 4 $\mu$ m, 6 $\mu$ m, and 14 $\mu$ m. This ISO code is expressed in 3 numbers: 19/17/14. Each number represents a contaminant level code for the correlating particle size. The code includes all particles of the specified size and larger. It is important to note that each time a code increases the quantity range of particles doubles as can be seen from table 2. ([www.precisionfiltration.com](http://www.precisionfiltration.com))

Table 2. ISO 4406:1999 CODE CHART

Range code	Particles per milliliter	
	More than	Up to / Including
24	80000	160000
23	40000	80000
22	20000	40000
21	10000	20000
20	5000	10000
19	2500	5000
18	1300	2500
17	640	1300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2,5	5
8	1,3	2,5
7	0,64	1,3
6	0,32	0,64

([www.precisionfiltration.com](http://www.precisionfiltration.com))

## 7.2 Parker's cleanliness testing

The cleanliness test is performed in particular room at Parker's facilities at Ylöjärvi (*figure 10*, page 36). The test is advised to be made two times a week by supervisor or selected person from manufacturing. The goal is to find out how many particles the tested hose contains after proper clean up during the production, and to measure the largest particle size. The number of the particles must meet the requirements of ISO 4406:1999, and the largest particle cannot be bigger than 500µm. If both conditions are achieved, the hose passes the test and the shipment can be sent to the customer. As mentioned, all the batches are not inspected, but if a customer wants to have cleanliness test made for their specific order, it can be made, and the total number of tests per week increases.



*Figure 10. Cleanliness testing room at Parker Ylöjärvi*

### **7.3 The cleanliness test**

The cleanliness test starts by measuring the correct amount of ethanol to pour into the hose. The calculations are made by Excel and the idea is to fill half of the hoses inner volume with ethanol. After the correct amount is found out and put into the hose, both ends of the hose are plugged for shaking. This stage needs to be done properly so the particles inside can be mixed with the ethanol as well as possible and the most of them would be able to come out when the ethanol is poured into a container.

The next step is to attach the container which contains the ethanol flushed through the hose, to the particle calculator and write down the results to another ready Excel layout that is the actual report that comes out from the test. When the test in accordance with the standard ISO 4406:1999 is done, the next step at the cleanliness test is to drain the same ethanol trough a filter. Now all the particles that came out from the hose are caught on the filter and they can be inspected by microscope.

The largest particle that can be found from the filter is measured with a computer aided measuring program, and a picture is taken of it to be attached to the report. Now the cleanliness test is finished and the final report can be printed out and stored to Parkers own register and a copy can be sent to the customer if requested. See Parker's cleanliness test report from attachment number 6.

After the test report is made, it is easy to see productions quality level of cleanliness and possible further actions can be evaluated. If the tested hose does not pass the test regard to the number of particles or the size of the largest particle, the result must be confirmed by running three more tests from the same batch. This way it can be seen if the quality failure was only a separate deviation, or if none of the three other hoses pass the test, conclusions can be made that something is wrong with the manufacturing cell that made them. If all four hoses from the batch fail the test, the reasons will be found out and corrected. Possible errors that can cause the quality problems are broken cutting blade, incorrect brushing or brushes poor quality, incorrect hose cleaning with compressed air, or wrong sized cleaning plug.

## 8 CONCLUSIONS

Parker Hannifin Ylöjärvi has a clear vision what it wants and require from its products. It has competition in Finland, but Parker also knows how it is able to fare at the hydraulic system markets and which features are its strengths. Parker does not compete with low prices or production volumes, but a high level of customer satisfaction. This ambition requires high quality products, good customer service and fast availability of the desired product. In order to achieve these targets Parker has to have polished process and effective tools to measure its performance from the quality point of view. Parker operates in accordance with well-tried ideologies and uses many of their tools to get the best possible process and, by implication, the end product. Thorough quality assurance serves Parker's own important objectives and the invested time and effort into it is understandable.

When this thesis was started, Parker had a fairly new production process, and its planned quality assurance methods were mainly taken into operation. During this research these already used methods were checked and their results analyzed. Corrective actions were made and implement to Parker's PFMEA, Control Plan, cleanliness testing and TPM. Performed actions were updates for these documents and processes so that they kept meeting the changed or improved requirements. Quality journey tracking center was implemented into use as a completely new quality tracking tool. Production process's current state evaluation was also updated by  $C_{pk}$  and GAGE R&R measurements during the thesis research.

Parker's quality assurance methods were mapped and updated. With performed implementations the whole quality assurance process became a coherent whole and it was brought to the desired level. From this perspective can be stated, that the thesis project was successful. Parker Ylöjärvi received a confirmation that its quality assurance methods are properly in use and it have an updated and effective process to maintain and improve the quality level of its products.

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Parker Hannifin commercial brochure:  
(Parker The Win Strategy)

Parker's own Process Failure Mode and Effect Analysis document:  
(PFMEA, Parker)

(Production part approval process manual, MS Word document, Parker, 2014)

Tanja Karjalainen, Eero E. Karjalainen, 2002, SIX SIGMA Uuden sukupolven johtamis- ja laatumenetelmä:  
(Tanja Karjalainen, Eero E. Karjalainen, 2002)

AIAG FMEA manual, 4<sup>th</sup> edition, read 24.2.2014  
<http://www.aiag.org/staticcontent/press/releases/GENERAL/AIAG%20FMEA%20Manual%20The%20Benchmark.pdf>:  
([www.aiag.org](http://www.aiag.org))

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<http://www.precisionfiltration.com/products/iso-4406-cleanliness-code.asp>:  
([www.precisionfiltration.com](http://www.precisionfiltration.com))

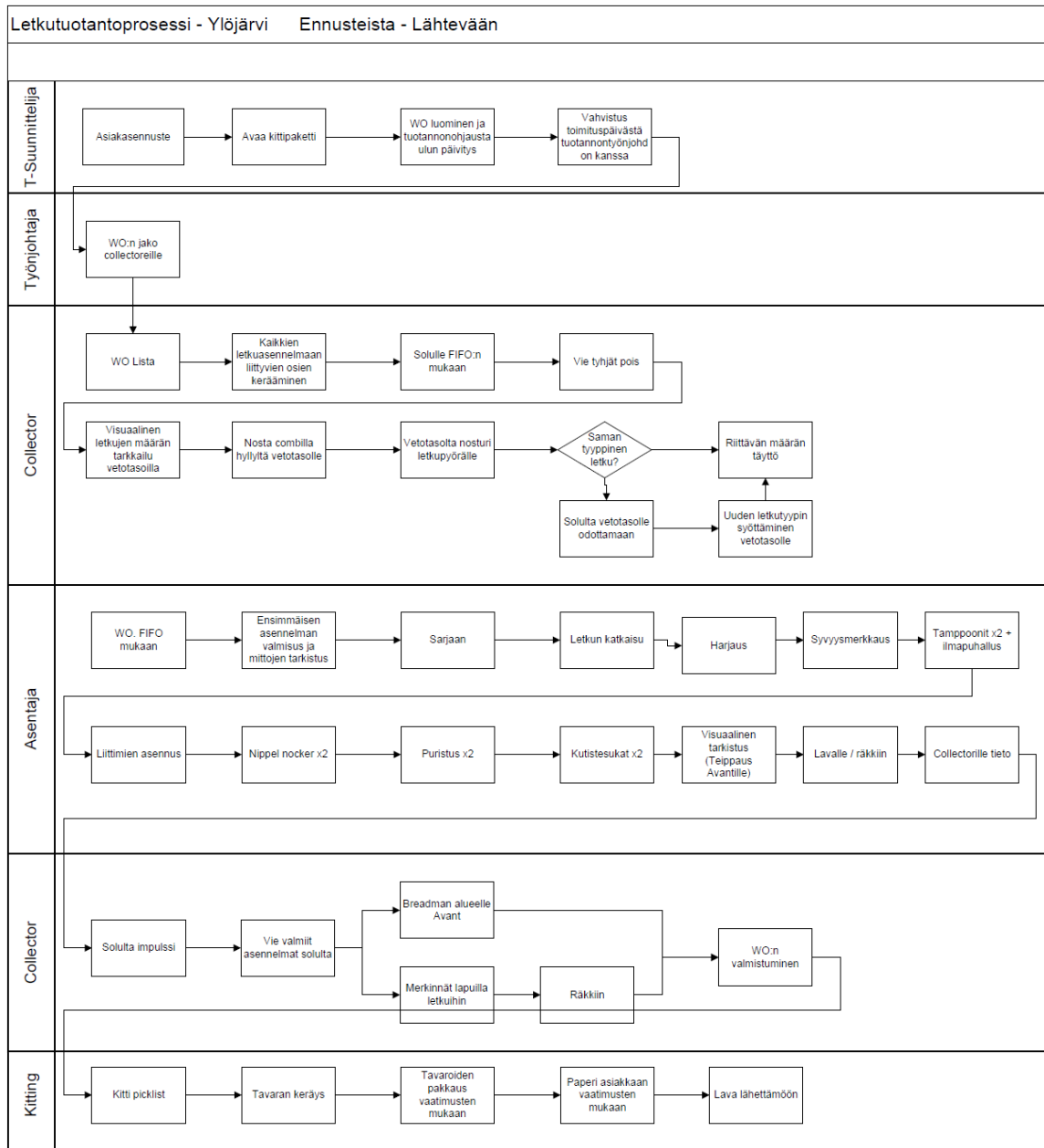
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<http://smallbusiness.chron.com/definition-ppap-39756.html>:  
([www.smallbusiness.chron.com](http://www.smallbusiness.chron.com))

ATTACHMENTS

Attachment 1. Parker’s SIPOC (Parker, 2014)

Suppliers (Providers of the required resources)	Inputs (Resources required by the process)	Process (Top level description of the activity)		Outputs (Deliverables from the process)	Customers (Anyone who receives a deliverable from the process)	
		Requirements			Requirements	
Picker	BOM, fittings, hose, blue boxes	Clean from supplier	Part picking	Parts in blue fitting boxes and hose reel	Correct too BOM and as received from supplier	Hose assembler
Veniano, Mucke, Wickliffe, Helsowen Components, C&M, Hi-Tech, Rodamtic	Batch identification	Supplier batch codes			Traceability of data	Correct WO and Batch No
Maintenance	Saw blade	Cutting speed, Debris extractor	Hose cut	Hose cut to correct length	Tech sheet	Hose assembler
Maintenance / Supervisor	Skiving tool, P80	Tool set to depth/dia	Skive	Hose skived to correct depth/dia	Tech sheet	Hose assembler
Maintenance	Brush	Both ends (Follow WI)	Brush	Loose debris removed from hose end	Cleanliness standard	Hose assembler
Maintenance	Compress air	Pressure, Each end 5 sec	Air blast	Removal of loose debris	Cleanliness standard	Hose assembler
Maintenance / Supervisor	Depth tooling, markers	Insertion depth (Tech sheet)	Mark insertion depth	Insert depth correctly marked	Tech sheet	Hose assembler
Supervisor	P80, sponge	Follow WI	Lubricate fittings for insertion	Fitting is lubricated	Quantity	Hose assembler
Hose assembler	Fitting	Follow WI	Introducing fittings by hand	Partially inserted fitting	Up to 1 mm gap	Hose assembler
Maintenance	Pusher		Insert using pusher	Fully inserts fitting	To meet insert depth mark	Hose assembler
Maintenance	Crimping Machine	Dia size, crimp dia, both ends (Tech sheet)	Crimp	Crimp fittings to correct dia.	Tech sheet	Hose assembler
Maintenance	Compress air	Pressure, One end 3 sec	Air blast	Remove any loose debris, and excess P80	Cleanliness standard	Hose assembler
Picker	Caps	Cleanliness (?), Cap both end, Cap type (BOM)	Cap	Capped assy	Correct to BOM	Hose assembler
Maintenance	Etching machine	Etch customer part num, Wo, & date	Etch ferrule	Hose assembly identified	Tech sheet	Hose assembler
				Cleanliness report	Cleanliness standard (JCB & JOY)	Quality/Production

## Attachment 2. Parker's Process map (Parker, 2014)





Attachment 3. Parker's PFMEA (Parker, 2014)

2 (3)

X	Air Clean Hose		8	M		1	Weekly cleanliness testing. Cell process audit.	5	40									
			8	M		3	Weekly cleanliness testing. Cell process audit.	5	120									
X	Marking of insertion depth (Witness)		10	C		2	1st/ Last check and frequency. Buddy/ Firewall checks	3	60									
			10	K		2	1st/ Last check and frequency. Buddy/ Firewall checks	3	60									
			3	K		1	Visual confirm before/ after crimping operation and at part ending. Buddy/ Firewall checks	2	6									
	Assembly of fittings by hand or Nipple Insertion (Position)		8	C		3	Insert depth mark comparison after insertion and before crimp. Firewall check	2	48									
			8	C		2	Insert depth mark comparison after insertion and before crimp. Firewall check	2	32									
			6	K		2	Audit of process and cleanliness.	3	36									
X	Crimping		10	C		1	Measurement of CD on first/ last piece and every 20th from batch. Firewall check	2	60									
			10	C		1	Measurement of CD on first/ last piece and every 20th from batch. Firewall check	2	60									
			6	K		3	1st/last check and frequency. Buddy/ Firewall check	2	36									
			10	C		2	Insert depth mark comparison after insertion and before crimp. Firewall check	2	40									
X	Set Phase Angle		8	K		3	First/ last piece control. Firewall check	2	48									
X	Polyester assembly		7	M		2	First/ last piece control. Firewall check	2	28									
		4	K		2	First/ last piece control. Firewall check	2	16										
		9	C		2	1st/ Last check and frequency. Firewall checks	2	36										
		9	C		2	1st/ Last check and frequency. Firewall checks	2	36										
		4	K		2	1st/ Last check and frequency. Firewall checks	3	24										

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Attachment 3. Parker's PFMEA (Parker, 2014)

3 (3)

X	Clamping of steel rings		6	K		2	Measurement of CD on first/ last piece and every 20th from batch. Firewall	2	24									
			3	K		2	1st/ last check and frequency. Firewall checks	2	12									
			4	M		3	Measurement of CD on first/ last piece and every 20th from batch. Firewall checks	2	24									
	Clamping of central female		4	K		2	Measurement of CD on first/ last piece and every 20th from batch. Firewall checks	2	16									
			4	K		2	Measurement of CD on first/ last piece and every 20th from batch. Firewall checks	2	16									
			4	K		2	Measurement of CD on first/ last piece and every 20th from batch. Firewall checks	2	16									
X	Pin Type Markers		4	K		2	First/ last piece control. Firewall checks	2	16									
X	Spiral Guard		4	K		2	100% check during start. Firewall checks	2	16									
	Cap assembly		4	K		2	First/ last piece control. Firewall check	2	16									
			7	M		2	First/ last piece control. Firewall check	2	28									
	Part I/D		4	K		3	First/ last piece control. Firewall check	3	36									
	Pack		5	K		2	Feeder line feeder compliant	7	96									
			5	K		2	Feeder line feeder compliant	4	40									
X	Operator		10	K		3	Final Inspection Process	2	60									
X	Training/ OEs/ Hs		5	K		2	Final Inspection Process	2	96									
X			5	K		2	Final Inspection Process	2	20									

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## Attachment 4. Service report (Parker, 2014)



## SERVICE REPORT

№ 02461

Customer / Asiakas PARKER HANVIFIN OY		Machine type / Konetyyppi	
Address / Osoite VANHA VAASANTIE		Serial No / Sarjanro	
Invoice address / Laskutusosoite Ylöjärvi		Service Engineer / Huoltomies J. K.	
Return No / Palautusno TIL.NO. 11903089 ON			
Customers note / Asiakkaan kommentit VUOSIHUOLTO			
Service operations / Huoltotoimenpiteet FR20VS-0999 FR160VSG1-26805 PURISTINPÄIDEN HUOLTO 120UC-34912 SUODATTIMEN VAIHTO 120UC-34812 KALIBROINTI 120UC-35012 120UC-35112 FR20VS-34198 FR140VS-26702 FR20VSG2-241008 FR145VSG2-39305 FR145VSG2-39205			
Guarantee / Takuu <input type="checkbox"/>		No guarantee / Ei takuuta <input checked="" type="checkbox"/>	
		Installation / Käyttöönotto <input type="checkbox"/>	
Type / Numero	Parts / Osat	Pcs / Kpl	Notes
053017/16	JOUSI	6	
053087/16	JOUSI	3	
053103	JOUSI	16	
053104	JOUSI	16	
713124	SUODATIN	6	
705019	SUODATIN	4	
704022	KULMALIITIN	2	
Start / Alkoi 11.2.14		Time / Klo	
End / Päättyi 12.2.14		Time / Klo	
Daily allowance / päiväraha 2		Hotel and other costs / Hotelli- ja muut kulut 100€	
We hereby confirm and accept the service report / Vahvistamme ylläolevan huoltoraportin			
Date / Pvm 12.2.14		Signature / Allekirjoitus	
		Travel time and distance / Matka-aika ja matkan pituus 7h 511km	
		Working hours / Norm. tunnit 14h	

## Attachment 5. Maintenance certificate (Parker, 2014)



## MAINTENANCE CERTIFICATE


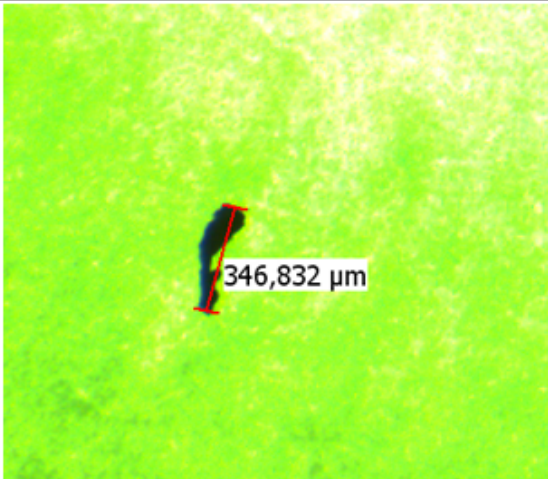
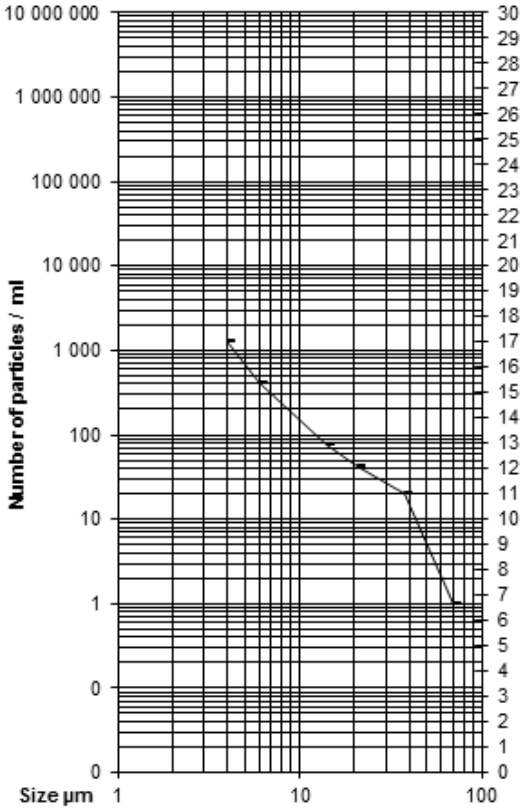
№ 01568

Date: Pvm:	12.2.14	Customer: Asiakas:	PARKER
Type of machine: Koneen tyyppi:	FD 145 US G2	Control unit type: Ohjauksyksikön tyyppi:	US
Number of machine: Koneen sarjanro:	39205	Control unit No: Ohjauksyksikön nro:	

1	General visual inspection for external damages / Ulkoisten vahinkojen yleistarkastus	Signature Kuittaus	<i>JK</i>
2	Test crimping and control of dimensional accuracy / Koepuristus ja mittatarkkuuden tarkastus		
2.1	Check of crimping diameters (die set 19) / Puristusmitan tarkastus (leukasarja nro 19)  Seamless hydraulic tube with 25 mm diameter, length 65 mm ± 1 mm and wall thickness 2 mm / saumaton hydrauliputki, halkaisija 25 mm, pituus 65 mm ± 1 mm, putken seinämä 2 mm  Nominal diameter / Nimellishalkaisija  Test results / Tulokset: 1. 22 mm _____ mm 2. 21 mm _____ mm 3. 20 mm _____ mm  Real diameter / todellinen halkaisija  2.2 Check of conicality / Tarkasta kartiokkuus <input type="checkbox"/> 2.3 Check of roundness / Tarkasta pyöreys <input type="checkbox"/>	Signature Kuittaus	<i>JK</i>
3	Check of mechanics and crimping head / Koneen ja puristusyksikön tarkastus	Signature Kuittaus	<i>JK</i>
4	Check of hydraulics / Hydrauliiikan tarkastus	Signature Kuittaus	<i>JK</i>
5	Check of control unit and electrical functions / Ohjauksyksikön ja sähkötoimintojen tarkastus		
5.1	Re-check dimensional accuracy and recalibrate the machine if necessary / Tarkasta mitan tarkkuus ja kalibroi tarvittaessa  Nominal diameter / Nimellishalkaisija  Test results / Tulokset: 1. 22 mm _____ mm 2. 21 mm _____ mm 3. 20 mm _____ mm  Real diameter / todellinen halkaisija  2.2 Check of conicality / Tarkasta kartiokkuus <input checked="" type="checkbox"/> 2.3 Check of roundness / Tarkasta pyöreys <input checked="" type="checkbox"/>	Signature Kuittaus	<i>JK</i>
6	Lubrication of crimping head / Puristuspuun rasvaus	Signature Kuittaus	<i>JK</i>
7	Oil change / Öljyn vaihto <i>Säädätin ulos</i>	Signature Kuittaus	<i>JK</i>
8	Else / Muuta		

Attachment 6. Cleanliness report (Parker, 2014)

ANALYSIS REPORT						
<b>Customer:</b>	Parker Hannifin Oy	F038458	<b>Analysis number:</b>			
<b>System type:</b>	462-12 L=1750	18.2.2014	<b>Cell number:</b>			
SIZE	COUNTS/ml	ISO 4406 CODE	SAE A S4059		WATER ANALYSIS	
> 4 µm(c)	7687	20	A		<b>Water Content:</b>	
> 6 µm(c)	4198	19	B			
> 14 µm(c)	518	16	C			
> 21 µm(c)	230		D			
> 38 µm(c)	44		E			
> 70 µm(c)	3		F			
REMARKS						
			<p style="text-align: center;"><b>ISO 4406 CHART</b></p> 			
GENERAL RECOMMENDATION						
ISO 20/19/15: Low pressure systems						
ISO 19/18/14: Low pressure valves and high pressure cylinders						
ISO17/16/13: Gear pumps and proportional valve						
ISO 17/15/11: Gear-, piston-, and vane pumps						
ISO 15/14/10: Sensitive servo systems and hydrostatic drives.						
ISO 13/12/9: Silt sensitive systems.						