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Improving coolant filling for a shift towards electric vehicles

A production improvement study at Volvo Cars

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Quality and Operations Management & Production Engineering

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Cover:
[New Volvo XC40 T5 plug-in hybrid, Volvo Cars Press Picture]

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Abstract

The automotive industry is facing a technology shift, from traditional petrol and diesel cars into electric powered cars, due to a sustainability awareness from the market and technological advancements. To take part of this technological shift, automotive manufacturers need to develop and produce cars run by a whole new power train. Volvo Cars state that their sustainability goal is to bring 1 million electrified cars to the streets by 2025. To be able to do this, the manufacturing units need to adapt the production to meet new technical requirements and standards that is set for the new car models. A car powered by a battery will need a larger cooling system than what is needed in the petrol and diesel cars due to that not only the motor will need cooling, but also the battery.

This study is mapping the current filling capacity of the coolant filling station at Volvo Torslanda and evaluates potential improvements in order to increase the coolant filling station to meet future arising demand.

This was done by collecting qualitative data in terms of interviews and quantitative data in terms of process data and pressure measurements. This created an understanding of the process and map of the current state of the coolant filling station could be done.

The main findings are that the coolant filling station doesn't run on its full capacity. There are wastes in terms of waiting times from the operators and the equipment isn't trimmed to perform at its best. To improve this, recommendations on applying visual management and actions to trim the equipment are suggested. Upon these suggestions a future state map was developed and a maximum filling volume of 21,8 liters for the improved station was calculated.

Keywords: Coolant filling, Process optimization, Value stream mapping, Six-sigma, Automotive manufacturing

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Table of contents

1 Introduction 1

1.1 Background 1

1.2 Purpose 2

1.3 Scope 2

1.4 Delimitations 2

2 Theory 3

2.1 Processes and process mapping 3

2.2 Filling of liquid systems 4

2.3 Capability 4

2.4 Machinery capacity 5

2.5 Lean Production 5

Seven wastes 5

2.6 Visual management 6

2.7 Six Sigma (DMAIC) 7

2.8 Theory of constraints 8

3 Methodology 9

3.1 How the study was performed 9

3.2 Data collection 10

Qualitative data gathering 10

Quantitative Data collection 13

Data stratification and distribution analysis 14

3.3 Ethical consideration 15

4 Results 17

4.1 Organizational structure 17

4.2 SIPOC 18

4.3 Station layout 19

4.4 Cooling system architecture 21

4.5 Equipment filling process 21

4.6 Analyze of overall process 23

4.7 Analyze of equipment filling process 27

4.8 Pressure Measurement 30

Initiating phase 31

Evacuation 1 32
Vacuum test 32
Evacuation 2 32
Filling 33
Pressure test 33
Leveling 34
4.9 Improving the process 34
4.10 Estimate filling volume 37
5 Discussion 40
5.1 Discussions on the result 40
5.2 Study methodology and future studies 42
6 Conclusion 43
7 References 44

Appendices

Appendix I – Interview Questions
Appendix II – Process controller inputs
Appendix III – Boxplots for overall process
Appendix IV – Boxplots for equipment filling process
Appendix V – Prediction modelling, linear regression

Abbreviations

C1, C2, C3, C4 - Abbreviation for equipment number 1-4 on line 1:42 in VCT

DMAIC - Define, Measure, Analyze, Improve, Control (six-sigma method)

EV - Electric vehicle

ICE - Internal Combustion Engine vehicle

Line 1:42 - Location of the coolant filling process in VCT

ME - Manufacturing Engineering department at VCT

R&D - Research and Development department at VCT

SIPOC - Supplier-input-process-output-customer diagram (six sigma method)

TC - Final assembly plant at VCT

TOC - Theory of constraints

Tooling - Facility, Tooling and Equipment department at VCT

TPS - Toyota Production system

VCT - Volvo Cars Torslanda plant

VED - Diesel engine vehicle

VEP - Petrol engine vehicle

VSM - Value Stream Mapping

1 Introduction

This chapter contains an introduction to the present study. It begins with a background to the study, followed by the purpose, its research questions and finally delimitations of the study.

1.1 Background

The automotive industry faces a change in customer demand and technological advancements (Knupfer et al., 2017). Due to raising costs on fossil fuel and an increasing sustainability awareness, the market has started its migration towards fossil free powered vehicles. Volvo Cars state that their sustainability goal is to bring 1 million electrified cars to the streets by 2025 (Volvo Cars, 2016). The sustainability needs to be aligned in the whole value chain, from material to customer. This includes the manufacturing, which is facing new challenges associated with changed product designs. When starting to produce new car models, there is a collaborative work between the Research & Development (R&D) and Manufacturing Engineering (ME) departments in order to prepare the production for the upcoming models. The new car models can cause both design and production challenges. The design challenge is to design the cars in a way that emphasizes line production without compromising with the functionality of the car and also adopt the cars for a new power train containing a large battery. Manufacturing challenges can occur due to the new designs, where the production plants need to adopt its current facilities into being able to produce the new car models.

The upcoming new models at Volvo Cars are electric vehicles (EVs). In comparison to internal combustion engines (ICEs) the EVs uses a completely different power train design. Instead of a combustion engine the electrical vehicles are equipped with an electrical motor, and instead of consuming either diesel or petrol the cars power comes from a large battery.

Considering the major design change of the EVs, both R&D and ME needs to prepare for change.

This study will look into one of the challenges that might arise with the introduction of EVs in the future. As mentioned the EVs' power comes from a large battery instead of a combustion fuel. Battery packs generate a large amount of heat when providing an electrical motor with power. This affects the design of the cooling system of the car, in comparison to an ICE the EV needs cooling not only for the motor but also for the battery. This means that the cooling system for an EV could be significantly larger than for an ICE.

The cooling systems are filled with coolant liquid, a water and glycol mixture, at the coolant filling station located at line 1:42. The coolant filling station in Volvo Cars plant Torslanda (VCT) has four filling equipment. A car is filled with coolant by one equipment that moves along the line simultaneously with the car.

The increased volume in the future cooling systems for EVs can cause the cooling filling station in VCT to be at a critical point. There is an uncertainty in the capacity of today's coolant filling station and the ability for the station to meet the future requirements, which are of high uncertainty as well. Volvo initiated this study to investigate the uncertainty and to identify the capacity of today's process of filling coolant liquid in VCT.

1.2 Purpose

The purpose of this study is to map the current filling capacity of the coolant filling station at VCT and evaluating potential improvements in order to increase it to meet future arising demand.

1.3 Scope

The conducted case study will focus on answering the following research question and sub questions.

- How will the transformation towards producing electric vehicles affect the coolant filling requirements in the production?
    - What parameters affect the coolant filling station to improve its capacity and how are they improved?
    - How should R&D, ME and Tooling at VCT collaborate to support this transformation?

1.4 Delimitations

The study is limited to mapping the coolant filling process in the Volvo Cars plant in Torslanda. Volvo has similar processes in the rest of their production plants, but these will not be included due to limitations in costs and travel possibilities.

A number of assembling activities are performed at the coolant filling station, which are not related to the coolant filling process, these activities are not included in this study. This study has only included an investigation on the activities with a direct link to the coolant filling process.

The suggested improvement actions that has been developed in this study were not implemented due to the limited period of time the study was performed.

2 Theory

The following chapter describes the theoretical frameworks used in the methodology when conducting this study. Covering the fundamentals of Lean production, Six Sigma, capacity and capability measurements, process mapping theories and filling of liquid systems.

2.1 Processes and process mapping

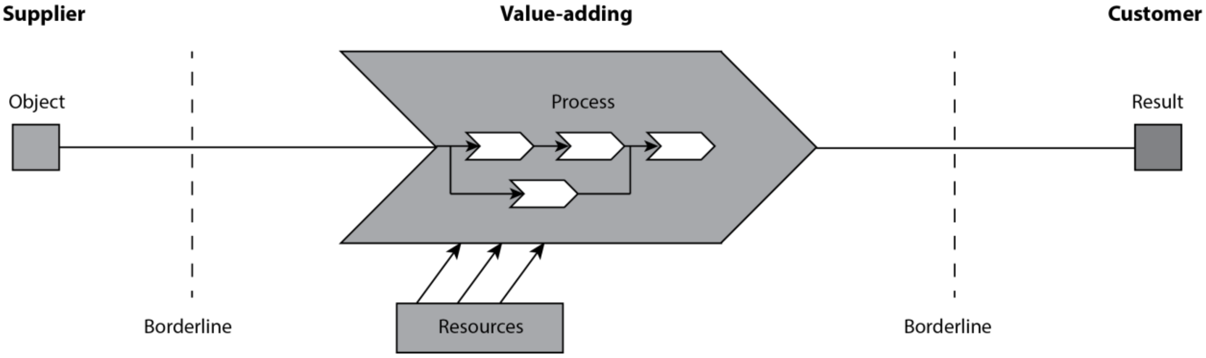

Figure 1 - Process definition reproduced from Bergman and Klefsjö (2010)

Bergman and Klefsjö (2010) describe a process by the definition "a process is a network of activities that are repeated in time, whose objective is to create value to external or internal customers", illustrated in Figure 1. The purpose of each process is to satisfy its' customers with the smallest possible resource. When improving an existing process, it is important to understand the process as it is before the improvement work takes action. It is crucial to understand for who value is created and what it consists of. Therefore, being systematic when describing the process at an initial stage of improvement work is needed. To gain knowledge about the process, process mapping can be applied. Process mapping can be performed in different ways, i.e. using a flow chart to identify different activities within a process, or a block diagram to identify where within an organization activities are performed (ibid.)

Damelio (2011) describes the reasons for mapping a process in the following terms; visualize the work performed, identify functions within the process, mapping relationships between functions, improve measurement and improvement capabilities. Bergman and Klefsjö (2010) mentions that the knowledge that is created by defining and mapping a process is highly valuable in itself, since it is an excellent way to further continue with improvement work, as it generates a shared picture of the current situation. According to Kalman (2002) process mapping is both a process intervention as well as an analytical tool. As an analytical tool, process mapping works to visually describe how activities are performed to show cross-functional relationships in organizations. As a process intervention it works as an action learning tool. When constructing a process map it facilitates inquiry and dialogue between departments and becomes a catalyst for change. There are several types of process maps; value stream maps, process hierarchy map, subprocess map, flowcharts and block diagram. It is common to be needed to use several different process maps on one process, depending on the level of the map. (ibid)

A process map also acts to show the inputs to a process and their effect on the output. The inputs can, depending on their characteristics, be categorized into three groups; controllable inputs (C), standard operating procedures (SOP) and noise (N) (Hammersberg, 2017). Controllable inputs are inputs that can be changed to see effect on the output. Standard operating procedures describe how the process is run and are often rules and constraints that need to be fulfilled, and thereby cannot be changed. Noise are inputs that are hard or too expensive to control but that affect the output, for example the humidity or air temperature (ibid.).

2.2 Filling of liquid systems

When filling a system with liquid, which could be anything from filling one liter milk pack with milk or a coolant system within a car containing small hoses with coolant fluid, two techniques are considered to be used; gravity filling or evacuation filling. Gravity filling is performed by letting the fluid flow into the system from an opening with a set volume and is normally used when filling e.g. milk packs. When filling, the air within the system is let out through an opening or a vent to avoid over pressurizing the system. When filling more complex systems that contain a number of components on different height levels, it is hard to let the air out when using gravity filling. Air might get trapped in the system which affect the total volume being filled to be lower than what is wanted. To overcome this, evacuation filling is used. Automotive manufacturers use the evacuation filling method to ensure the right level of liquid by minimizing the air left in the system in several liquid filling operations, such as coolant fluid filling and brake fluid filling (Pourmovahed et al, 1999). The study by Cerilles (2005) describes the filling process for brake fluid filling using evacuation fill. The process contains of several steps that needs to be performed: Evacuation 1, Leak check, Evacuation 2, Fluid fill, Leveling/Purge/Scavenge. Mali (2016) also confirmed this method of filling and also includes the step of performing a pressure test which is specifically used for coolant systems. Through pressurizing the system with air before the evacuation step is initiated it is ensured no leakages occur. Cerilles (2005) performed a study comparing different vendors of equipment for filling liquids in a manufacturing environment. The conclusion is that the evacuation filling method is the “best-practice” and most equipment vendors are supplying their customers with this method.

2.3 Capability

A process’ ability to produce units within set tolerance limits is called its capability (Bergman and Klefsjö, 2010). Measuring capability is normally done over a set of time using statistics from the process control. Variation within capability over a period of time might occur even though elimination of all potential causes has been done. This can be due to variation between different working shifts, machines or product specifications. Capability measures are divided into machine capability and process capability. Machine capability is estimated by analyzing a homogeneous set of data from, for example, the same machinery, the same set-up or the same working shift. Process capability needs data collected over a longer period of time, since a process average might vary (ibid.).

2.4 Machinery capacity

Lödding and Rossi (2013) mentions that it is usually hard to appreciate the flexibility of machinery capacities but mentions a number of alternatives on how to do this. A company can change the amount of machinery by buying or renting new machines and thereby increase the capacity. This is preferable when using standard machines with short delivery lead times. Another alternative is to change the intensity on the existing machinery. This could be increasing the cutting speed of a machine. Changing intensity could also be to optimize the programming of the machinery but requires that it has not been used to its full potential until now. The possibilities for increasing the intensity of machinery are, though, often very restricted in the industrial practice (ibid.).

2.5 Lean Production

Lean production is a production philosophy originating from Toyota Production System (TPS). It is a broad subject which considers many aspects of a system, from the people in the system all the way down to the detailed pieces of a single process. The main focus areas in TPS is eliminating waste and establishing a corporate culture that at every occasion emphasis continuous improvements (Liker and Hoseus, 2008).

Within Lean production “learn by doing” and “go to Gemba” are commonly used to get to know process (Liker and Hoseus, 2008). Learning by doing means learning a process by being a part of it and by executing the work tasks. In traditional lean fashion, this is done by observing the process at Gemba, which means standing and observing in the factory and progressively gather more knowledge about the process It is deeply rooted in the Toyota culture how important it is to fully understand a process to be able to improve it (ibid.).

Seven wastes

Within Lean production there are seven wastes that are considered and tried to get eliminated to reduce the non-value adding work (Bergman and Klefsjö, 2010). In Table 1 these seven wastes are listed with a description upon each one of them. Slack et al. (2010) describe the elimination of waste as one of the major parts of Lean. For example, this could be done by conducting a value stream mapping of the process to determine what activities that are value adding and which activities that are non-value adding. In the end, the customer doesn’t want to pay for non-value adding activities, only the value adding ones.

Table 1 - Seven wastes of Lean according to Bergman and Klefsjö (2010)

Overproduction	*Producing products before they are required. It is a waste to produce too much, too early or too fast. Pull scheduling, producing products until when they are needed is wanted.*
Waiting	*People and parts waiting for a cycle to finish is considered waste as no value-adding work is performed.*
Unnecessary transportation	*A transport of goods does not create value itself. If an unnecessary transport can be eliminated, waste has been eliminated.*
Over-processing or incorrect processing	*A process producing defect products or products in need of adjustments must be adjusted.*
Excess inventory	*Products and materials waiting in storage do not create value. It also hides balancing issues and late deliveries from suppliers.*
Unnecessary movement	*People and parts being moved during work is not value-adding. These movement should be eliminated or decreased to the biggest extent.*
Defects	*Producing products with defects that needs rework is a waste. Inspecting products is also a waste that could be eliminated by producing the right products.*

2.6 Visual management

Using visual management is a way of communicating a state of a process or to visualize a problem so that everyone can see it (Liker and Hoseus, 2008). Visual management can be used in a line production for communicating the current state of a process to the operator. Strong visual control is according to Liker and Hoseus (2008) when the visual control directly indicates if the process reaches outside of the standard. By indication, the system should both provide a value for the deviation and give some sort of signal that the deviation has occurred.

According to Tezel, Koskela and Tzortzopoulos (2016) visual management can have a good effect on reducing wastes, production costs, quality problems and safety issues at the operational level, which might lead to economic gains for an organization. Tezel, Koskela and Tzortzopoulos (2016) further mentions a number of functions that visual management fulfill, and why visual management is actual applied in production environments. One function is discipline, which is closely related to process standardization, and acts through visual management to communicate process requirements, work instructions and process flows in an easily understood manner. Discipline leads to consistency in terms of reduced variability by reducing human errors. Visual management acts to achieve another function, job facilitation that relieves people's effort, both physical and psychological, on routine work by providing them with sufficient aids. By using visual clues, wastes in terms of waiting, unnecessary movement and searching for products can be eliminated (ibid.).

2.7 Six Sigma (DMAIC)

Six Sigma was developed in the late 1980's within Motorola's Communications Division in order to handle customer complaints regarding warranty claims and focusing on reducing unwanted variation (Barney, 2002; Bergman and Klefsjö, 2010). Since then Six Sigma has been widely spread around the world and is today common in several different industries and companies. Schroeder et. al (2007) have developed a definition on what Six Sigma is, based on interviews with several organizations working with it. It is clear that different organizations might have various definitions on what Six Sigma is, based on their own operations and in what way Six Sigma is applied. Although, the purposed definition developed by Schroeder et. al (2007) goes: "Six Sigma is an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives."

In Six Sigma, a structured method called DMAIC (Define, Measure, Analyze, Improve and Control) is used for members of a project to follow to solve problems and improve processes. Following a structured method helps the project team to not jump into conclusions and helps ensure a wide search of alternative solutions among the way (Schroeder et al. 2007). Lokkerbol and de Mast (2012) claims that DMAIC functions as a problem structuring device that breaks down a problem into subtasks within the DMAIC-cycle into deliverables. By doing this, the user finds a strategy for analyzing and solving a problem, and thus structure it up by hand.

The different stages of the cyclic process DMAIC have some similarities to the Plan-Do-Check-Act (PDCA) cycle and includes several tools that are commonly used, such as the Seven Improvement Tools and the Seven Management Tools. These include, among others, control chart, histogram, scatter plot and interrelation graph, all with the prime function to structure and analyze numerical and verbal information (Bergman and Klefsjö 2010). The define stage focuses on defining the problem and creating a project plan where the inputs to the problem (X's) and outputs (Y's) are described and approved by the project team. This includes mapping the process and its customers, both internal and external, and planning for the project execution. The measure stage continues by getting to understand the current state of the process by collecting reliable data that will be used to expose the underlying causes of the problems. The data is used to set a current state value stream map that confirms the current process flow. The data collection can consist of both quantitative and qualitative data depending on the problem. The analyze stage is where the data collected in the measure stage is analyzed to generate theories that explain potential causes to the problem. Data charts are used that show the link between the process inputs (Xs) and the critical outputs (Ys). In the improve stage, solutions are developed that will be able to solve the problems with the inputs that affect the outputs. The solutions are evaluated and optimized and a "to be" value stream map is developed. The solutions get tested in a pilot testing to document the new data created and whether the solutions are working accordingly to the plan. When this is done, a preparation for a full-scale implementation is made. Finally, the control stage is where the project is completed by handing over the improved process to the process owner including procedures for maintaining the gains.

The documentation that is handed over usually includes before and after data, control documents, a system for monitoring the solutions implemented and completed project documentation (George el al. 2005). It is important to know that the DMAIC cycle is an iterative process where the project team always should be ready to be able to jump between the stages when new data and findings has appeared.

2.8 Theory of constraints

Theory of constraints (TOC) was a concept developed by Eli Goldratt in the 1980's and the concept about how to improve and manage how a system constraint performs in the context of the whole system (Cox and Schleier, 2010). TOC can be described as looking at systems and processes as a chain, where the chain is not stronger than its weakest link. Even though the system or process is improved, but the weakest link is still the same the overall result will not be improved.

When applying TOC, the first task is to understand the system, its goal and measurements. When having this knowledge, you are able to adapt the five steps (Cox and Schleier, 2010):

1. Identify the constraints.
2. Decide how to exploit the constraints.
3. Subordinate/synchronize everything else to constraints.
4. If needed, elevate the system's constraint.
5. If the constraint has been broken, go back to step 1.

TOC looks at a system with the eyes of cause-and-effect logic and focuses on managing the system constraints, interdependencies and variability (Cox and Schleier, 2010).

3 Methodology

This study has been conducted as a case study with both qualitative and quantitative analysis. The study has adopted Six Sigma and its DMAIC approach to structure the collection and analysis of the data. This method was chosen due to the characteristics of the present study, which contained a significant amount of quantitative data. The Six Sigma methodology has several tools to be use for this kind of data and which makes it a good approach. The following chapter describes the methods and tools used to conduct this case study and the risk factors involved.

3.1 How the study was performed

Figure 2 describes how the study was performed in order to fulfil the purpose with the study and to answer the research questions. Step 3 and step 4 has been an iterative process where the data collection has been done on questionings arising from the mapping process, see Figure 2.

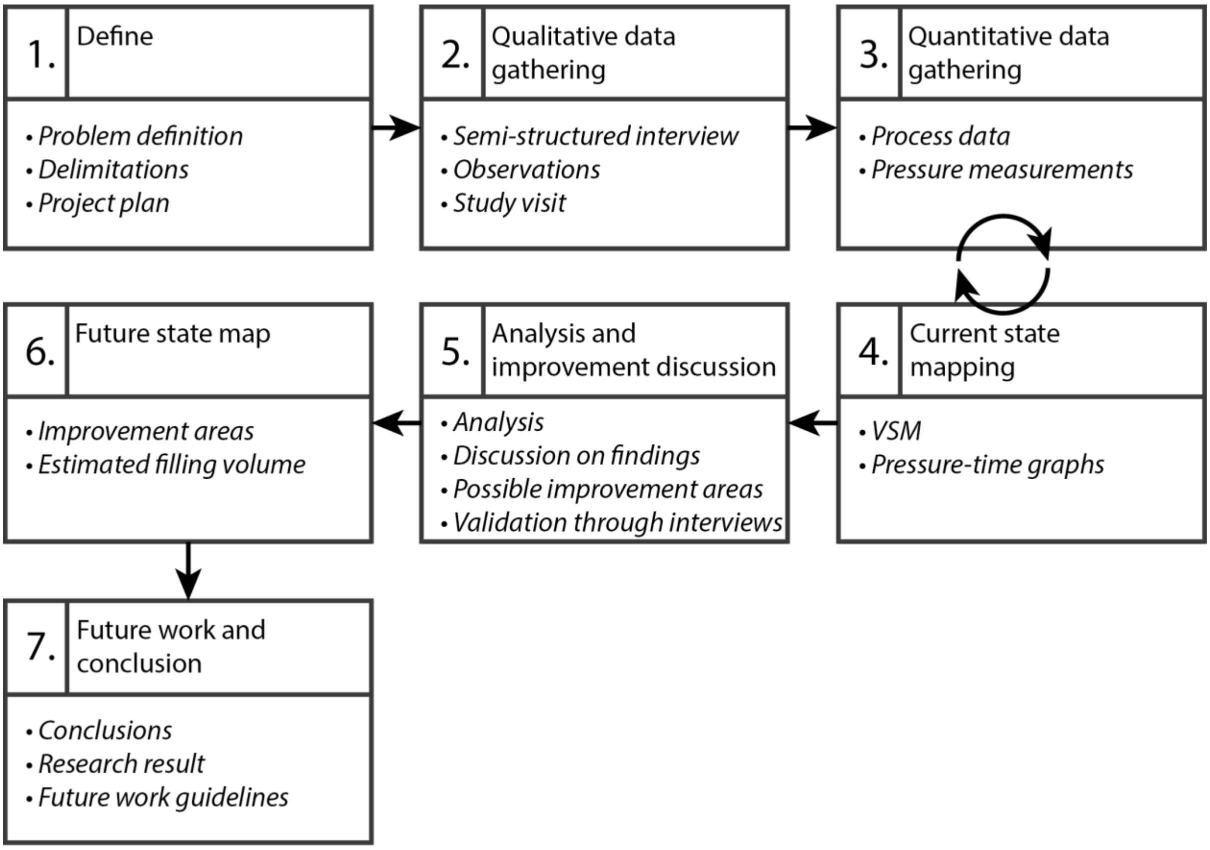

Figure 2 – Overall illustration that describes how the study was performed

Step 1: Define study

The first step was to define the goals with the study. This was done through interviews with the different stakeholders within the study in order to set a clear goal, defined research questions and set delimitations of the scope. A project plan was developed with time limits for the different upcoming steps.

Step 2: Qualitative data gathering

When the scope was set an initial data gathering was done to get a picture of the process as it is today. This was made through semi-structured interviews to get a picture of the organizational structure around the process. By observations at the coolant filling station an understanding of how the operators and the filling equipment perform their operations was developed. A study visit to Volvo Group Tuve plant was done to get a picture of how a coolant filling process was done in other contexts.

Step 3: Quantitative data gathering

Quantitative data were gathered in three ways. First, unprocessed raw-data from the filling equipment were gathered to get statistics on lead times from the process. To dig deeper and to see the actual filling process, pressure measurements were performed on the expansion tank while executing the equipment filling process.

Step 4: Current state mapping

The first part of the purpose with the study was to map the capacity of today. By using the gathered data, the current state was mapped. Several mapping tools were used to bring a detailed picture of the as-is performance of today.

Step 5: Analysis and improvement discussion

When the mapping had been performed, an analysis of the current state was done in cooperation with the regarded units at Volvo. Discussions on general findings of the current state and development of improvement efforts were discussed and examined.

Step 6: Future state map

After developing suggestions for improvement, a future state map was created. This includes the implemented improvement suggestions and an estimated maximum filling volume.

Step 7: Future work and conclusion

The final step was a conclusion upon the work performed within the study and the results achieved. At last, the research questions were answered.

3.2 Data collection

Both qualitative and quantitative data was collected through the study and the research strategy therefore has a mixed methods approach (Bryman and Bell, 2011).

Qualitative data gathering

The methods used in this chapter have been a part of the qualitative data gathering.

Observations - walk the process

Liker and Hoseus (2008) explains how looking at graphs and collected data is not enough to get the whole picture of a process and its occurring problems. By walking the process, and observing a production cell, things that are not visual in graphs can be found such as waste, how operators follow standardized routines and the use of visual management. To be able to get to know the actual filling process and how machines and operators integrate with each other it is crucial to observe the process. Observation of the process was done through several visits to the factory and the station. Observations were conducted both together with representatives from different departments and individual visits by the study group. During the observations notes were taken and different areas were observed, such as process times, team boards, equipment controllers and product specifications.

Interviews

Interviews is a prominent data collection strategy in both qualitative and quantitative research. A semi-structured interview is a type of interview where the interviewer has a set of questions prepared in advance but where he is able to be flexible and ask follow-up questions based on the responses and the interviewee's perceived knowledge about the station (Bryman and Bell, 2011).

Interviews were conducted with employees involved in the coolant filling process from ME, R&D and the tooling division, see Table 2. In the define phase, the purpose with the interviews were to get a picture of how the different departments are involved in the coolant filling process, to define the problem statement and to get to know the coolant filling process. The interviews were semi-structured since the interviewee's backgrounds and knowledges differ depending on their role, which caused the follow-up questions to be slightly different. The main questions from the semi-structured interviews can be found in Appendix I. The interviews had the purpose of creating an understanding on how the organizational structure is built around the coolant filling station. It was essential to know how different divisions work towards the station and how they interact between each other.

The interviews were held in Swedish due to the interviewees main language. To analyze the information gathered in the interviews, the information was coded to identify themes among the responds (Bryman and Bell, 2011). The information was used to create the problem statement and create an organizational structure to identify the information flow between the departments.

Table 2 - Data on performed interviews

Interviewee Title	Division	Date
Commodity Engineer	ME	22/1 2018
Commodity Engineer	ME	22/1 2018
Commodity Engineer	ME	22/1 2018
System Commodity Engineer	ME	24/1 2018
Manager Powertrain Installation	ME	1/2 2018
Manufacturing Engineer	ME Core	1/2 2018
Product Development Engineer	R&D Outer Cooling	5/2 2018
Equipment Engineer	Tooling	6/2 2018
Senior Project Manager Equipment	Tooling	6/2 2018
Industrial Engineer	Industrial Engineering	9/2 2018

SIPOC

A SIPOC diagram (supplier-input-process-output-customer) is a process mapping tool used to highlight critical information in a study's early stage. It helps the research team and it's sponsors to agree on the scope and boundaries of the project and that the outputs of a process match the inputs (George et al., 2005). Depending on the process the supplier and customer can be both internal or external customers. Creating a SIPOC is best done by a team with widespread knowledges of the process so that the essential outputs and customer requirements won't be missed. It is filled out by first deciding on what the output is. Then deciding on who the customer is. Then the actual process is defined and named. Next, the input to the process is identified and at last, the supplier of the input is examined (Hammersberg, 2017). The sequence of filling the SIPOC diagram is illustrated in Table 3.

Table 3 – SIPOC structure, numbering corresponds to the order of the steps when constructing a SIPOC

5	4	3	1	2
Supplier	Input	Process	Output	Customer

In this study a SIPOC was constructed in the define phase to determine the process outputs and inputs. The data for the SIPOC was gathered through observations and interviews.

Quantitative Data collection

The methods used in this chapter have been a part of the quantitative data gathering.

Process Logs

In VCT there is a server that saves log entries from different equipment lines, which includes log-data from the coolant filling station and its equipment. This server's datafiles are reachable from within the Volvo network and the log-files are continuously updated. The log files cover the different equipment activities and also the interactions from operators that trigger sensor changes. The log files consist of every log entry sent from the line and equipment, which can cause a problem when analyzing a specific process. In this study Python and Microsoft Excel was used to filter out the relevant data from the raw data. The time stamps filtered out along with the corresponding event occurring at the given time stamp from the log-file were analyzed by visualizing the data and split the data up into different categories.

Pressure testing

To evaluate the process steps within the equipment cycle, pressure testing in the expansion tank was performed. The pressure testing is a method that has been developed in-house by R&D and similar studies on equipment filling and pressure testing has been made by Mali (2016). R&D has provided the study with some less accurate pressure measurements from earlier studies. Since evacuation-filling is based on pressurizing the system, this measurement method is a good way to identify how the filling is performed.

The pressure testing was performed with a pressure sensor and a measurement PC-software. The pressure sensor was mounted with a custom hose that extends the expansion hose from the expansion tank, as seen in Figure 3.

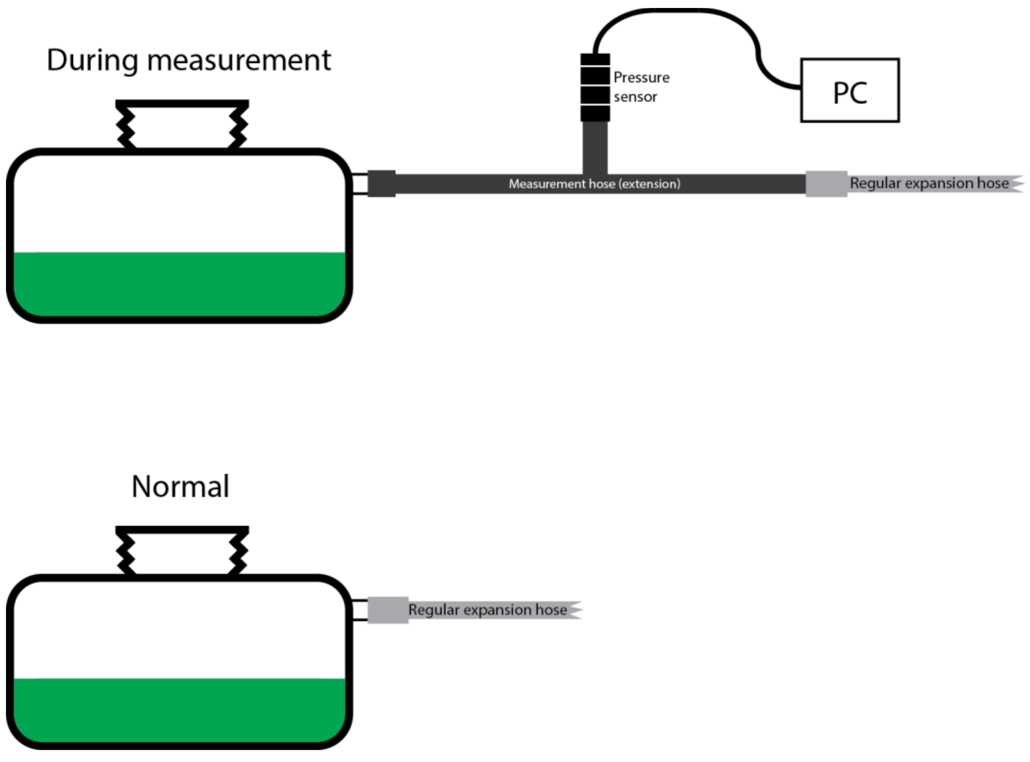

Figure 3 - Pressure measurement setup, illustrating expansion tank while measurement equipment is mounted (during measurement) and expansion tank without measurement equipment (normal)

The data obtained from a pressure measurement consist of pressure values (bar) and the corresponding time value. The measurements were performed at 10 Hz and all data was exported to an Excel-file. From the raw data a pressure-time line plot was drawn. The different process steps were identified by matching the time stamps from the process monitor with the pressure measurement graph.

Value Stream Mapping

Value stream mapping (VSM) is a rather simple but efficient tool for mapping a product flow. VSM takes both information and material flow into consideration. It has a primary focus on decreasing lead times, minimizing waste and what activities that are value-adding (Rother and Shook, 2003). As described by Locher (2008) a VSM should be conducted in 4 steps; preparation, current state mapping, future state mapping and implementation. The most significant importance is to map the current state in a detailed way, so it can be improved according to the shared vision for the process flow. The VSM traditionally follows one product and defines the different value-adding and non-value adding activities in the flow. Identification of future improvements can preferably be made by identifying the different types of waste in the process (Locher, 2008).

In this study a VSM was used to map the process, by identifying the different process steps. The current state VSM showed the activities performed and their time utilization. From this it could be found whether the activities were value- or non-value-adding. By making a future state VSM in the end of the study the effects on taken improvement actions was visualized.

Data stratification and distribution analysis

The data that has been collected during this study is considered to be primary data, which are data collected upon the actual case of this study. The use of primary data gives the study a high trustworthiness, where conclusions are based on data of the specific situation that is investigated.

When evaluating a set of data, regarding lead times within the coolant filling process received from the process monitoring, an analysis is required to find the proper lead times for the current state VSM. In activities performed by operators there might be variations due to various reasons such as random events, new operators, different operators and so on. To analyze the data and its distribution and finding the overall mean times of the operator times boxplots were used. Boxplots provided an instant picture of variation and might give insight into strategies for finding what caused the variation (George el al. 2012).

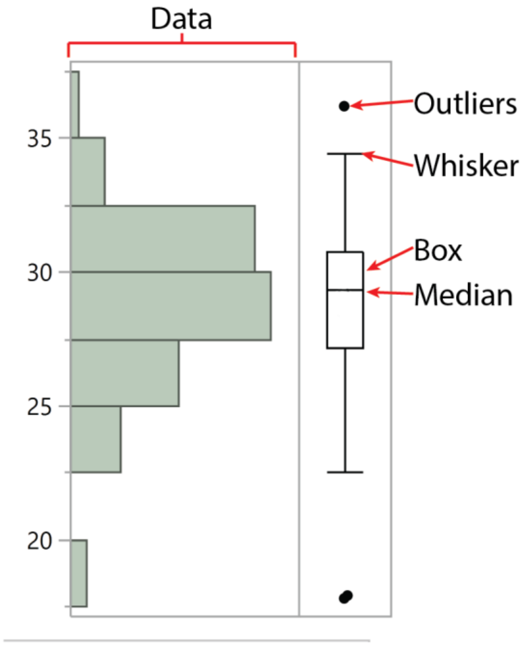

Figure 4 - Box plot, arrows and notations describing the different part of a box plot.

A boxplot, see Figure 4, comprises the data into what the name says; a box. Inside the box 50% of the data set, the 2nd and 3rd quartiles, is shown. Outside the box the rest of the data is shown by “whiskers” which is a single-line that is above or below the 2nd and 3rd quartile. Outliers is shown as separate markers. Times outside the box can be deviating from the standard operating procedure due to break or disturbance in the production. The times inside the box are therefore used for the current state VSM. The box plots were created with the statistics software JMP Pro.

Regression modelling is a method that can be used to identify patterns and predict process outcomes, by analyzing the function Y = f(x), (Rhinehart, 2016). For example, to determine the volume (Y) and how it is dependent of the time (x). One can with a large data set predict the function f(x) to estimate Y. In this study the estimated volume for a specific process time will be calculated with the following linear equation;

$$Volume = a + b * process\ time$$

The variables *a* and *b* are determined from the data set using the prediction modelling method in JMP Pro.

However, as Rhinehart (2016) also mentions it can be hard to determine which type of model to use for a prediction and which data points that represent the whole population in an appropriate way without bringing to complex data into the regression model. As mentioned above a validation of a data set using box plots can be helpful for prediction modeling.

3.3 Ethical consideration

According to Bryman and Bell (2011) there are four main areas regarding ethics that need to be taken into consideration when conducting a research involving humans. These four areas are harm to participants, lack of informed consent, invasion of privacy and deception. Harm to participants can involve different types of harm, from physical harm to harming a participant’s self-esteem or career opportunities. Avoiding harming the participating people within the scope of the study will be done by letting them be fully anonymous if this is wanted. The second area is the lack of informed consent, which is about not giving the whole background information of the study such as scope and reason to conducting the research. Avoiding this will be done by always giving a participant information on what the study is about, why it is done and what their role might be in it. Linked to this is the invasion of privacy aspect, which due to the degree of informed consent can vary the perception of privacy. The last aspect, deception, is about giving readers another picture of the research than what it is. Overall in this research, a high level of transparency towards people coming across the study have been of high importance to obtain a high ethical level without harming participants.

4 Results

This section presents the results of the data collected as well as suggested improvements upon the results.

4.1 Organizational structure

An important part of defining a project is to define the different people involved in the process, as mentioned by Damelio (2011). Through the semi-structured interviews held, information was gathered regarding collaborations in between different units an organizational chart has been constructed, Figure 5. The main departments within this study are ME, R&D and Tooling. The organizational chart, see figure 5, shows the representatives from each department that has been involved in this study. ME Cooling installation provides the coolant filling process with work instructions containing process times for the operations that needs to be performed on the production line. ME Cooling installations work is mostly concentrated to manual labor and does not include more than a machining time for the equipment. The difference between ME Cooling installation and ME Core is that ME Core is working in earlier stages of projects. R&D provides both Tooling and ME with technical instruction and requirements that need to be fulfilled. The technical requirement contains information about quality targets that needs to be archived, for example the level of coolant fluid in the system after the filling process is concluded. Tooling are responsible to purchase, operate and maintain equipment according to technical requirements from R&D. Industrial Engineering (IE), Process Engineering is a production technician that works closely to the production line with continuous improvement projects and securing the daily drift.

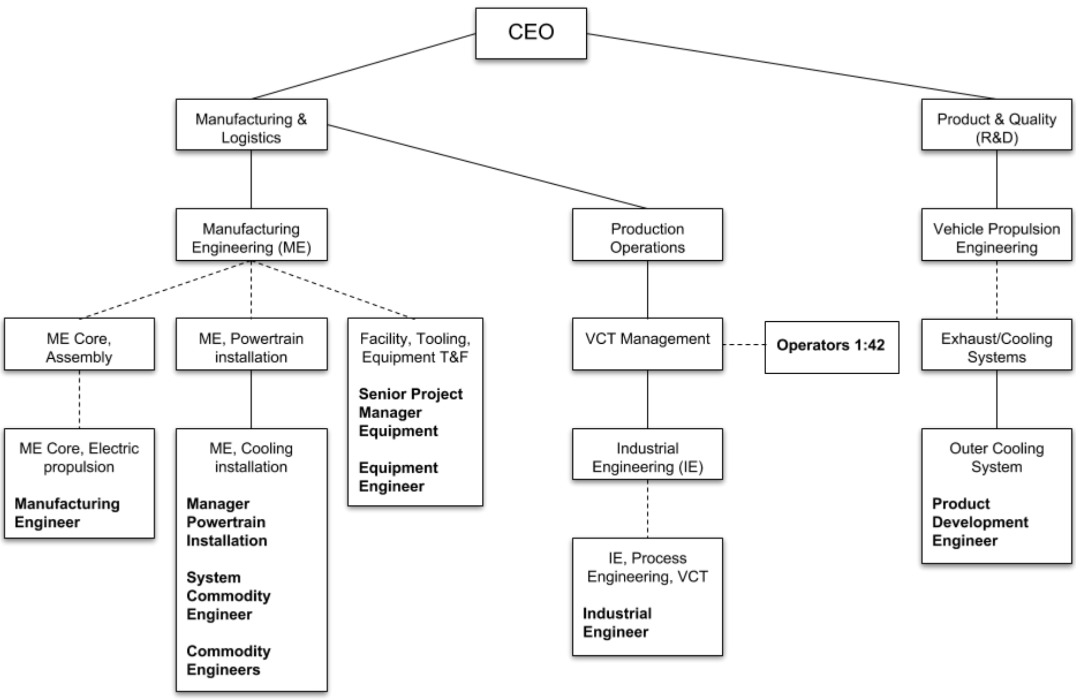

Figure 5 - Organizational chart

What was concluded from the interviews among the ME and Tooling workers, was that they experienced that the technical requirements from R&D could be delivered at any time and also that these requirements could be required to be implemented right away. This could result in problems due to that ME and Tooling need to make fast decisions and implement new solutions right away, without the needed time to explore options to meet the requirements.

What was also observed during this study was that the responsibility areas surrounding the coolant filling station are to a great extent divided into the different departments. It is unclear if there is anyone who has an overall knowledge and responsibility over the coolant filling station. Responsibilities and knowledges are divided among the departments depending on characteristics of task. This goes against the statement made by Liker and Hoseus (2008) who claims that to be able to improve a process it is important to fully understand it.

4.2 SIPOC

Table 4 – SIPOC process map

Supplier	***Inputs***	***Process***	***Output***	***Customers***
Previous station *Fluid supplier (fluid machinery)*	*Production schedule* *Empty fluid tank* *Requirements* *Coolant fluid* *Software* *Operators work*	*Car arrives* *Operator pulls string* *Equipment goes down* *Mount hose* *Filling* *Dismount hose* *Equipment goes up* *Equipment return*	*Filled fluid tank* *Equipment measurement data* *Line measurement data*	*Next station* *End customer*

The input and output of the station is illustrated in a SIPOC, Table 4. The SIPOC was developed after the interviews to get a good picture of people involved in the study as well as the process in a large scope. The SIPOC is a rather simple input and output process in the sense of products. A non-filled car enters the station and the output should be a filled car. However, an important output of the station is the data acquired by the process monitor, for both the equipment and the manual work. The process steps are described in more detail in Chapter 4.3.

4.3 Station layout

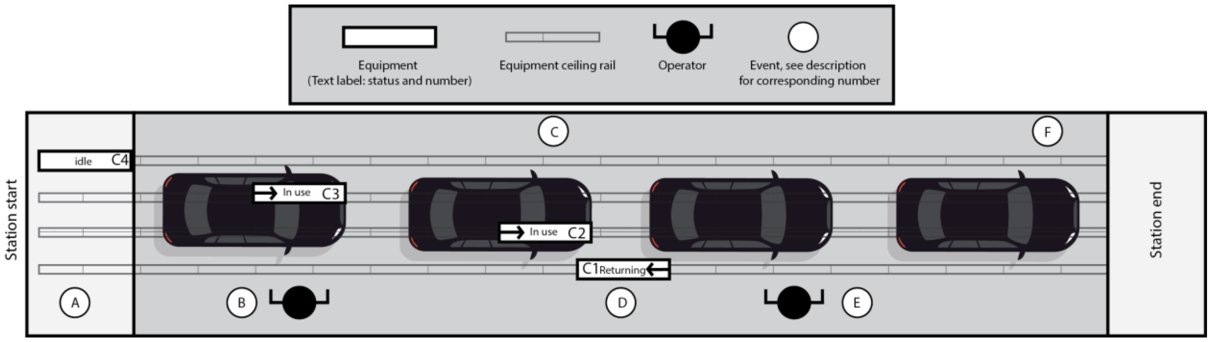

Figure 6 - Station layout, VCT line 1:42 seen from above. Illustrating the station and the equipment placement.

The coolant filling station (1:42 in VCT) is illustrated with a view from above in Figure 6. The station layout is based on the observations at the production line and was constructed by upon the findings. The coolant filling station contains four filling equipment (C1-C4) mounted in the roof following the cars above them. The scenario in the figure could be a real setting where one equipment is idle (C4), one is assembled (C3), one is filling (C2) and the last one is returning to its home position (C1). This station, including the operators and the equipment, was defined as the Overall process within this study.

According to the held interviews the station has four filling equipment but is calculated to be able to run on three of these. The reason to why there are four equipment is to be able to run the operations if one breaks down or needs maintenance. The takt time is 58,2 seconds and the cycle time for three equipment is 174,6 seconds. The line speed is 0,103 m/s and the return speed of the equipment is 0,667 m/s.

The following section describes the different steps performed along the line and are indicated by the letters A-F in Figure 6.

A. The equipment moves along a rail mounted above the car in the roof, parallel to the line. The equipment’s starting position is placed right before the start of the actual station. The equipment returns to the idle-station when finished processing a car and waits until the next car arrives.

B. When a car arrives at the station, an idle equipment starts to move along the car. From this point an operator can initiate the first process step by pulling a string (Arm up/down string in Figure 7). The equipment arm (Equipment arm in Figure 7) goes down to operating position. Further on, the operator takes the nozzle (Hose with nozzle in Figure 7) from the equipment arm and places it on the expansion tank (Expansion tank in Figure 7). The filling sequence is then initiated when the operator pushes the start button located on top of the nozzle.

C. The car and corresponding equipment moves along the line, while performing the filling sequence.

D. The equipment alerts the second operator with help of a blinking light and an audio signal when the filling sequence is completed. The second operator then pushes the stop button and places the nozzle in the nozzle holder and pushes a button on the equipment arm that retrieves the it.

E. When the equipment arm reaches its top position, the equipment changes direction and starts to move back along the rails to the idle position at the start of the station.

F. Finished filled car is handed over to the next station.

In addition to the activities described above, the operators do perform some other assembling operations that is performed during and after the filling process.

Figure 7 illustrates a side view with a mounted nozzle on the expansion tank, which is a snapshot of the process at letter C in Figure 6.

Figure 7 - Illustration of equipment filling car at station 1:42 in VCT

To emphasize data evaluation and deeper understanding in the process the station has been split up into smaller process steps. The following list describes the process steps and refers back to where the specific process step is happening along the line in Figure 6 (indicated by (#) where # corresponds to the lettering).

- Car arrival (A) - From the point where the equipment starts to move along a car until operator pulls the strap to initiate the equipment arm to go down.
- Arm going down (B) - Operator pulls string to initiate the equipment arm to go down and waits until it has reached its bottom position and is ready to provide the operator with the nozzle.
- Arm down to nozzle taken (B) - Time from equipment arm is down until the operator takes the nozzle out of its holder.

- Mount nozzle (B) - Operator takes the nozzle from the nozzle holder and mounts it to the expansion tank and starts the filling sequence by pushing the start button on the nozzle.
- Equipment filling process (C) - From operator pushing the start button until equipment has finished the filling sequence and signaling with light and audio.
- Filling finished to dismount (C) - From the equipment filling process is finished until the operator starts dismount the nozzle by pushing the stop button.
- Dismount nozzle (D) - Operator pushing stop button and dismounts the nozzle. Placing the nozzle in the nozzle holder on the equipment arm.
- Nozzle returned to arm going up (D) - Time from operator has returned the nozzle in the holder until button pressed signaling the equipment to retrieve the arm to the top position.
- Arm going up (D) - Time for equipment arm to move from bottom to top position.
- Equipment returning (E) - Time for equipment to return back to the start (to the idle station)

4.4 Cooling system architecture

The cooling systems are different depending on the type of motor system. Currently both petrol (VEP) and diesel (VED) engine vehicles are produced. Some of the systems also have an electric motor in addition to a petrol engine, which means that it is a hybrid vehicle. The hybrid cooling systems have a larger volume than the non-hybrid cooling systems. The motor systems can also be of different, ranging in power and addons like heaters. All these variations cause the coolant systems to have a varying volume and complexity.

To simplify this study the variety of cooling systems used today can be categorized into two groups. In the following chapters the hybrid cars will be referred to as large systems, approximately 13 liters, and the non-hybrid cars as small systems, approximately 9 liters.

4.5 Equipment filling process

The four equipment are purchased from the equipment manufacturer Agramkow but are fully owned and operated by Volvo. Therefore, Tooling has the ability to change the parameters within the equipment. The equipment is controlled by an equipment control system. In the equipment controller panel at the station a set of input parameters can be set to control the equipment process, see Appendix II . The parameters can be divided into different categories;

- Time parameters - executes an operation for set time or a waiting for a set time.
- Pressure parameters - target pressures or safety levels, which a process step should archive or stop at if exceeded.

The equipment filling process can be broken down into smaller process steps. From the process monitor, meetings with Tooling representatives and observations at the production line the following equipment filling process steps has been defined;

- Initiating - fastening nozzle griper to expansion tank
- Evacuation 1 - evacuate air from the system to a predefined vacuum pressure, targeting 40 mBar.
- Vacuum test - perform a check that the desired vacuum pressure is reached and ensure no leakages occurred.
- Evacuation 2 - perform one more vacuum suction to ensure that the predefines vacuum pressure is still reached.
- Filling - initially, the equipment uses the under-pressure created in the cooling system to inject the liquid. When the system is reaching atmospheric pressure, the equipment forces liquid into the system until an over-pressure of 1.5 bar is reached. In this stage, the system is top-filled.
- Pressure test - ensures that the over-pressure is stable to determine that there are no leakages in the system.
- Leveling - due to the system being top-filled, in the leveling phase the equipment sucks liquid out of the system and dropping the pressure to around 1 bar. The leveling is controlled by the pressure drop and the nozzle pipe, see Figure 8. The pipe is designed so that it reaches as far into the expansion tank as the required level of 48 mm with a tolerance of ±2 mm, x1 in Figure 9, that is specified in the technical requirement by R&D. This level is a quality requirement, if the level is too low there is a risk of needing to refill the coolant system since the level decreases when the car is driven.

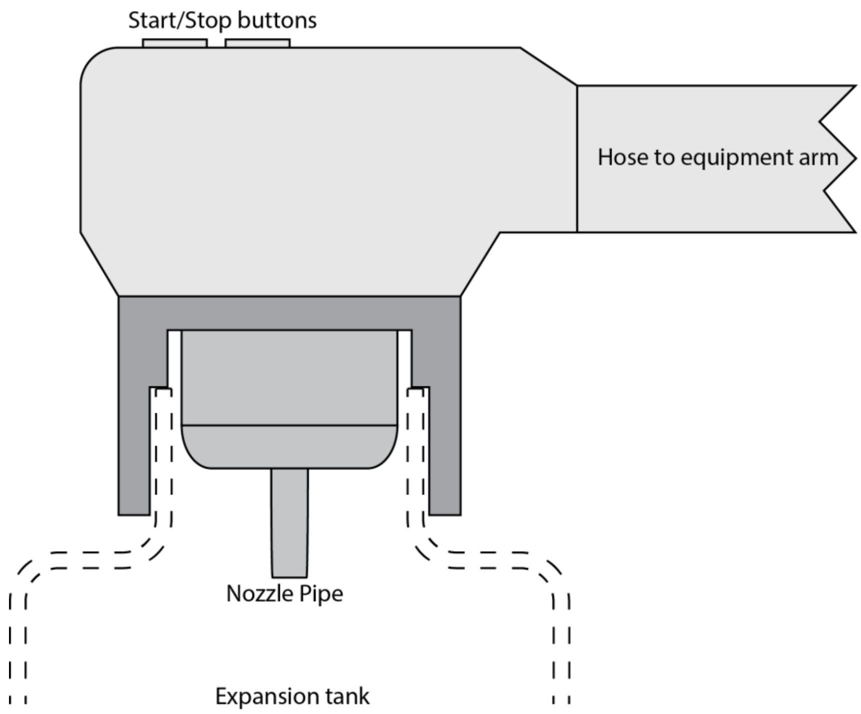

Figure 8 - Equipment nozzle mounted on the expansion tank

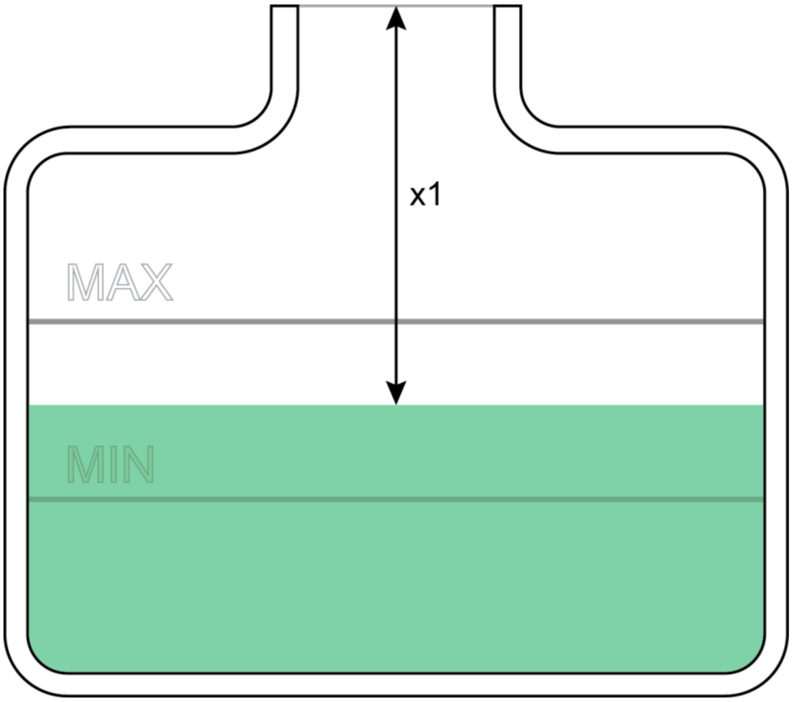

Figure 9 - Expansion tank with technical requirement (x1)

4.6 Analyze of overall process

The overall process includes the main process steps within the coolant filling station including both the filling equipment and the operators. Starting with Car arrival and ending with the Equipment returning. The process times acquired from the process monitor are based on one week's production, week 9 in 2018. The sample size is approximately 4000 produced cars. The data contains times for each process step for each produced car.

When regarding the average times for each process step it can be identified which of the process steps that utilize the most amount of time. Figure 10 shows two stacked columns with each process time, illustrating the time for the whole process divided into large systems and small systems.

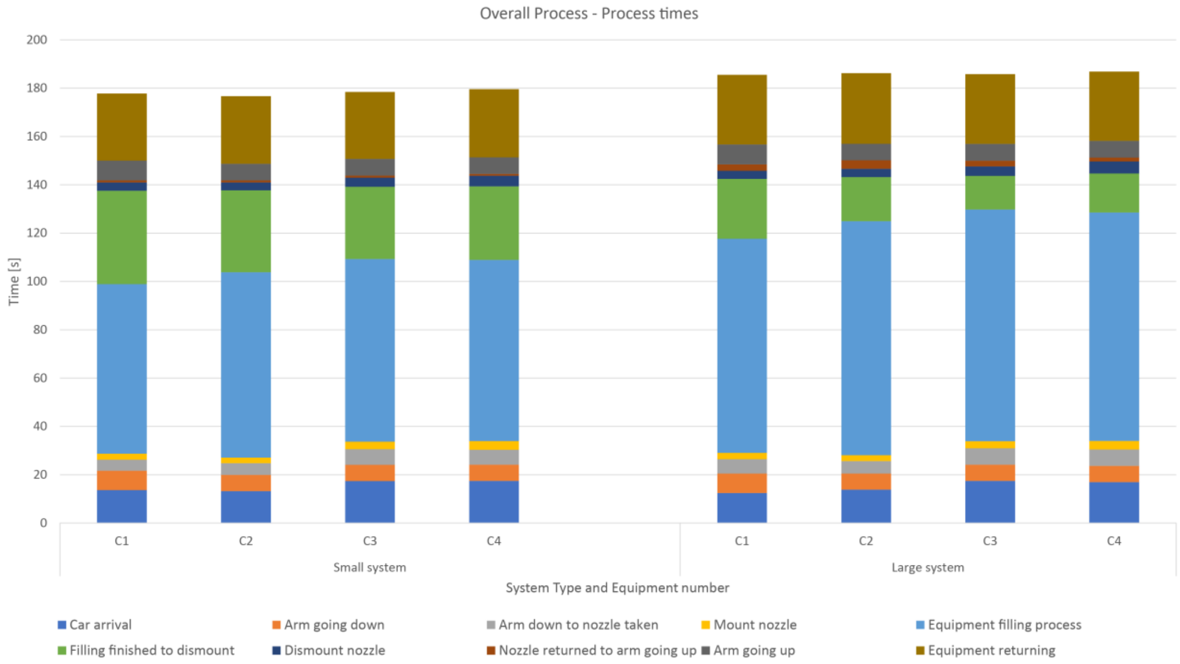

Figure 10 - Overall process times, divided by equipment and system type

Appendix III contains the distribution box plots of the times for each process step. Table 5 and 6 contains the times for each process step. The time presented is the average time of data within the box of the boxplots.

Table 5 - Overall process times for small system

Process Step	Time [s]	Variation [±s]	Equipment
Car arrival	15,1	7,1	C1-C4
Arm going down	8	0	C1
	6,7	0	C2
	6,7	0	C3
	6,7	0	C4
Arm down to nozzle taken	5	2,9	C1-C4
Mount nozzle	2,4	0,3	C1
	2,2	0,3	C2
	3	0,4	C3
	3,6	0,5	C4
Equipment filling	70,2	0,5	C1
	76,6	0,7	C2
	75,5	0,6	C3
	75,5	0,6	C4
Filling finished to dismount	31,6	13,2	C1-C4
Dismount nozzle	3,4	0,6	C1
	3,3	0,6	C2
	3,7	0,5	C3
	4,3	0,5	C4
Nozzle returned to arm going up	0,7	0	C1-C4
Arm going up	8,2	0	C1
	6,9	0	C2
	6,9	0	C3
	6,9	0	C4
Equipment return	28,2	1,7	C1-C4

Table 6 - Overall process times for large system

Process Step	Time [s]	Variation [±s]	Equipment
Car arrival	15,1	6,8	C1-C4
Arm going down	8	0	C1
	6,7	0	C2
	6,7	0	C3
	6,7	0	C4
Arm down to nozzle taken	5,6	2,7	C1-C4
Mount nozzle	2,5	0,5	C1
	2,4	0,4	C2
	2,9	0,3	C3
	3,5	0,5	C4
Equipment filling	88,6	0,3	C1
	96,8	0,4	C2
	95,9	0,3	C3
	94,7	0,4	C4
Filling finished to dismount	14,9	10,7	C1-C4
Dismount nozzle	3,3	0,6	C1
	3,3	0,7	C2
	3,7	0,8	C3
	4,5	1	C4
Nozzle returned to arm going up	2	0	C1-C4
Arm going up	8,2	0	C1
	6,9	0	C2
	6,9	0	C3
	6,9	0	C4
Equipment return	28,9	1,5	C1-C4

The variation is significantly higher on three process times; car arrival, arm down to nozzle taken, and filling finished to dismount. This is due to the mentioned times are highly operator dependent. The operators do perform other operations that aren’t associated with the filling process which can cause variations.

The process times indicates that there is a variation between the different equipment. The equipment filling time is remarkable in this aspect, where C1 performs better than the other equipment with a mean time of 70,2 seconds for a small system in contrast to around 76 seconds for equipment C2-C4. The distribution of data points for the equipment filling process, including both small and large systems is visualized in a scatter plot seen in Figure 11.

Variation in mount nozzle and dismount nozzle occur due to the equipment placement, the distance from the equipment arm to the expansion tank differs between the equipment.

Figure 11 - The equipment filling process time for each serial number (each produced car has a unique serial number).

Waiting is one of the seven wastes according to the Lean philosophy (Liker and Hoseus, 2008). Waiting is a major contributor to longer utilization times of the equipment. The following process steps are considered as waiting; car arrival, arm down to nozzle taken, filling finished to dismount. By illustrating the value-adding process steps and the non-value-adding process steps in a simplified VSM, see Figure 12 for small system and Figure 13 for large system. The VSM is based on the process times in Table 5 and 6.

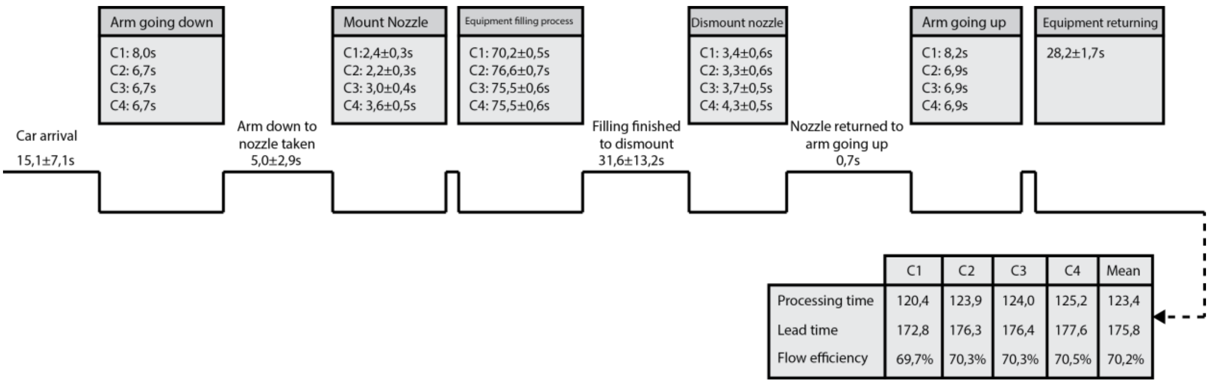

Figure 12 - VSM - Small system

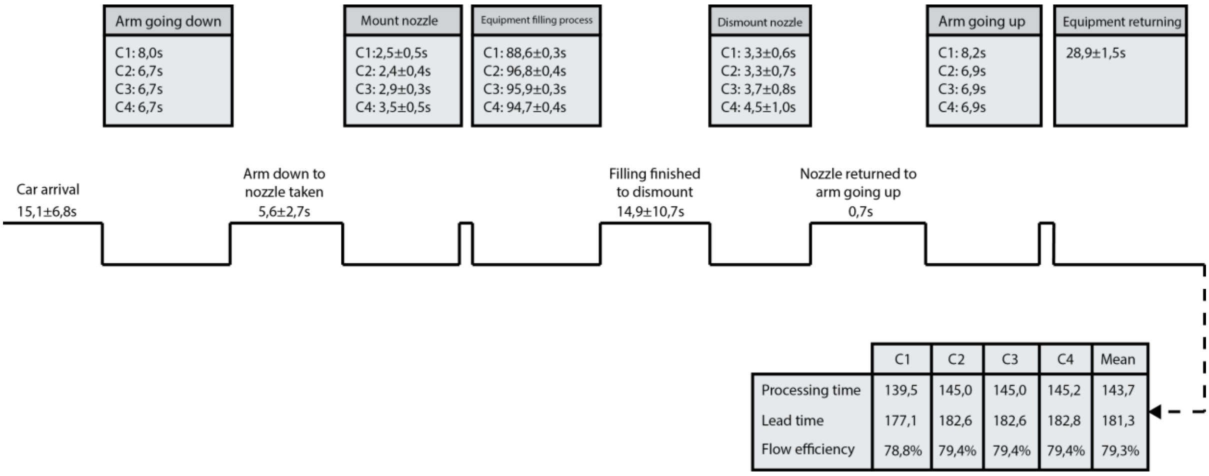

Figure 13 - VSM - Large system

The VSM illustrates the process times (grey boxes) and the waiting times. The processing time for each equipment indicates the performance, which once again shows that C1 performs the process steps faster than C2-C4. The lead time is the total time that one equipment is occupied. By dividing the processing and the lead time the flow efficiency is calculated. The flow efficiency indicates how much of the total time that is utilized by the process steps. As seen, the flow efficiency is in average higher on the larger systems, this due to the waiting times are less on the large systems.

4.7 Analyze of equipment filling process

When analyzing the overall process, it was identified that the equipment filling process is the process step that utilizes the largest share of the total process time. To examine further, the equipment filling process was analyzed separately, through investigating the process steps within the equipment filling process.

Two types of measurements were performed on the equipment filling process; time measurements and pressure measurements. The time measurements are based on the same data sample as the time measurement on the overall process, through data gathering in the process monitor. Figure 14 shows the equipment filling process steps for small and large systems.

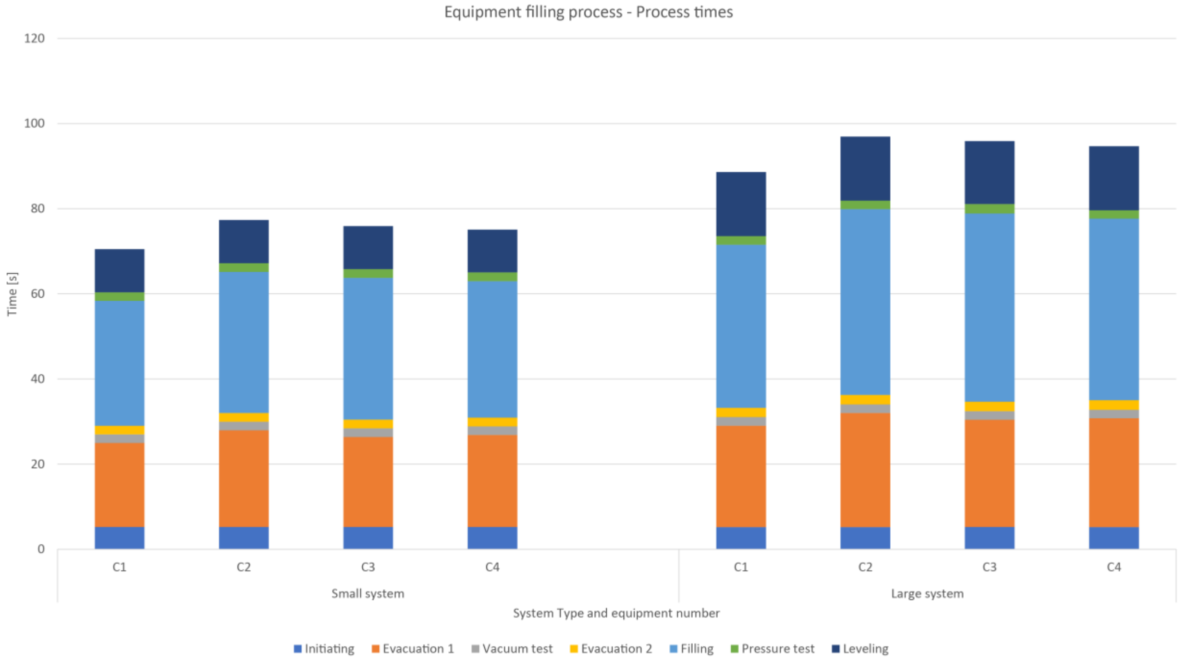

Figure 14 - Equipment filling process times, divided by equipment and system type

Table 7 and 8 contains the times for each process step. The time presented is the average time of data within the box of the boxplots, see Appendix IV.

Table 7 - Equipment filling process times for small system

Process Step	Time [s]	Variation [±s]	Equipment
Initiating	5,2	0	C1-C4
Evacuation 1	19,7	0,2	C1
	22,4	0,2	C2
	21	0,2	C3
	21,6	0,2	C4
Vacuum test	2	0	C1-C4
Evacuation 2	2	0	C1-C4
Filling	29,2	0,4	C1
	32,8	0,4	C2
	33,1	0,4	C3
	32	0,4	C4
Pressure test	2	0	C1-C4
Leveling	10	0	C1-C4

Table 8 - Equipment filling process times for large system

Process Step	Time [s]	Variation [±s]	Equipment
Initiating	5,2	0	C1-C4
Evacuation 1	23,8	0,1	C1
	26,7	0,1	C2
	25,2	0,1	C3
	25,5	0,1	C4
Vacuum test	2	0	C1-C4
Evacuation 2	2,2	0,1	C1-C4
Filling	38,3	0,3	C1
	43,6	0,3	C2
	44,1	0,3	C3
	42,7	0,3	C4
Pressure test	2	0	C1-C4
Leveling	15	0	C1-C4

The variation in the equipment process times is overall small or none at all. However, there is some variation in Evacuation 1 and Filling. This variation origins in the variety of cooling systems, as mentioned in Chapter 4.4. The measurement proves the thesis that the variation is small and that the systems can be categorized into large and small systems.

There is a number of input parameters in the equipment controller, see raw input data for the equipment controller in Appendix II . These inputs have been divided into controllable (C) and standard operating procedure (SOP) (Hammersberg, 2017). In this case, the controllable inputs are time considered to be set to a fixed value that can be changed without affecting the quality and performance of the output of the equipment filling process. The SOP-inputs are considered not to be changeable since those inputs are controlled by set target limits to be reached and are only affected by the design of the cooling system. The following, table 9, shows which of the times that can be regarded as controllable (C), where a change can be made, and standard operating procedure (SOP).

Table 9 - Categorization of equipment filling process times by controllable (C) and standard operating procedure (SOP)

	C	SOP
Initiating	x	
Evacuation 1		x
Vacuum test	x	
Evacuation 2	x	
Filling		x
Pressure test	x	
Leveling	x	

Initiating, vacuum test, evacuation 2, pressure test and leveling are all controllable factors that are executed for a predefined time in the process controller. Evacuation 1 and Filling are standard operating procedures that are executed based on a target pressure value and system volume and are therefore controlled by the type of system that is filled.

4.8 Pressure Measurement

To evaluate the equipment filling process, further pressure measurements has been performed. The pressure measurement data is gathered from 18 different cars by attaching a measurement equipment to the expansion tank. All four filling equipment has been covered in the measurement. At least two measurements have been performed on each equipment at separate occasions. The result of the measurement is pressure-time graphs that indicates the pressure change in the equipment filling process. By matching the timestamps from the process monitor and the corresponding pressure measurement graph for a specific car, the different steps can be visualized. Figure 15 shows one example of a pressure measurement, with process steps indicated.

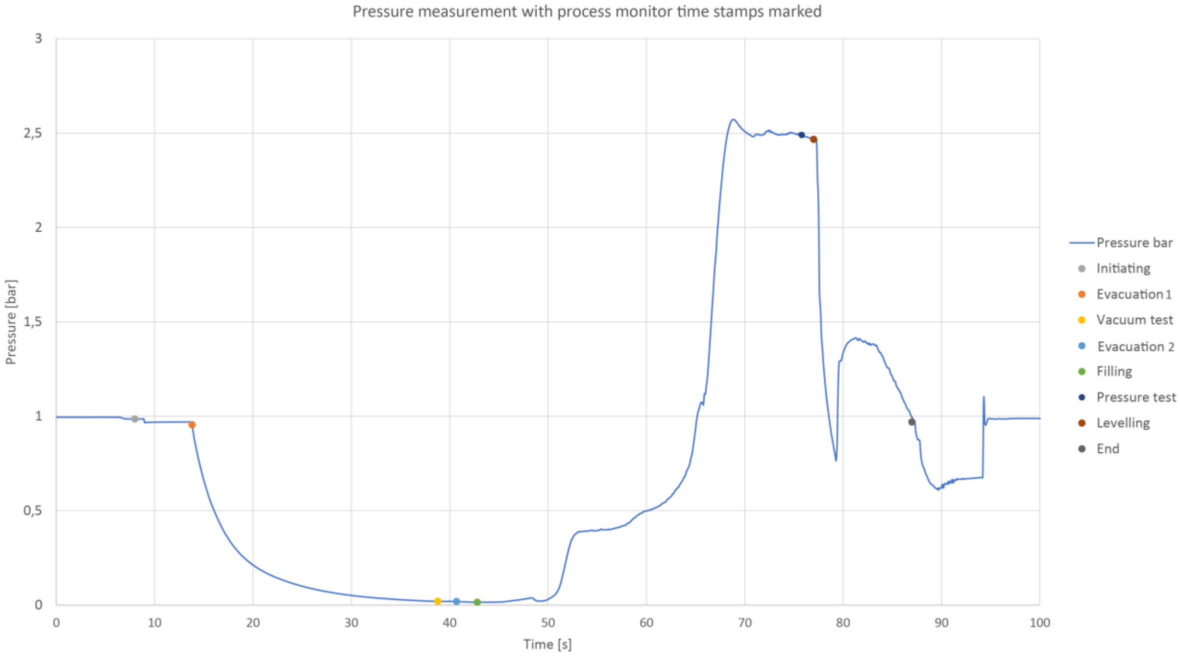

Figure 15 - Pressure measurement with time stamps (markers) indicating the start of each process step within the equipment filling process.

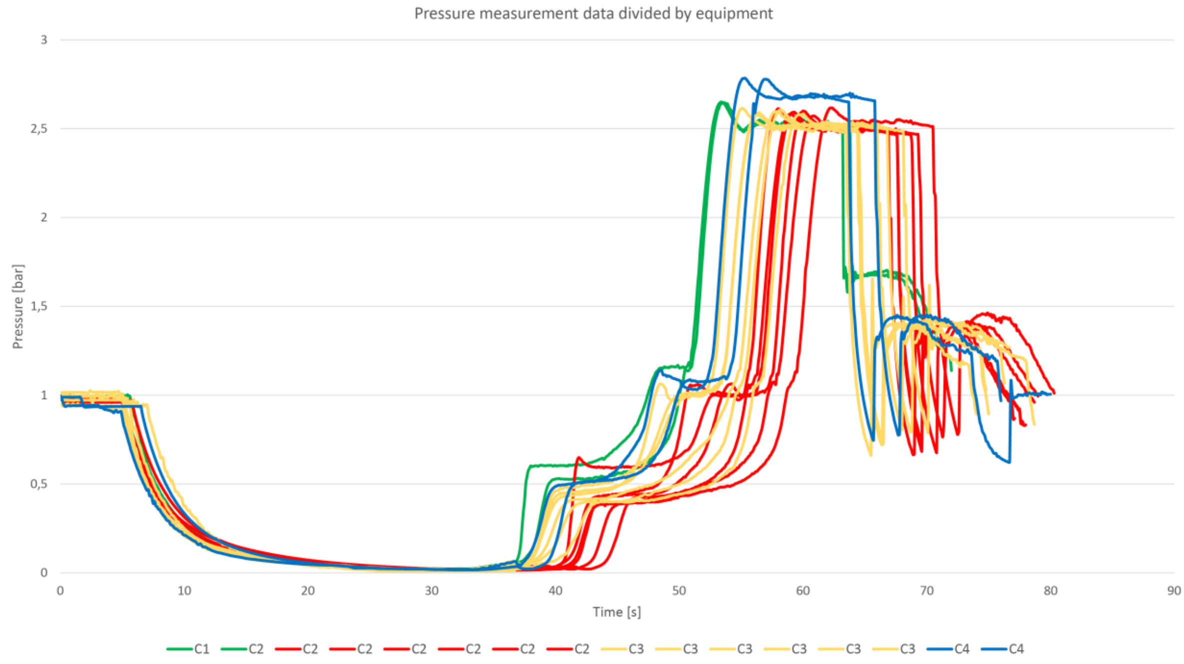

Figure 16 - Result of pressure measurements performed at line 1:42 in VCT. Color coded by equipment (C1-C4).

In Figure 16 all the pressure measurements are shown. The different colors indicate which equipment it corresponds to. As seen in Figure 16 there is a difference in performance between the equipment. It can also be identified, from the process monitoring, that the different equipment performs differently.

To be able to recognize where the equipment differs in detail, the different process steps has been plotted separately. This illustrates variation in a clearer way than illustrating the complete measurement in one graph and makes comparisons of the systems and equipment more convenient. Through the interviews performed and the meetings held with R&D and Tooling, each process step has been discussed and possible factors that can be changed has been identified.

Initiating phase

The initiating phase has a fixed-time in the equipment controller of five seconds for all equipment. During this time the nozzle gripper needs to fasten to the expansion tank. Observations at the production line has showed that this is done in one second, which indicates that there is room for improvements.

Evacuation 1

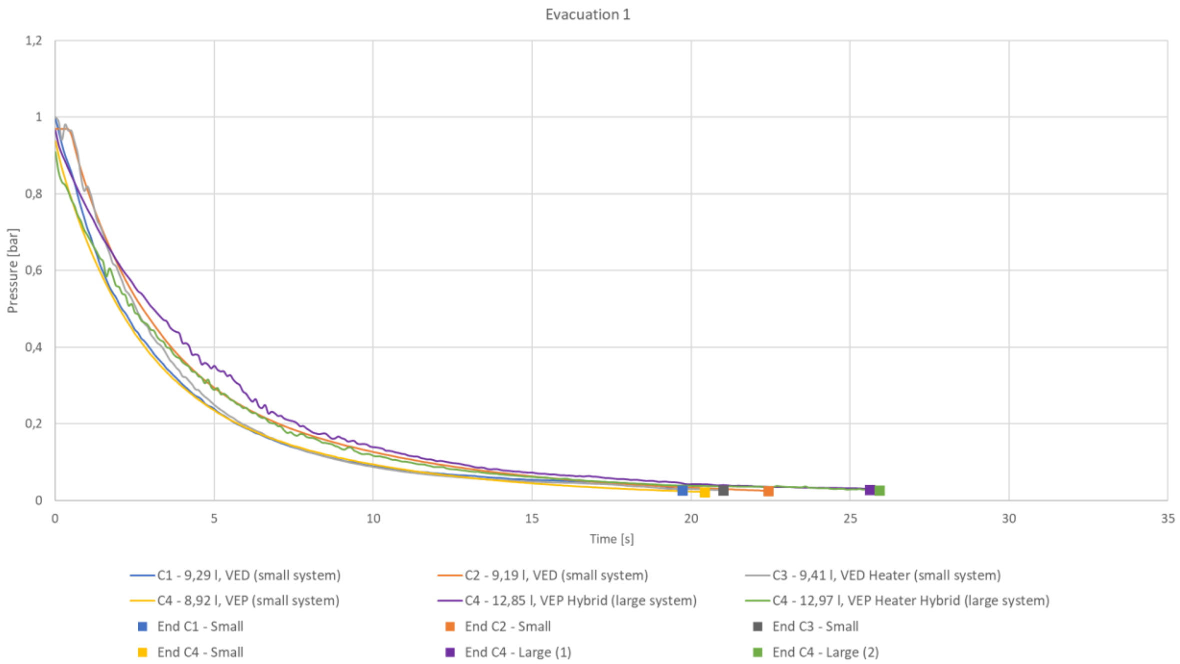

Figure 17 - Evacuation 1 process step from pressure measurement

The Evacuation 1 for the different equipment is illustrated in Figure 17, where the time when it is done is indicated by a marker. Factors that according to R&D and Tooling affect the time it takes to evacuate a system is the volume and complexity of the cooling system. In this case the focus is to determine a process step time for a large system and small system. The process has a target value, to reach below 40 mbar before executing the next step (vacuum test), this has been confirmed by R&D to be a correct level to avoid quality defects.

As seen in Figure 17 and Table 7 and 8 there are variations between the equipment. Equipment C1 performs evacuation faster than the rest. According to the performed measurements, the time it takes to evacuate a system is mostly affected by the systems volume, the different equipment are stable, and the evacuation times do not differ from one time to another.

Vacuum test

The vacuum test is a fixed-time of two seconds in the equipment controller. According to Tooling this is time dependent because of that the system needs to stabilize to be able to measure if the pressure is steady. The vacuum test is stable across all equipment and system types.

Evacuation 2

Evacuation 2 is performed to ensure that the vacuum pressure is still at 40 mbar. As seen in Table 7 and 8, evacuation 2 takes about two seconds for both small and large systems and can be considered as controllable.

Filling

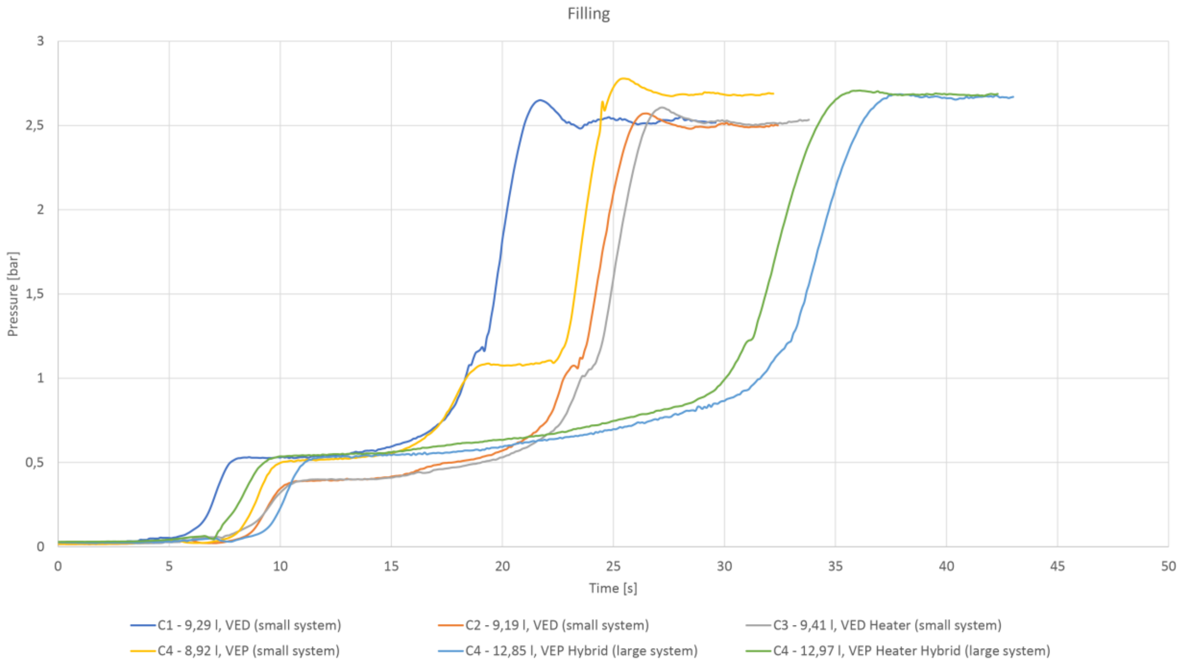

Figure 18 - Filling process step from pressure measurement

The filling cycle, see Figure 18, as well as evacuation 1, mainly depend on the volume of the system. Comparing the different equipment in the pressure-time graphs and the measurement data in table 7 and 8, it has been identified that C1 is performing better than the other three equipment.

As seen in Figure 18 the pressure is stable for more than 5 seconds in the end of the filling sequence. This is due to a fixed parameter in the equipment controller.

Pressure test

The pressure test is performed in the same way as the previous mentioned vacuum test, see above for details.

Leveling

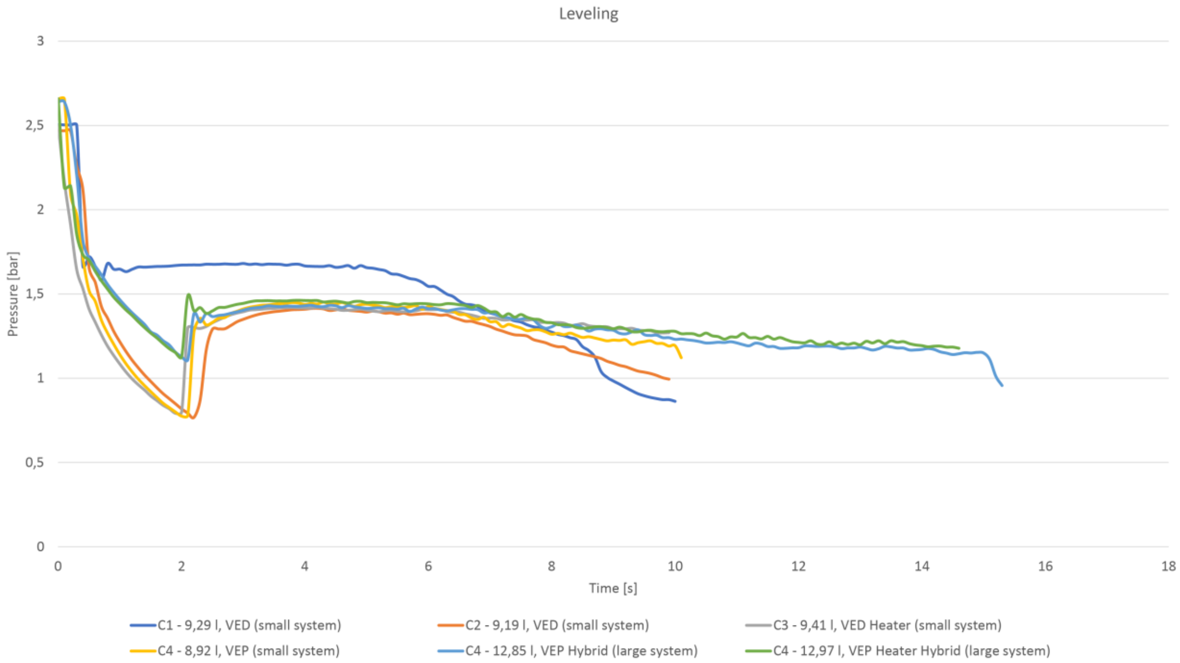

Figure 19 - Leveling process step from pressure measurement

The leveling time is a fixed time, it is 10 seconds for small systems and 15 seconds for large systems. Both times, for small and large system could be shortened, as seen in Figure 19 the pressure reaches a stable pressure earlier than 10 seconds for small systems and 15 seconds for large systems.

From observations at the production line it has been identified that the liquid level is stable after about five seconds from initiating the leveling phase.

4.9 Improving the process

According to Bergman and Klefsjö (2010) about eliminating waste with a lean approach the current state VSM can be evaluated and waste can be eliminated. The waiting times from the current state VSM are the following; car arrival, arm down to nozzle taken and filling finished to dismount. Due to the fact that operators need to walk between different cars the process times for car arrival and filling finished to dismount are not set to 0 seconds. Table 10 suggest the new times to be applied in the future state VSM for the above-mentioned waiting times.

Table 10 - Suggested improved process times

Process Step	Current state time [s]	Future state time [s]
Car arrival	15,1	2
Arm down to nozzle taken	5	0
Filling finished to dismount	31,6	3
Nozzle returned to arm going up	0,7	0,7

To be able to decrease the waiting times, developing a visual management onto the station is suggested (Tezel, Koskela and Tzortzopoulos, 2016). Visual management was implemented at the brake fluid station in VCT, from where inspiration have been gathered. It is suggested to mount screens onto each equipment that is easily viewed by the operators and contain the following information:

- When the equipment is idle the screen indicates when the current equipment will start to move along with a car using a time countdown. This is to give the operator sufficient information on when the operator needs to be ready to pull the string and thereby being able to do it within two seconds from the equipment is starting to move.
- When the string has been pulled, the operator should stay in position and immediately mount the nozzle and start the filling. From the data analysis and observations, it is proven that this is done at some times, while at other the operator pulls the string and then walks to perform other tasks which results in waiting times.
- When the filling has started the screen should show every process step of the filling including a countdown that indicates on how much time is left until the process is done. As before, this would serve as an aid towards the operator to be able to be in place to dismount the nozzle within three seconds. The audio and light signal used today should be improved with a clearer light and louder audio signal.

Through observations and interviews with the operators at the station it has been determined that the stress level on the station can be high. This is due to that equipment process is hard to monitor while performing other assembling activities. Visual management gives the operators the opportunity to have a better overview of the ongoing equipment filling process. This might have a positive impact on the social sustainability on the station, by decreasing the stress level.

The next step in optimizing the station for the future state, the equipment filling process should be optimized. Considering the pressure-time graphs and the collected data it has been identified that the process steps are currently controlled by an input in the process controller. The following improvements can be made on the equipment process:

- ***Shorten the initiating step to 2 seconds*** - The initiating step improvement is based in the pressure measurement and the time measurement of the nozzle gripper fastening on the expansion tank. Due to the equipment is idle waiting to execute evacuation 1 after the gripper has fastened on the expansion tank the time can be shortened to 2 seconds without risk of nozzle gripper failure.
- ***Shorten the waiting time from filling pressure achieved until pressure test starting from 5 seconds to 0 seconds.*** - According to R&D and Tooling this time could be changed without compromising the quality of the operation. A previous measurement gathering performed by R&D in the Volvo plant in Ghent, Belgium, confirms this possible improvement. The more optimized equipment in Ghent don't have a delay after reaching the target pressure, instead the pressure test is performed right away.
- ***Shorten leveling from 15 and 10 seconds to 5 seconds.*** - Observations of the leveling in VCT indicates that the targeted level is archived after 5 seconds. The pressure measurement also indicate that the pressure has reached 1 bar and is stable after 5 seconds. Onwards, the pressure is stable until the current ending after 10 seconds for

small systems and 15 seconds for large systems. The leveling step could be set to 5 seconds for all systems.

As a result of the suggested improvements, a pressure-time graph has been developed, see Figure 20.

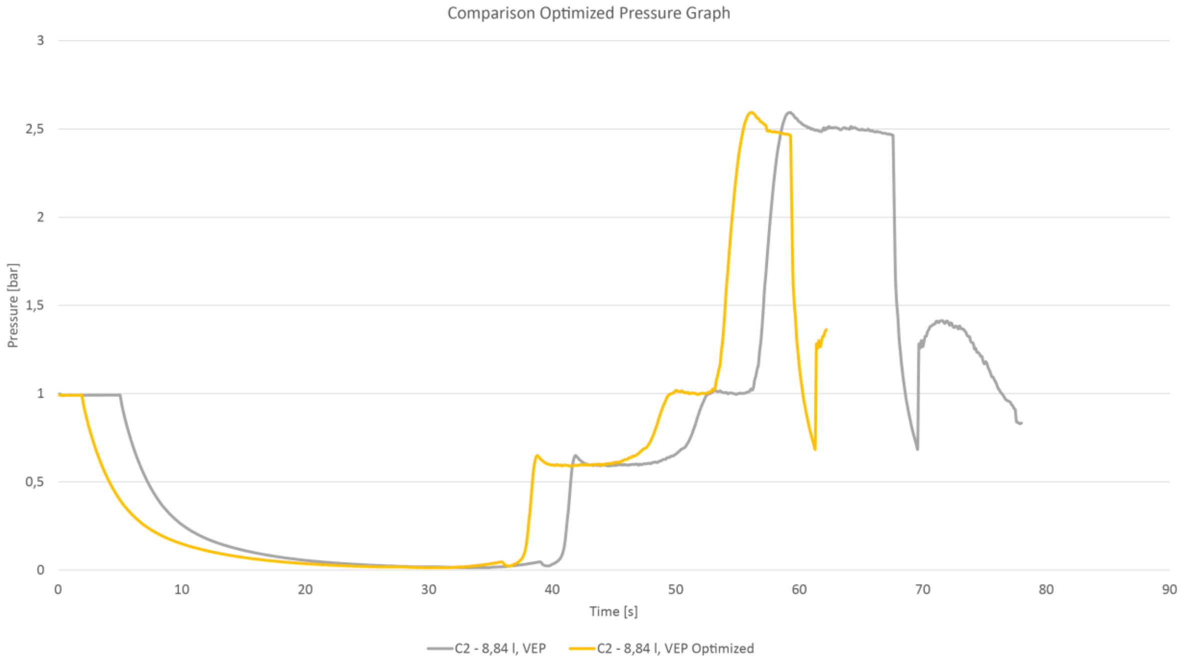

Figure 20 - Optimized pressure-time graph on the equipment filling process

As seen in Figure 20, by removing the waiting times the equipment filling process time is significantly shorter. From about 78 seconds to 62 seconds, a 16 seconds gain on small system. The target pressures in evacuation 1 and filling are still reached.

To be able to estimate a maximum filling volume some pre-calculations are needed. The maximum time for Evacuation 1 and Filling needs to be determined. In table 11 the maximum cycle time per equipment was calculated, by knowing the line speed of 0.103 m/s and equipment return speed of 0.667 m/s. Table 11 shows the result for both three equipment, as the current setup is, but also the result for four equipment. According to interviews with Tooling there is a possibility to invest in an additional equipment without rebuilding the whole line, which would increase the machinery capacity (Lödding and Rossi, 2013). Therefore, a calculation with four running equipment has been included. As have been mentioned earlier in Chapter 4.3, three equipment in this case are four equipment in total, where all four are used but the production can still pursue if one breaks down.

Table 11 - Maximum allowed cycle time and travel distance for three and four equipment

Number of equipments	3	4
Max cycle time/equipment [s]	174,6	232,8
Distance before returning [m]	15,6	20,8
Equipment forward [s]	151,2	201,7
Equipment return [s]	23,4	31,1

Knowing the maximum cycle time for one equipment and subtracting the total time used for all other activities, except Evacuation 1 and Filling, the maximum times for Evacuation 1 and Filling for three and four equipment was calculated, see table 12.

Table 12 - Evacuation 1 and Filling (total time for both process steps) calculation, Evacuation 1 and Filling = Max cycle time - sum of all other process steps

[s]	C1	C2	C3	C4	C1	C2	C3	C4
Number of equipments	3				4			
Car arrival	2	2	2	2	2	2	2	2
Arm going down	8	6,7	6,7	6,7	8	6,7	6,7	6,7
Mount nozzle	2,4	2,2	3	3,6	2,4	2,2	3	3,6
Initiating	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2
Evacuation 1								
Vacuum test	2	2	2	2	2	2	2	2
Evacuation 2	2	2	2	2	2	2	2	2
Filling								
Pressure test	2	2	2	2	2	2	2	2
Leveling	5	5	5	5	5	5	5	5
Filling finished to dismount	3	3	3	3	3	3	3	3
Return nozzle	3,4	3,3	3,7	3,7	3,4	3,3	3,7	3,7
Nozzle returned to arm going up	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7
Arm going up	8,2	6,9	6,9	6,9	8,2	6,9	6,9	6,9
Equipment return	23,4	23,4	23,4	23,4	31,1	31,1	31,1	31,1
Max cycle time	174,6	174,6	174,6	174,6	232,8	232,8	232,8	232,8
Evacuation 1 and filling	**107,3**	**110,2**	**109**	**108,4**	**157,8**	**160,7**	**159,5**	**158,9**

4.10 Estimate filling volume

To estimate and determine process times for Evacuation 1 and Filling separately, linear prediction models were used. As seen in Appendix V the measurement data for each equipment has been analyzed with a linear approximation. The result from this models are 8 linear functions, one for each Evacuation 1 in each equipment and one for each Filling in each equipment. The equations estimate the volume for a given time. The function is as follow and the values for a, b are shown in Table 13.

$$Volume \; = \; a \; + \; b * Filling\, Time \;(1)$$
$$Volume \; = \; a \; + \; b * Evacuation\, 1\, Time \;(2)$$

Table 13 - a and b for equation (1) and (2), for evacuation 1 and filling for each equipment

	a	b
C1 - evacuation 1	-9,099	0,939
C1 - filling	-2,985	0,424
C2 - evacuation 1	-8,035	0,763
C2 - filling	-1,753	0,332
C3 - evacuation 1	-9,828	0,898
C3 - filling	-1,813	0,330
C4 - evacuation 1	-11,112	0,938
C4 - filling	-2,018	0,349

Using the maximum cycle time calculations and the Evacuation 1 and Filling time (Table 12) together with the estimation functions in Table 13 a maximum filling volume was estimated for each equipment. Calculations were made on a scenario with three respectively four running equipment, see Table 14.

Table 14 - Estimated maximum volume calculation, based on equation (1) and (2) and the total evacuation 1 and filling time from Table 12

	C1	C2	C3	C4	C1	C2	C3	C4
Number of equipments		3				4		
Max cycle time [s]	174,6	174,6	174,6	174,6	232,8	232,8	232,8	232,8
Evacuation 1 and filling [s]	107,3	110,2	109,0	108,4	157,8	160,7	159,5	158,9
Filling [s]	69,4	71,0	73,2	72,0	104,2	106,2	110,1	108,8
Evacuation 1 [s]	37,9	39,2	35,8	36,4	53,6	54,5	49,4	50,1
Estimated max volume [l]	**26,4**	**21,8**	**22,3**	**23,1**	**41,2**	**33,5**	**34,5**	**35,9**

As seen in Table 14 C2 has the lowest maximum filling volume of 21,8 liter. Applying the theory of constraints (Cox and Schleier, 2010), it is concluded that C2 is the constraint at the coolant filling station. Since a system is not stronger than its weakest link, the coolant filling station should be planned upon capacity of C2.

The future state VSM, see Figure 21, is based on the capacity of C2, with a filling volume of 21,8 liter and the improvement suggestions where the waiting times have been eliminated.

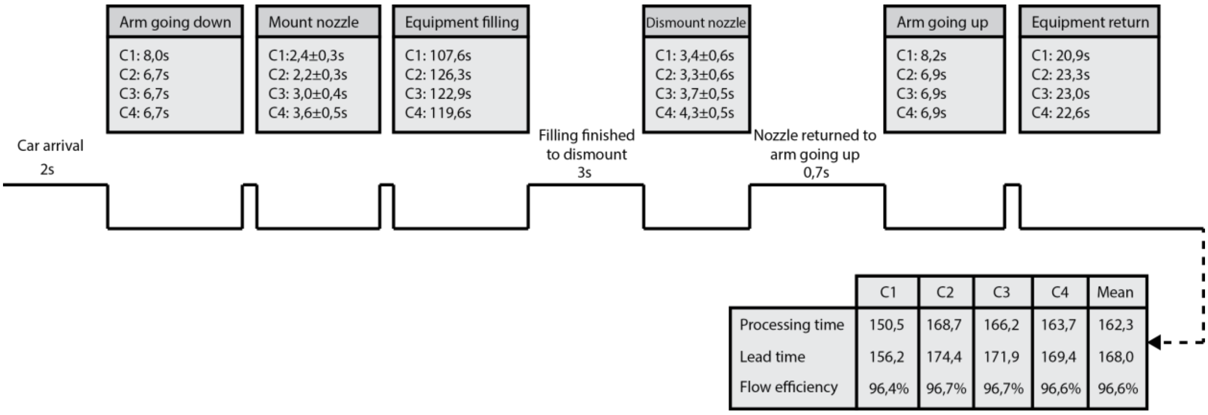

Figure 21 - VSM - Future state, based on 21,8 liter

When comparing the current and future state VSM, the main difference is shortened waiting times and increased flow efficiency. Process time and lead time differ less and as a result the flow efficiency is significantly higher in the future state. Due to the more efficient flow the return time for the equipment has been shortened.

To visualize the suggested improvements even further Figure 22 shows a comparison in overall process time for a small system, with the process without improvements on the left column and with improvements suggestions on the right column. This indicates that with the improvement suggestions the current small system could be processed on the station in about 100 seconds in comparison to around 180 seconds as it is today.

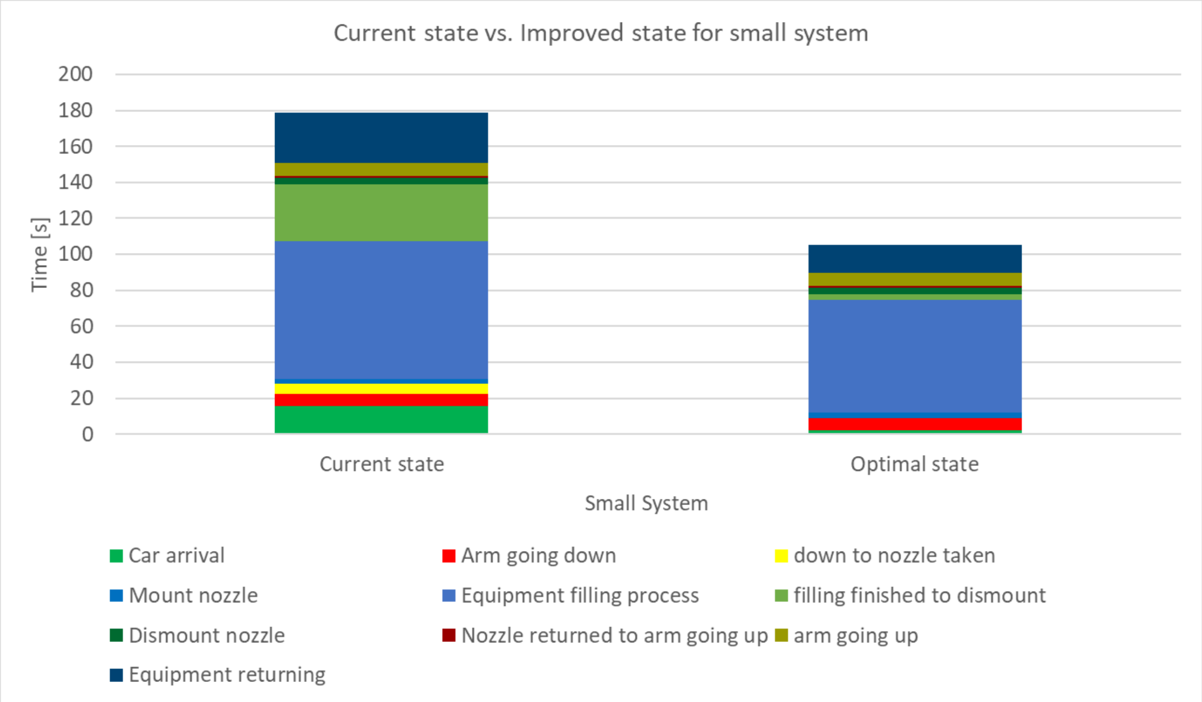

Figure 22 - Comparison process time for small system, without (left) and with (right) improvement suggestions

5 Discussion

The background to why this study was executed was the knowledge of that the first fully electric cars will start being produced in the upcoming years. There has been a common knowledge that the cooling systems of these cars will be bigger, since a battery needs more cooling capacity than a diesel or petrol engine. This requires Volvo to adapt the production to fit for the larger cooling systems, and the questioning have been whether the existing station including its layout and machinery will be able to fill the future cooling volumes. This section contains discussions on the results and learnings from the study as well as how Volvo can benefit from this study and take the work even further.

5.1 Discussions on the result

The study has been successful in terms of mapping the station and creating an understanding of how it works. Parameters have been identified that affect the output of the station, the volume to be filled.

The capability of a process is its ability to produce an outcome within set tolerances (Bergman and Klefsjö, 2010). The machinery capability of the coolant filling stations' equipment has been evaluated and the results indicate that variation occur between the different equipment. All the equipment are programmed with the same input parameters and the variation in performance might occur due to variation in quality. This variation has not been evaluated during this study. The different equipment has been purchased in different occasions, which could mean that the variation occur due to that the supplier has delivered equipment with quality differences. Another potential cause could be that rework or maintenance has been performed by Volvo, which has caused differences in components within the different equipment. This is suggested to be further evaluated, perhaps by involving the supplier.

When analyzing the current state VSM, it was identified that waiting times from the operators had the largest impact on the equipment lead times. To be able to eliminate the wastes, as suggested, by using visual management as an aid for the operators to get a better picture of the process further changes are required. The operators perform assembling activities at the station, but since the scope of the study was to map the coolant filling this was a delimitation and have not been considered. To decrease the lead times, rebalancing will be needed which prioritize the filling process and its process steps. The assembling work tasks will be needed to be fitted thereafter and might need to be moved to other production stations as well.

In addition to that visual management will serve as an aid that will lead to decreased lead times, a dimension of social sustainability could also be improved by implementing it. Since it gives the operators a better view of the process, the visual management can also serve as an aid to decrease the stress level at the coolant filling station. By knowing for how long the process has left until the operator needs to be at a certain place, the operator will be able to plan his surrounding work tasks without having to be observant on whether the filling process is done or not. So, visual management could both increase the capacity of the coolant filling station as well as the well-being among the operators regarding their stress-levels.

Estimated maximum filling volumes has been calculated for each equipment based on the data collected and measurements that has been performed. The calculations were made by linear regression modeling due to the data set collected, which calculates a linear relationship between volume and time. Since the data contains two sizes of cooling systems, named small and large systems in this study, a linear regression was preferred. Though, the data indicates that the filling time is exponential towards the volume which means that filling a larger system would be faster in terms of liters per second. The estimated volumes are therefore regarded to be a bit lower than what might turn out to be the real result after implementing the suggested improvements.

What was discovered during this project was that there are similar liquid filling stations in Volvo Cars plants that have been improved in certain ways. The brake-fluid filling station in VCT has equipment that is working similar to the coolant filling station. Here, the station is equipped with visual management and some operations performed have been automated to decrease the work tasks done by the operators. Another example, at the Volvo plant in Ghent, Belgium, the coolant filling station has three equipment, in contrast to four at VCT, and are still able to perform the operations with the same takt. According to interviews, this was because of constraints that did not allow Ghent to have four equipment and they were thereby forced to optimize the current equipment. These two examples indicate that it might exist in-house knowledges that can be applicable somewhere else within the organization.

One of the improvements includes investing in a new equipment, this means that five equipment in total are used on the station. This option might be initially costly due to rebuild of the line and purchase of an equipment. Another issue that might occur if investing in a fifth equipment is the length of the line. If Volvo decides to invest in a new equipment one thing to consider is that four equipment can be used at the same time without the need to extend the lines length.

What has occurred to be a problem during our investigation is to get the estimated values for the filling volumes on the first car models entirely powered by electricity. It seems to be an uncertainty within the organization which origins in the development departments where different numbers have occurred on different occasions. For a ME-unit that want to base decisions on facts, the communication with development departments are of high importance. If the facts are uncertain the result of a production preparation can also be uncertain. According to Lean philosophy it is important to understand the process to be able to improve it (Liker and Hoseus, 2008). As seen during this study there might be lack of overall knowledge about the process, because of the departments are focused on their specific tasks. A possible way for different departments to obtain a better knowledge about the station is to continuously share knowledge about changes and improvements. One example, Tooling might be able inform ME about technical advancements in visual management systems for equipment, which could emphasize the design of work instructions. Another example, R&D and Tooling might be able to communicate on how advancements in equipment technology might impact the design of the vehicles.

5.2 Study methodology and future studies

Volvo has a history of producing cars and are used to continuously initiate new car projects. However, Volvo will be facing a great challenge and technological changes within production when the new electric car models start being produced. The power train is different from what has been experienced since the start of the company. The production lines will need to adapt and many stations, in addition to the coolant filling station, will face new technical requirement and work tasks. Learning points from this study is that knowing what to prepare for and knowing how operations are performing today facilitates a transform into a technological shift.

The six-sigma and DMAIC approach that has been followed in this project has been successful. The DMAIC approach has encouraged to use structured methods and tools to break down an initially broad problem description into smaller manageable areas. The method has encouraged to ask “why” and by iterating finding the root cause to smaller problems. The downside of using DMAIC and six-sigma is to know when to stop iterating and breaking down the problems into smaller areas. In this study, it could have been possible to go even deeper into the technicality about the equipment and investigate components within the equipment for example.

Volvo could face the same kind of challenges at other production plants worldwide where the electric cars will be produced. The same methodology used in this study, could be used to investigate and analyze the stations within other Volvo plants. Starting off by defining and mapping the station in detail to understand what input and output parameters that affect the station. Collecting quantitative data from the process monitor and pressure measurements. The two quantitative data sets provide future studies with data suitable for identifying possible improvement areas on both station and equipment level, resulting in a potential maximum filling volume.

6 Conclusion

The aim with this study was to map and see how the current state of the coolant filling station at VCT would fit into a predicted increase of coolant systems in the upcoming car models. The capacity and the operations have been well fitted for the today's takt of production and has not required any radical improvement efforts. To answer the research questions the coolant filling process and its surrounding organization has been examined and will be answered in this section.

Two critical parameters have been identified that affect the capacity of the coolant filling station and which has a potential to be improved.

- The first parameter is wastes within the process in terms of waiting times by the operators. To decrease these waiting times our recommendation is to start using visual management to a greater extent where the operator can see when it is time to perform the next operation and thereby improve the overall efficiency of the process.
- The second parameter in the coolant filling station is the actual filling process. The filling process was examined, and it turned out to be sub optimized. Improvement actions would make the filling more effective, resulting in a capacity of filling more volume in a shorter amount of time.

Collaboration between R&D, ME and Tooling to support future transformation

- The future technical requirements need to be communicated to all involved departments in a more structured way. R&D needs to in an early stage involve Tooling, to ensure that the vehicle designs are as smoothly as possible to implement in the factory.
- ME and Tooling needs to have a common understanding about the bottlenecks in each station and together with production technicians balance the stations around the bottlenecks to ensure as little waste as possible.
- ME and Tooling should consider using visual management on equipment with critical lead times to ensure that the work standard is followed.
- Future improvement projects should investigate and share lessons-learned within the company globally. For example, the improved coolant filling station in Ghent, the knowledge should be shared among all Volvo plants.

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Appendix I – Interview questions

Statement to interviewees: We are investigating the coolant filling station and the changes that might occur when transitioning from ICE's to EV's.

- Regarding the statement, what would your desired result from that study be? What do you want to be reported?
- Do you have any specific details about the topic that you would like to know more about?
- If the station is rebuilt/changed, who are involved, and are you involved?
- What are your biggest challenges in a transformation from ICE's to EV's?

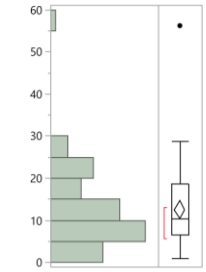
Appendix II – Process controller inputs

	C1	C2	C3	C4	
Pressuretest setting motor					
Step30, air inlet level (Pset3)	1,5	1,4	1,5	1,4	bar
PF30A_T, already filled	2	2	2	2	s
PF30B_t, major pressure leak	60	60	60	60	s
Step30_t, Delay on PSet3 and dPset1	15	15	15	15	s
Step31, Air pressure test level (PSet2)	1	1	1	1	bar
Step31, Air press. Diff level (dPSet1)	3	3	3	3	mbar
Step31_T, pressure test time	5	5	5	5	s
PF31_T, Delay on dPSet1	5	5	5	5	s
Evacuation Setting Motor					
Step40,42, Evacuation level (PSet1)	40	40	40	40	mbar
Step40_T, Delay on PSet1	5	5	5	5	s
PF40A, Major vacuum leak level (PSet3)	70	70	70	70	mbar
PF40A_T, Major vacuum leak time	40	30	30	30	s
PF40B_T, Minor vacuum leak time	90	95	90	95	s
PF41, Vacuum test level (Pset2)	60	60	60	60	mbar
Step41_T, vacuum test time	2	2	2	2	s
Step42, delay on PSet1	2	2	2	2	s
PF42_T, Minor vacuum leak time	15	15	15	15	s
Filling settings motor					
Step52, fill pressure level (PSet3)	1,5	1,5	1,5	1,5	bar
Step52, flow level FSet1	5	5	5	5	p/s
Step52_T delay on PSet3 and FSet1	5	5	5	5	s
PF52A_T time out filling	99	99	99	99	s
PF52B, min filling volume	8	8	8	8	l
PF52B, max filling volume	15	15	15	15	l
PF53, Fill pressure test level (PSet2)	1	1	1	1	bar
Step53_T, Fill pressure test time	2	2	2	2	s
Step54_T, leveling time	15	10	15	10	s
Step54, leveling level (PSet1)	0,5	0,6	0,6	0,6	bar

Appendix III – Boxplots for overall process

C1 – Large system

Car arrival



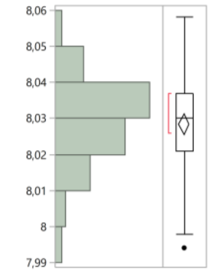
Quantiles

100.0%	maximum	56,16
99.5%		56,16
97.5%		33,5055
90.0%		24,254
75.0%	quartile	18,6525
50.0%	median	10,395
25.0%	quartile	6,4775
10.0%		2,705
2.5%		1,09625
0.5%		0,89
0.0%	minimum	0,89

Summary Statistics

Mean	12,485833
Std Dev	8,9993312
Std Err Mean	1,0605814
Upper 95% Mean	14,600572
Lower 95% Mean	10,371094
N	72

Arm going down



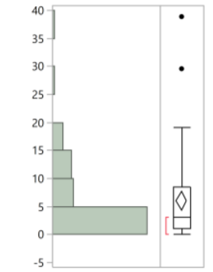
Quantiles

100.0%	maximum	8,058
99.5%		8,058
97.5%		8,0514
90.0%		8,0417
75.0%	quartile	8,037
50.0%	median	8,03
25.0%	quartile	8,021
10.0%		8,011
2.5%		7,9973
0.5%		7,994
0.0%	minimum	7,994

Summary Statistics

Mean	8,0282083
Std Dev	0,0121782
Std Err Mean	0,0014352
Upper 95% Mean	8,0310701
Lower 95% Mean	8,0253466
N	72

Arm down to hose taken



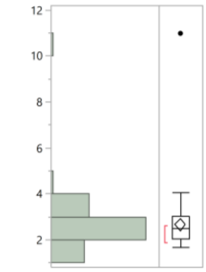
Quantiles

100.0%	maximum	38,779
99.5%		38,779
97.5%		31,1164
90.0%		15,5462
75.0%	quartile	8,4615
50.0%	median	3,036
25.0%	quartile	1,09525
10.0%		0,356
2.5%		0,0099
0.5%		0
0.0%	minimum	0

Summary Statistics

Mean	5,9305694
Std Dev	7,2390905
Std Err Mean	0,853135
Upper 95% Mean	7,6316723
Lower 95% Mean	4,2294666
N	72

Assemble hose



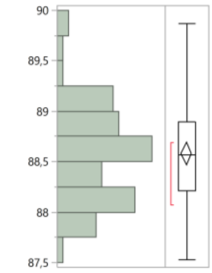
Quantiles

100.0%	maximum	10,972
99.5%		10,972
97.5%		5,252275
90.0%		3,4399
75.0%	quartile	3,00275
50.0%	median	2,498
25.0%	quartile	2,0515
10.0%		1,8107
2.5%		1,666025
0.5%		1,652
0.0%	minimum	1,652

Summary Statistics

Mean	2,6464444
Std Dev	1,1517887
Std Err Mean	0,1357396
Upper 95% Mean	2,9171015
Lower 95% Mean	2,3757874
N	72

Equipment filling



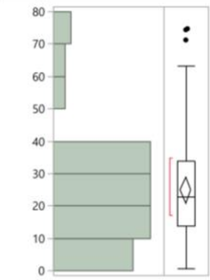
Quantiles

100.0%	maximum	89,864
99.5%		89,864
97.5%		89,843375
90.0%		89,1769
75.0%	quartile	88,89775
50.0%	median	88,568
25.0%	quartile	88,214
10.0%		87,95
2.5%		87,756225
0.5%		87,531
0.0%	minimum	87,531

Summary Statistics

Mean	88,574458
Std Dev	0,4780945
Std Err Mean	0,056344
Upper 95% Mean	88,686805
Lower 95% Mean	88,462112
N	72

Filling finished to dismantle



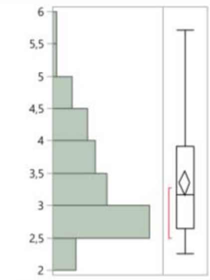
Quantiles

100.0%	maximum	74,564
99.5%		74,564
97.5%		74,31155
90.0%		47,8281
75.0%	quartile	33,97775
50.0%	median	22,8205
25.0%	quartile	13,96525
10.0%		4,662
2.5%		0,6984
0.5%		0,54
0.0%	minimum	0,54

Summary Statistics

Mean	24,795653
Std Dev	17,188754
Std Err Mean	2,0257141
Upper 95% Mean	28,834812
Lower 95% Mean	20,756494
N	72

Return hose



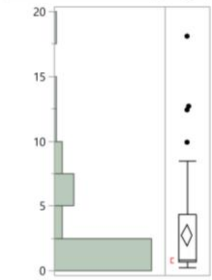
Quantiles

100.0%	maximum	5,719
99.5%		5,719
97.5%		5,373325
90.0%		4,5536
75.0%	quartile	3,917
50.0%	median	3,176
25.0%	quartile	2,64475
10.0%		2,5196
2.5%		2,26155
0.5%		2,25
0.0%	minimum	2,25

Summary Statistics

Mean	3,3446806
Std Dev	0,7929494
Std Err Mean	0,09345
Upper 95% Mean	3,5310145
Lower 95% Mean	3,1583466
N	72

Hose returned to arm going up



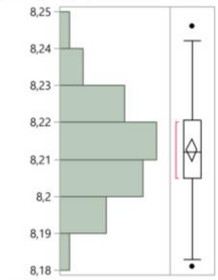
Quantiles

100.0%	maximum	18,068
99.5%		18,068
97.5%		13,612175
90.0%		7,5262
75.0%	quartile	4,35475
50.0%	median	0,805
25.0%	quartile	0,69175
10.0%		0,5062
2.5%		0,258975
0.5%		0,207
0.0%	minimum	0,207

Summary Statistics

Mean	2,6996389
Std Dev	3,5852922
Std Err Mean	0,4225307
Upper 95% Mean	3,5421413
Lower 95% Mean	1,8571365
N	72

arm going up



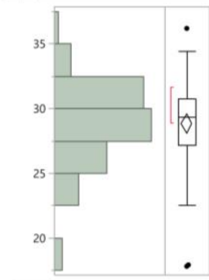
Quantiles

100.0%	maximum	8,246
99.5%		8,246
97.5%		8,2427
90.0%		8,2297
75.0%	quartile	8,22075
50.0%	median	8,212
25.0%	quartile	8,205
10.0%		8,1956
2.5%		8,18265
0.5%		8,181
0.0%	minimum	8,181

Summary Statistics

Mean	8,2124167
Std Dev	0,0128444
Std Err Mean	0,0015137
Upper 95% Mean	8,215435
Lower 95% Mean	8,2093984
N	72

Equipment return



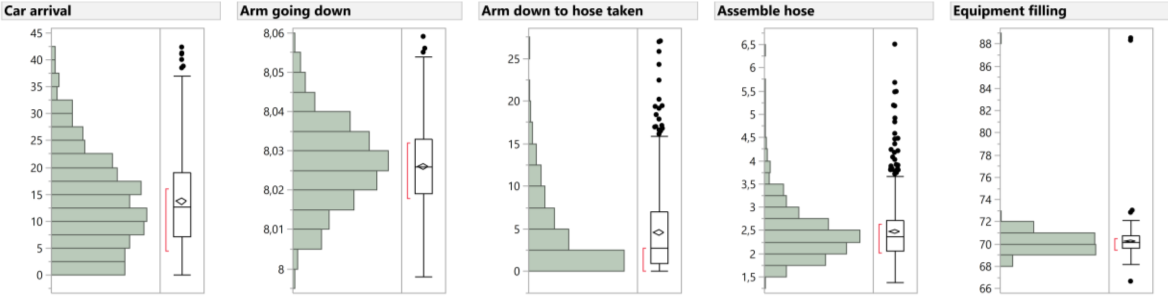
Quantiles

100.0%	maximum	36,163
99.5%		36,163
97.5%		34,751425
90.0%		32,2603
75.0%	quartile	30,72825
50.0%	median	29,3315
25.0%	quartile	27,1805
10.0%		24,9056
2.5%		17,8681
0.5%		17,779
0.0%	minimum	17,779

Summary Statistics

Mean	28,804778
Std Dev	3,2151807
Std Err Mean	0,3789127
Upper 95% Mean	29,560308
Lower 95% Mean	28,049247
N	72

C1 – Small system

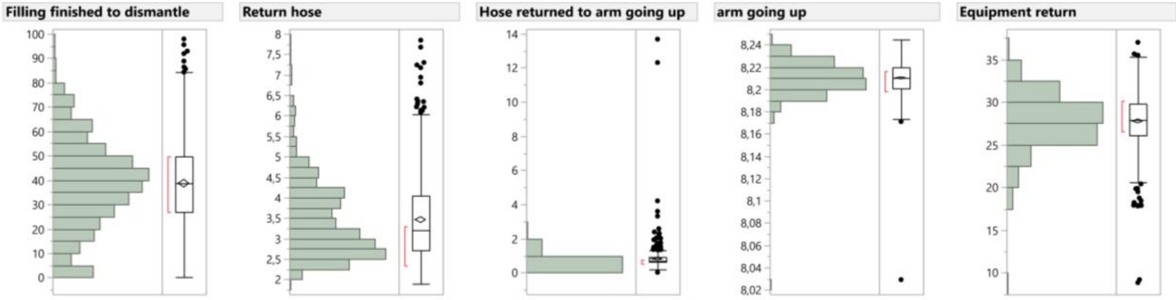


Quantiles

		Car arrival	Arm going down	Arm down to hose taken	Assemble hose	Equipment filling
100.0%	maximum	42,29	8,059	27,01	6,499	88,514
99.5%		40,5774	8,05458	25,13618	5,47822	72,92878
97.5%		33,115	8,048	16,5468	4,0062	71,5159
90.0%		25,862	8,039	11,6514	3,2288	71,1646
75.0%	quartile	19,05	8,033	6,988	2,707	70,72
50.0%	median	12,57	8,026	2,776	2,369	70,104
25.0%	quartile	7,07	8,019	0,92	2,053	69,633
10.0%		2,904	8,012	0,3616	1,8348	69,2392
2.5%		0,511	8,006	0,0762	1,6863	68,659
0.5%		0,1542	7,99942	0	1,5592	68,26186
0.0%	minimum	0,06	7,998	0	1,367	66,622

Summary Statistics

	Car arrival	Arm going down	Arm down to hose taken	Assemble hose	Equipment filling
Mean	13,636413	8,0258741	4,5445988	2,4722138	70,198574
Std Dev	8,6738735	0,0106907	4,7265043	0,6172779	1,2384178
Std Err Mean	0,3318965	0,0004091	0,1808547	0,0236195	0,0473867
Upper 95% Mean	14,288075	8,0266773	4,8996976	2,5185894	70,291615
Lower 95% Mean	12,984751	8,0250709	4,1895	2,4258381	70,105533
N	683	683	683	683	683



Quantiles

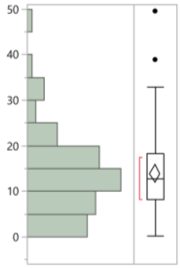
		Filling finished to dismantle	Return hose	Hose returned to arm going up	arm going up	Equipment return
100.0%	maximum	97,821	7,84	13,675	8,245	36,983
99.5%		92,40424	7,27038	3,94696	8,24117	35,4049
97.5%		76,7212	6,0159	1,5316	8,235925	33,4775
90.0%		63,5158	4,6908	1,1076	8,228	31,5458
75.0%	quartile	49,726	4,042	0,895	8,22	29,796
50.0%	median	38,84	3,21	0,719	8,21	27,836
25.0%	quartile	26,781	2,719	0,609	8,201	26,103
10.0%		13,3994	2,4702	0,513	8,194	23,7852
2.5%		1,39	2,279	0,3794	8,185075	20,4107
0.5%		0,4067	2,07398	0,25984	8,174245	17,81354
0.0%	minimum	0,308	1,905	0,013	8,029	8,826

Summary Statistics

	Filling finished to dismantle	Return hose	Hose returned to arm going up	arm going up	Equipment return
Mean	38,675903	3,4638302	0,8206384	8,2103226	27,761606
Std Dev	18,709088	0,9604345	0,7424049	0,0145449	3,2456234
Std Err Mean	0,7158834	0,03675	0,0284073	0,000557	0,1241903
Upper 95% Mean	40,081503	3,5359869	0,8764147	8,2114161	28,005447
Lower 95% Mean	37,270303	3,3916734	0,764862	8,209229	27,517765
N	683	683	683	682	683

C2 – Large system

Car arrival



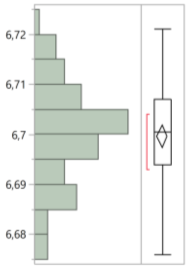
Quantiles

100.0%	maximum	49,513
99.5%		49,513
97.5%		38,1185
90.0%		24,855
75.0%	quartile	18,213
50.0%	median	12,7185
25.0%	quartile	8,1965
10.0%		2,8835
2.5%		0,3705
0.5%		0,118
0.0%	minimum	0,118

Summary Statistics

Mean	13,80781
Std Dev	9,0801643
Std Err Mean	0,9907272
Upper 95% Mean	15,778326
Lower 95% Mean	11,837293
N	84

Arm going down



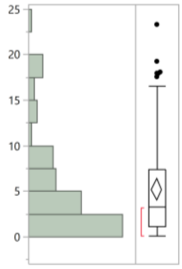
Quantiles

100.0%	maximum	6,721
99.5%		6,721
97.5%		6,718
90.0%		6,713
75.0%	quartile	6,707
50.0%	median	6,7005
25.0%	quartile	6,694
10.0%		6,685
2.5%		6,677
0.5%		6,676
0.0%	minimum	6,676

Summary Statistics

Mean	6,6995595
Std Dev	0,0101368
Std Err Mean	0,001106
Upper 95% Mean	6,7017594
Lower 95% Mean	6,6973597
N	84

Arm down to hose taken



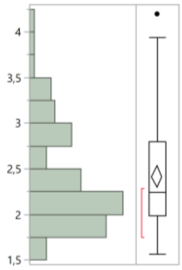
Quantiles

100.0%	maximum	23,283
99.5%		23,283
97.5%		19,086125
90.0%		14,863
75.0%	quartile	7,424
50.0%	median	3,232
25.0%	quartile	1,1025
10.0%		0,418
2.5%		0,089
0.5%		0,062
0.0%	minimum	0,062

Summary Statistics

Mean	5,1336905
Std Dev	5,4380861
Std Err Mean	0,5933438
Upper 95% Mean	6,3138275
Lower 95% Mean	3,9535534
N	84

Assemble hose



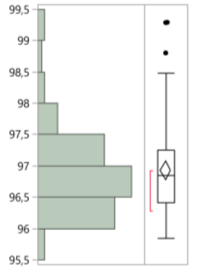
Quantiles

100.0%	maximum	4,194
99.5%		4,194
97.5%		3,898875
90.0%		3,282
75.0%	quartile	2,80175
50.0%	median	2,2455
25.0%	quartile	1,982
10.0%		1,817
2.5%		1,64325
0.5%		1,566
0.0%	minimum	1,566

Summary Statistics

Mean	2,4120238
Std Dev	0,5642536
Std Err Mean	0,0615651
Upper 95% Mean	2,5344743
Lower 95% Mean	2,2895733
N	84

Equipment filling



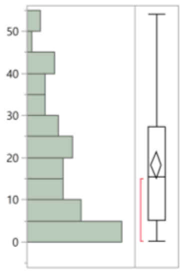
Quantiles

100.0%	maximum	99,284
99.5%		99,284
97.5%		99,2195
90.0%		97,834
75.0%	quartile	97,25075
50.0%	median	96,8475
25.0%	quartile	96,415
10.0%		96,196
2.5%		96,003
0.5%		95,841
0.0%	minimum	95,841

Summary Statistics

Mean	96,925821
Std Dev	0,6829501
Std Err Mean	0,074516
Upper 95% Mean	97,074031
Lower 95% Mean	96,777612
N	84

Filling finished to dismantle



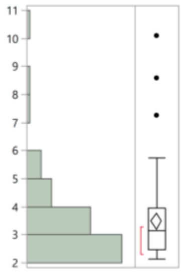
Quantiles

100.0%	maximum	53,953
99.5%		53,953
97.5%		52,86575
90.0%		40,558
75.0%	quartile	27,28
50.0%	median	15,4735
25.0%	quartile	5,032
10.0%		1,313
2.5%		0,582625
0.5%		0,244
0.0%	minimum	0,244

Summary Statistics

Mean	18,192536
Std Dev	14,795765
Std Err Mean	1,6143503
Upper 95% Mean	21,403413
Lower 95% Mean	14,981658
N	84

Return hose



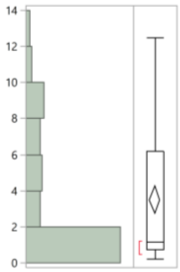
Quantiles

100.0%	maximum	10,083
99.5%		10,083
97.5%		8,409875
90.0%		5,034
75.0%	quartile	3,9605
50.0%	median	3,1595
25.0%	quartile	2,48125
10.0%		2,348
2.5%		2,144625
0.5%		2,138
0.0%	minimum	2,138

Summary Statistics

Mean	3,4749643
Std Dev	1,372406
Std Err Mean	0,1497418
Upper 95% Mean	3,7727947
Lower 95% Mean	3,1771339
N	84

Hose returned to arm going up



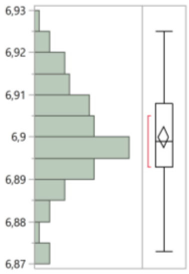
Quantiles

100.0%	maximum	12,485
99.5%		12,485
97.5%		12,00375
90.0%		8,989
75.0%	quartile	6,1755
50.0%	median	1,163
25.0%	quartile	0,75925
10.0%		0,658
2.5%		0,492375
0.5%		0,219
0.0%	minimum	0,219

Summary Statistics

Mean	3,4901905
Std Dev	3,5373741
Std Err Mean	0,3859592
Upper 95% Mean	4,2578477
Lower 95% Mean	2,7225332
N	84

arm going up



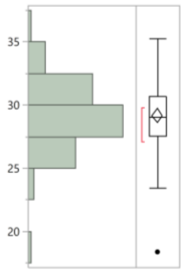
Quantiles

100.0%	maximum	6,925
99.5%		6,925
97.5%		6,922
90.0%		6,915
75.0%	quartile	6,908
50.0%	median	6,899
25.0%	quartile	6,893
10.0%		6,886
2.5%		6,873125
0.5%		6,873
0.0%	minimum	6,873

Summary Statistics

Mean	6,8999167
Std Dev	0,0113331
Std Err Mean	0,0012365
Upper 95% Mean	6,9023761
Lower 95% Mean	6,8974572
N	84

Equipment return



Quantiles

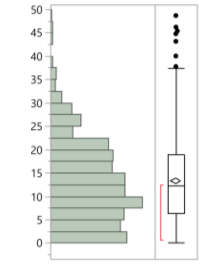
100.0%	maximum	35,25
99.5%		35,25
97.5%		34,412375
90.0%		32,398
75.0%	quartile	30,71625
50.0%	median	29,019
25.0%	quartile	27,56
10.0%		26,639
2.5%		23,526375
0.5%		18,346
0.0%	minimum	18,346

Summary Statistics

Mean	29,141643
Std Dev	2,5907682
Std Err Mean	0,282676
Upper 95% Mean	29,703874
Lower 95% Mean	28,579412
N	84

C2 – Small system

Car arrival



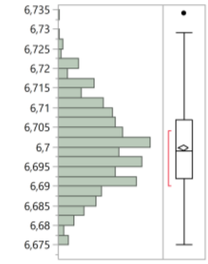
Quantiles

100.0%	maximum	48,606
99.5%		44,74058
97.5%		31,8825
90.0%		25,5096
75.0%	quartile	18,915
50.0%	median	12,241
25.0%	quartile	6,4035
10.0%		2,4276
2.5%		0,75135
0.5%		0,13467
0.0%	minimum	0

Summary Statistics

Mean	13,238168
Std Dev	8,7326478
Std Err Mean	0,3101054
Upper 95% Mean	13,846893
Lower 95% Mean	12,629442
N	793

Arm going down



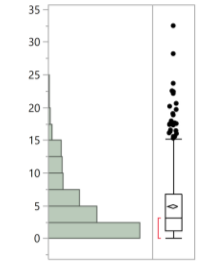
Quantiles

100.0%	maximum	6,734
99.5%		6,726
97.5%		6,72
90.0%		6,713
75.0%	quartile	6,707
50.0%	median	6,699
25.0%	quartile	6,692
10.0%		6,687
2.5%		6,68085
0.5%		6,67597
0.0%	minimum	6,675

Summary Statistics

Mean	6,6996431
Std Dev	0,0102899
Std Err Mean	0,0003654
Upper 95% Mean	6,7003604
Lower 95% Mean	6,6989259
N	793

Arm down to hose taken



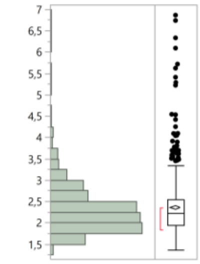
Quantiles

100.0%	maximum	32,462
99.5%		22,54632
97.5%		16,3092
90.0%		12,16
75.0%	quartile	6,832
50.0%	median	3,144
25.0%	quartile	1,2275
10.0%		0,4968
2.5%		0,13055
0.5%		0,02373
0.0%	minimum	0

Summary Statistics

Mean	4,8265044
Std Dev	4,7345404
Std Err Mean	0,1681285
Upper 95% Mean	5,1565345
Lower 95% Mean	4,4964743
N	793

Assemble hose



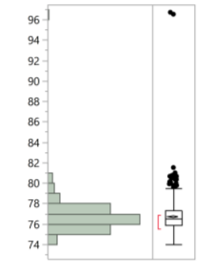
Quantiles

100.0%	maximum	6,857
99.5%		6,0922
97.5%		3,889
90.0%		3,0284
75.0%	quartile	2,5355
50.0%	median	2,219
25.0%	quartile	1,9395
10.0%		1,7694
2.5%		1,61825
0.5%		1,47869
0.0%	minimum	1,361

Summary Statistics

Mean	2,3428575
Std Dev	0,6357289
Std Err Mean	0,0225754
Upper 95% Mean	2,3871722
Lower 95% Mean	2,2985428
N	793

Equipment filling



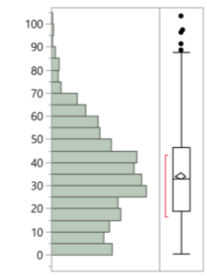
Quantiles

100.0%	maximum	96,684
99.5%		81,00636
97.5%		79,90895
90.0%		77,9756
75.0%	quartile	77,36
50.0%	median	76,479
25.0%	quartile	75,898
10.0%		75,4228
2.5%		74,82935
0.5%		74,24922
0.0%	minimum	74,014

Summary Statistics

Mean	76,718354
Std Dev	1,5175433
Std Err Mean	0,0538895
Upper 95% Mean	76,824138
Lower 95% Mean	76,612571
N	793

Filling finished to dismantle



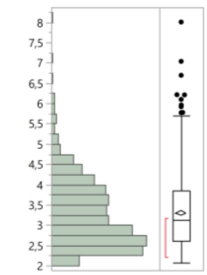
Quantiles

100.0%	maximum	103,256
99.5%		91,36386
97.5%		75,4757
90.0%		60,4452
75.0%	quartile	46,46
50.0%	median	32,846
25.0%	quartile	18,934
10.0%		7,3416
2.5%		1,22355
0.5%		0,5034
0.0%	minimum	0,269

Summary Statistics

Mean	33,905554
Std Dev	19,579461
Std Err Mean	0,6952871
Upper 95% Mean	35,270377
Lower 95% Mean	32,54073
N	793

Return hose



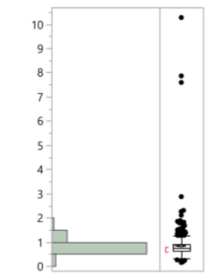
Quantiles

100.0%	maximum	8
99.5%		6,22337
97.5%		5,27605
90.0%		4,3968
75.0%	quartile	3,8585
50.0%	median	3,117
25.0%	quartile	2,6225
10.0%		2,371
2.5%		2,19055
0.5%		2,10137
0.0%	minimum	2,072

Summary Statistics

Mean	3,2909369
Std Dev	0,8438179
Std Err Mean	0,0299649
Upper 95% Mean	3,3497569
Lower 95% Mean	3,232117
N	793

Hose returned to arm going up



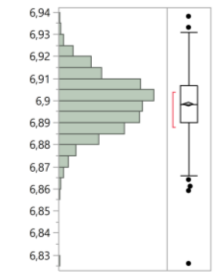
Quantiles

100.0%	maximum	10,266
99.5%		3,00954
97.5%		1,5006
90.0%		1,1172
75.0%	quartile	0,892
50.0%	median	0,744
25.0%	quartile	0,641
10.0%		0,5754
2.5%		0,48885
0.5%		0,23488
0.0%	minimum	0,148

Summary Statistics

Mean	0,8313455
Std Dev	0,5486494
Std Err Mean	0,0194831
Upper 95% Mean	0,8695902
Lower 95% Mean	0,7931009
N	793

arm going up



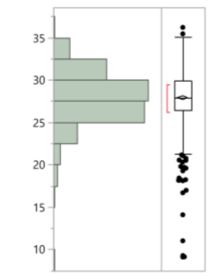
Quantiles

100.0%	maximum	6,938
99.5%		6,931
97.5%		6,922
90.0%		6,914
75.0%	quartile	6,907
50.0%	median	6,898
25.0%	quartile	6,89
10.0%		6,8824
2.5%		6,872
0.5%		6,86391
0.0%	minimum	6,826

Summary Statistics

Mean	6,898111
Std Dev	0,0124664
Std Err Mean	0,0004427
Upper 95% Mean	6,89898
Lower 95% Mean	6,897242
N	793

Equipment return



Quantiles

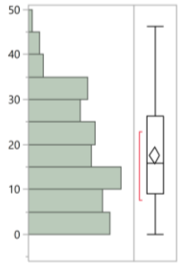
100.0%	maximum	36,168
99.5%		34,93568
97.5%		33,4796
90.0%		31,5818
75.0%	quartile	29,9435
50.0%	median	27,837
25.0%	quartile	26,456
10.0%		24,573
2.5%		20,44825
0.5%		10,93468
0.0%	minimum	9,074

Summary Statistics

Mean	27,894198
Std Dev	3,2498217
Std Err Mean	0,1154046
Upper 95% Mean	28,120733
Lower 95% Mean	27,667663
N	793

C3 – Large system

Car arrival



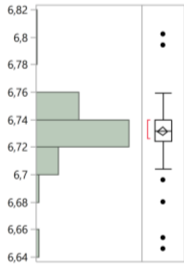
Quantiles

100.0%	maximum	46,335
99.5%		46,335
97.5%		41,62675
90.0%		33,3792
75.0%	quartile	26,309
50.0%	median	15,7655
25.0%	quartile	8,953
10.0%		2,5651
2.5%		0,205475
0.5%		0,027
0.0%	minimum	0,027

Summary Statistics

Mean	17,437557
Std Dev	11,294615
Std Err Mean	0,9545692
Upper 95% Mean	19,32491
Lower 95% Mean	15,550204
N	140

Arm going down



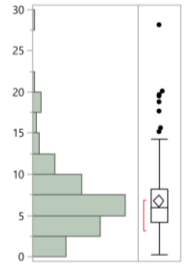
Quantiles

100.0%	maximum	6,802
99.5%		6,802
97.5%		6,75795
90.0%		6,747
75.0%	quartile	6,74
50.0%	median	6,732
25.0%	quartile	6,724
10.0%		6,7142
2.5%		6,6884
0.5%		6,646
0.0%	minimum	6,646

Summary Statistics

Mean	6,7311643
Std Dev	0,0174577
Std Err Mean	0,0014754
Upper 95% Mean	6,7340815
Lower 95% Mean	6,7282471
N	140

Arm down to hose taken



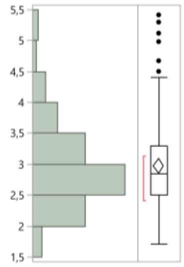
Quantiles

100.0%	maximum	28,108
99.5%		28,108
97.5%		19,545175
90.0%		11,7348
75.0%	quartile	8,26125
50.0%	median	6,0135
25.0%	quartile	4,1375
10.0%		2,1441
2.5%		0,526325
0.5%		0,27
0.0%	minimum	0,27

Summary Statistics

Mean	6,745
Std Dev	4,326891
Std Err Mean	0,365689
Upper 95% Mean	7,4680322
Lower 95% Mean	6,0219678
N	140

Assemble hose



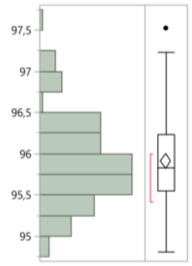
Quantiles

100.0%	maximum	5,408
99.5%		5,408
97.5%		5,0406
90.0%		3,8972
75.0%	quartile	3,29925
50.0%	median	2,846
25.0%	quartile	2,512
10.0%		2,19
2.5%		1,91045
0.5%		1,717
0.0%	minimum	1,717

Summary Statistics

Mean	2,9686786
Std Dev	0,7020059
Std Err Mean	0,0593303
Upper 95% Mean	3,0859852
Lower 95% Mean	2,851372
N	140

Equipment filling



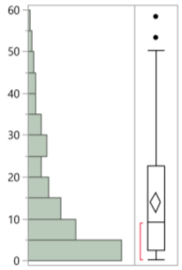
Quantiles

100.0%	maximum	97,521
99.5%		97,521
97.5%		97,182175
90.0%		96,7022
75.0%	quartile	96,233
50.0%	median	95,8245
25.0%	quartile	95,54825
10.0%		95,2717
2.5%		94,952675
0.5%		94,811
0.0%	minimum	94,811

Summary Statistics

Mean	95,906993
Std Dev	0,5331591
Std Err Mean	0,0450602
Upper 95% Mean	95,996085
Lower 95% Mean	95,817901
N	140

Filling finished to dismantle



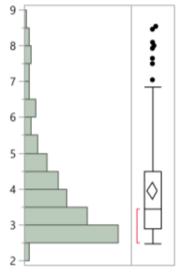
Quantiles

100.0%	maximum	58,328
99.5%		58,328
97.5%		48,48545
90.0%		34,9579
75.0%	quartile	22,651
50.0%	median	9,151
25.0%	quartile	2,42375
10.0%		0,931
2.5%		0,38595
0.5%		0,293
0.0%	minimum	0,293

Summary Statistics

Mean	13,883457
Std Dev	13,858368
Std Err Mean	1,1712459
Upper 95% Mean	16,199218
Lower 95% Mean	11,567696
N	140

Return hose



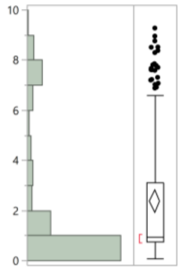
Quantiles

100.0%	maximum	8,53
99.5%		8,53
97.5%		8,03565
90.0%		6,275
75.0%	quartile	4,48675
50.0%	median	3,4365
25.0%	quartile	2,90475
10.0%		2,6995
2.5%		2,53025
0.5%		2,478
0.0%	minimum	2,478

Summary Statistics

Mean	3,9532071
Std Dev	1,4068209
Std Err Mean	0,1188981
Upper 95% Mean	4,1882898
Lower 95% Mean	3,7181245
N	140

Hose returned to arm going up



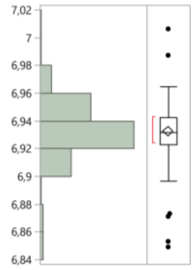
Quantiles

100.0%	maximum	9,259
99.5%		9,259
97.5%		8,61795
90.0%		7,593
75.0%	quartile	3,0945
50.0%	median	0,9445
25.0%	quartile	0,75825
10.0%		0,676
2.5%		0,307575
0.5%		0,086
0.0%	minimum	0,086

Summary Statistics

Mean	2,3618071
Std Dev	2,6586806
Std Err Mean	0,2246995
Upper 95% Mean	2,806078
Lower 95% Mean	1,9175362
N	140

arm going up



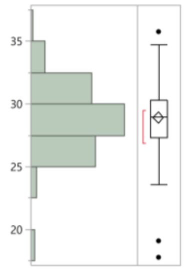
Quantiles

100.0%	maximum	7,006
99.5%		7,006
97.5%		6,965
90.0%		6,9528
75.0%	quartile	6,94275
50.0%	median	6,932
25.0%	quartile	6,923
10.0%		6,914
2.5%		6,87205
0.5%		6,849
0.0%	minimum	6,849

Summary Statistics

Mean	6,9323
Std Dev	0,0199166
Std Err Mean	0,0016833
Upper 95% Mean	6,9356281
Lower 95% Mean	6,9289719
N	140

Equipment return



Quantiles

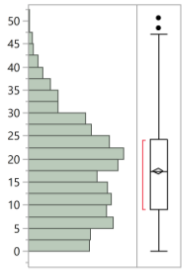
100.0%	maximum	35,731
99.5%		35,731
97.5%		34,08195
90.0%		31,9293
75.0%	quartile	30,289
50.0%	median	28,9955
25.0%	quartile	27,29175
10.0%		26,5493
2.5%		23,880725
0.5%		17,749
0.0%	minimum	17,749

Summary Statistics

Mean	28,890814
Std Dev	2,525926
Std Err Mean	0,2134797
Upper 95% Mean	29,312902
Lower 95% Mean	28,468727
N	140

C3 – Small system

Car arrival



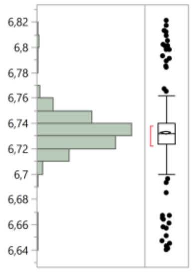
Quantiles

100.0%	maximum	50,58
99.5%		45,5412
97.5%		38,581325
90.0%		30,6639
75.0%	quartile	24,3415
50.0%	median	17,265
25.0%	quartile	9,0155
10.0%		4,1497
2.5%		1,462575
0.5%		0,256985
0.0%	minimum	0,013

Summary Statistics

Mean	17,361455
Std Dev	10,232645
Std Err Mean	0,3071329
Upper 95% Mean	17,964082
Lower 95% Mean	16,758828
N	1110

Arm going down



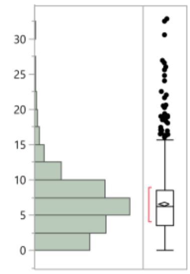
Quantiles

100.0%	maximum	6,821
99.5%		6,80678
97.5%		6,760225
90.0%		6,748
75.0%	quartile	6,74
50.0%	median	6,732
25.0%	quartile	6,724
10.0%		6,717
2.5%		6,706
0.5%		6,64922
0.0%	minimum	6,64

Summary Statistics

Mean	6,7322883
Std Dev	0,0167776
Std Err Mean	0,0005036
Upper 95% Mean	6,7332764
Lower 95% Mean	6,7313002
N	1110

Arm down to hose taken



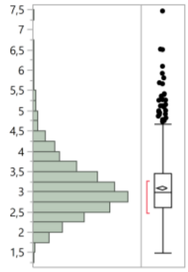
Quantiles

100.0%	maximum	32,75
99.5%		26,201875
97.5%		16,78435
90.0%		11,2557
75.0%	quartile	8,50625
50.0%	median	6,194
25.0%	quartile	3,588
10.0%		1,6341
2.5%		0,43675
0.5%		0,03811
0.0%	minimum	0

Summary Statistics

Mean	6,5017757
Std Dev	4,2187189
Std Err Mean	0,1266249
Upper 95% Mean	6,7502271
Lower 95% Mean	6,2533243
N	1110

Assemble hose



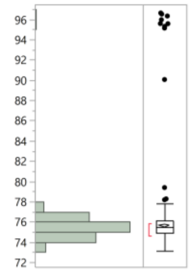
Quantiles

100.0%	maximum	7,45
99.5%		5,849285
97.5%		4,749075
90.0%		3,9843
75.0%	quartile	3,44925
50.0%	median	2,993
25.0%	quartile	2,62025
10.0%		2,3015
2.5%		1,92515
0.5%		1,744655
0.0%	minimum	1,488

Summary Statistics

Mean	3,0802486
Std Dev	0,7045652
Std Err Mean	0,0211475
Upper 95% Mean	3,1217423
Lower 95% Mean	3,038755
N	1110

Equipment filling



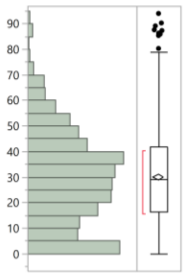
Quantiles

100.0%	maximum	96,602
99.5%		95,550785
97.5%		77,2144
90.0%		76,6989
75.0%	quartile	76,13125
50.0%	median	75,431
25.0%	quartile	74,87375
10.0%		74,3412
2.5%		73,80655
0.5%		73,27311
0.0%	minimum	73,112

Summary Statistics

Mean	75,621232
Std Dev	1,9879286
Std Err Mean	0,0596677
Upper 95% Mean	75,738306
Lower 95% Mean	75,504157
N	1110

Filling finished to dismantle



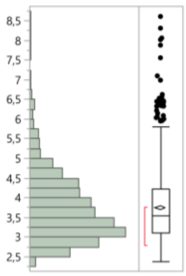
Quantiles

100.0%	maximum	93,861
99.5%		86,61423
97.5%		68,2954
90.0%		53,752
75.0%	quartile	41,77775
50.0%	median	29,1775
25.0%	quartile	16,33425
10.0%		4,3315
2.5%		0,684625
0.5%		0,342765
0.0%	minimum	0,06

Summary Statistics

Mean	29,869802
Std Dev	18,292369
Std Err Mean	0,5490457
Upper 95% Mean	30,947087
Lower 95% Mean	28,792516
N	1110

Return hose



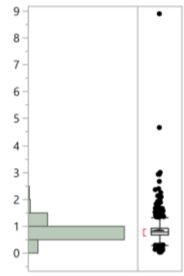
Quantiles

100.0%	maximum	8,6
99.5%		7,69229
97.5%		5,95125
90.0%		4,8038
75.0%	quartile	4,2275
50.0%	median	3,5455
25.0%	quartile	3,1035
10.0%		2,8231
2.5%		2,6171
0.5%		2,42553
0.0%	minimum	2,371

Summary Statistics

Mean	3,7425261
Std Dev	0,8716033
Std Err Mean	0,0261612
Upper 95% Mean	3,7938571
Lower 95% Mean	3,6911951
N	1110

Hose returned to arm going up



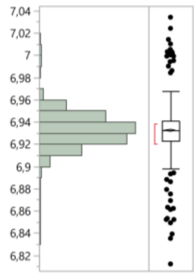
Quantiles

100.0%	maximum	8,881
99.5%		2,767145
97.5%		1,50325
90.0%		1,1284
75.0%	quartile	0,92925
50.0%	median	0,788
25.0%	quartile	0,675
10.0%		0,5534
2.5%		0,282775
0.5%		0,130215
0.0%	minimum	0,023

Summary Statistics

Mean	0,8324847
Std Dev	0,3994301
Std Err Mean	0,0119889
Upper 95% Mean	0,8560082
Lower 95% Mean	0,8089612
N	1110

arm going up



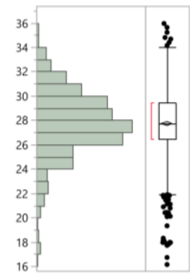
Quantiles

100.0%	maximum	7,034
99.5%		7,00389
97.5%		6,960225
90.0%		6,95
75.0%	quartile	6,941
50.0%	median	6,932
25.0%	quartile	6,923
10.0%		6,915
2.5%		6,903
0.5%		6,850665
0.0%	minimum	6,812

Summary Statistics

Mean	6,9321369
Std Dev	0,0180726
Std Err Mean	0,0005424
Upper 95% Mean	6,9332013
Lower 95% Mean	6,9310726
N	1110

Equipment return



Quantiles

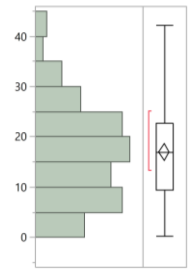
100.0%	maximum	35,936
99.5%		34,50538
97.5%		32,992375
90.0%		31,1315
75.0%	quartile	29,4615
50.0%	median	27,7295
25.0%	quartile	26,43225
10.0%		24,5537
2.5%		21,78115
0.5%		17,895715
0.0%	minimum	16,136

Summary Statistics

Mean	27,748068
Std Dev	2,7562771
Std Err Mean	0,0827297
Upper 95% Mean	27,910392
Lower 95% Mean	27,585743
N	1110

C4 – Large system

Car arrival



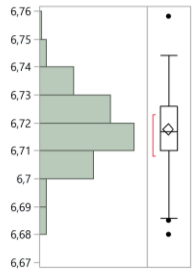
Quantiles

100.0%	maximum	42,108
99.5%		42,108
97.5%		40,501775
90.0%		29,6535
75.0%	quartile	22,77775
50.0%	median	16,876
25.0%	quartile	9,48825
10.0%		4,7168
2.5%		0,9358
0.5%		0,183
0.0%	minimum	0,183

Summary Statistics

Mean	16,972563
Std Dev	9,618591
Std Err Mean	0,8501714
Upper 95% Mean	18,654898
Lower 95% Mean	15,290227
N	128

Arm going down



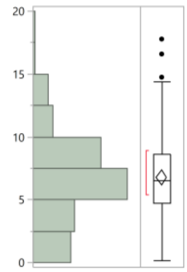
Quantiles

100.0%	maximum	6,758
99.5%		6,758
97.5%		6,741775
90.0%		6,734
75.0%	quartile	6,726
50.0%	median	6,717
25.0%	quartile	6,71
10.0%		6,7019
2.5%		6,68825
0.5%		6,68
0.0%	minimum	6,68

Summary Statistics

Mean	6,7175234
Std Dev	0,0124198
Std Err Mean	0,0010978
Upper 95% Mean	6,7196957
Lower 95% Mean	6,7153512
N	128

Arm down to hose taken



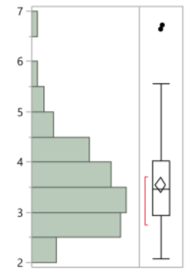
Quantiles

100.0%	maximum	17,739
99.5%		17,739
97.5%		14,62935
90.0%		11,2256
75.0%	quartile	8,61175
50.0%	median	6,4845
25.0%	quartile	4,74225
10.0%		1,5947
2.5%		0,3896
0.5%		0,127
0.0%	minimum	0,127

Summary Statistics

Mean	6,7462578
Std Dev	3,4738746
Std Err Mean	0,30705
Upper 95% Mean	7,3538544
Lower 95% Mean	6,1386612
N	128

Assemble hose



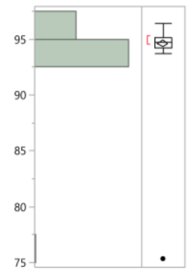
Quantiles

100.0%	maximum	6,714
99.5%		6,714
97.5%		5,54445
90.0%		4,5806
75.0%	quartile	4,02675
50.0%	median	3,463
25.0%	quartile	2,942
10.0%		2,6041
2.5%		2,10835
0.5%		2,074
0.0%	minimum	2,074

Summary Statistics

Mean	3,5408594
Std Dev	0,8453926
Std Err Mean	0,0747229
Upper 95% Mean	3,6887224
Lower 95% Mean	3,3929963
N	128

Equipment filling



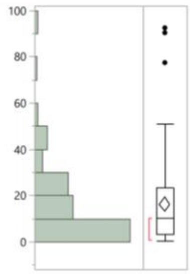
Quantiles

100.0%	maximum	96,398
99.5%		96,398
97.5%		95,8974
90.0%		95,4243
75.0%	quartile	95,1115
50.0%	median	94,731
25.0%	quartile	94,2105
10.0%		93,961
2.5%		93,749425
0.5%		75,326
0.0%	minimum	75,326

Summary Statistics

Mean	94,566609
Std Dev	1,8046368
Std Err Mean	0,1595089
Upper 95% Mean	94,882249
Lower 95% Mean	94,25097
N	128

Filling finished to dismantle



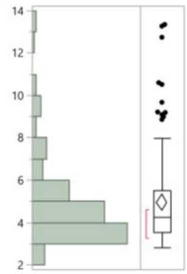
Quantiles

100.0%	maximum	92,416
99.5%		92,416
97.5%		71,470875
90.0%		42,8992
75.0%	quartile	23,2905
50.0%	median	10,3515
25.0%	quartile	3,36775
10.0%		1,683
2.5%		0,839425
0.5%		0,342
0.0%	minimum	0,342

Summary Statistics

Mean	16,159328
Std Dev	17,251269
Std Err Mean	1,5248112
Upper 95% Mean	19,176654
Lower 95% Mean	13,142002
N	128

Return hose



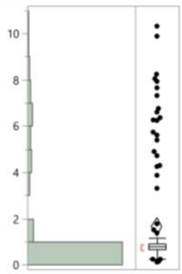
Quantiles

100.0%	maximum	13,33
99.5%		13,33
97.5%		12,24305
90.0%		7,963
75.0%	quartile	5,52325
50.0%	median	4,2565
25.0%	quartile	3,544
10.0%		3,1059
2.5%		2,920025
0.5%		2,816
0.0%	minimum	2,816

Summary Statistics

Mean	4,9476016
Std Dev	2,1423178
Std Err Mean	0,1893559
Upper 95% Mean	5,3223028
Lower 95% Mean	4,5729003
N	128

Hose returned to arm going up



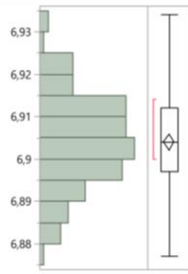
Quantiles

100.0%	maximum	10,312
99.5%		10,312
97.5%		8,191125
90.0%		5,7804
75.0%	quartile	0,92825
50.0%	median	0,7745
25.0%	quartile	0,65025
10.0%		0,506
2.5%		0,155825
0.5%		0,11
0.0%	minimum	0,11

Summary Statistics

Mean	1,648625
Std Dev	2,2355925
Std Err Mean	0,1976003
Upper 95% Mean	2,0396404
Lower 95% Mean	1,2576096
N	128

arm going up



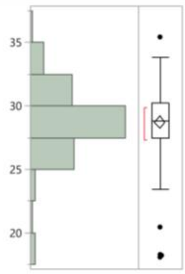
Quantiles

100.0%	maximum	6,934
99.5%		6,934
97.5%		6,924775
90.0%		6,9181
75.0%	quartile	6,912
50.0%	median	6,904
25.0%	quartile	6,897
10.0%		6,888
2.5%		6,881
0.5%		6,877
0.0%	minimum	6,877

Summary Statistics

Mean	6,9038984
Std Dev	0,0112066
Std Err Mean	0,0009905
Upper 95% Mean	6,9058585
Lower 95% Mean	6,9019384
N	128

Equipment return



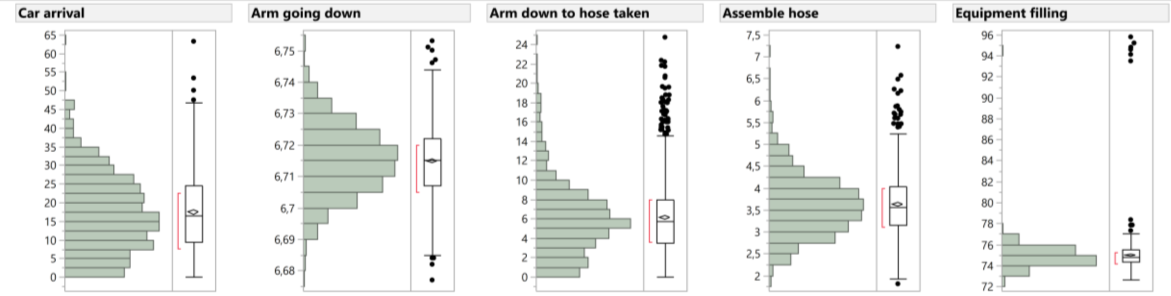
Quantiles

100.0%	maximum	35,396
99.5%		35,396
97.5%		33,191075
90.0%		31,9888
75.0%	quartile	30,262
50.0%	median	28,8165
25.0%	quartile	27,43275
10.0%		25,732
2.5%		18,746775
0.5%		18,05
0.0%	minimum	18,05

Summary Statistics

Mean	28,695539
Std Dev	2,7762427
Std Err Mean	0,2453875
Upper 95% Mean	29,181117
Lower 95% Mean	28,209961
N	128

C4 – Small system

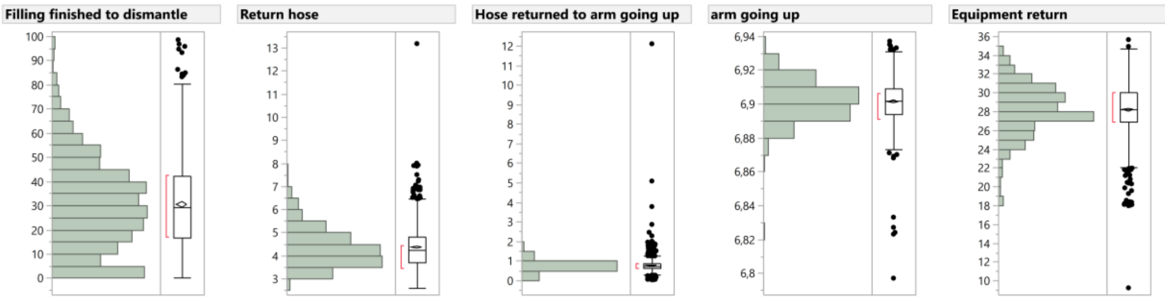


Quantiles

		Car arrival	Arm going down	Arm down to hose taken	Assemble hose	Equipment filling
100.0%	maximum	63,172	6,753	24,72	7,227	95,773
99.5%		46,77539	6,74478	21,1113	6,18001	93,72375
97.5%		39,62865	6,738	16,31115	5,10355	76,54565
90.0%		31,3412	6,729	10,7232	4,4888	75,9556
75.0%	quartile	24,559	6,722	7,9575	4,0235	75,484
50.0%	median	16,508	6,715	5,719	3,569	74,813
25.0%	quartile	9,4835	6,707	3,4845	3,147	74,306
10.0%		4,0402	6,701	1,4672	2,7742	73,8196
2.5%		0,96395	6,69305	0,46025	2,40635	73,2123
0.5%		0,32472	6,68461	0,11386	2,08864	72,84383
0.0%	minimum	0,051	6,677	0,025	1,807	72,678

Summary Statistics

	Car arrival	Arm going down	Arm down to hose taken	Assemble hose	Equipment filling
Mean	17,457309	6,7147672	6,1264808	3,6181169	74,972139
Std Dev	10,350039	0,0111815	3,8693381	0,7006892	1,6674615
Std Err Mean	0,3091286	0,000334	0,115567	0,0209278	0,0498027
Upper 95% Mean	18,063845	6,7154224	6,353233	3,6591789	75,069856
Lower 95% Mean	16,850772	6,7141119	5,8997286	3,5770548	74,874422
N	1121	1121	1121	1121	1121



Quantiles

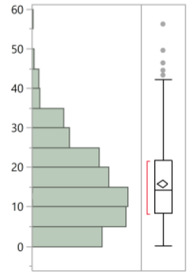
		Filling finished to dismantle	Return hose	Hose returned to arm going up	arm going up	Equipment return
100.0%	maximum	98,461	13,17	12,102	6,937	35,617
99.5%		88,90835	7,63913	2,34481	6,932	34,28739
97.5%		71,4397	6,43625	1,39115	6,924	33,32355
90.0%		55,3154	5,3946	1,0338	6,917	31,4814
75.0%	quartile	42,382	4,8115	0,87	6,909	30,069
50.0%	median	29,08	4,22	0,737	6,902	28,195
25.0%	quartile	16,8365	3,72	0,6265	6,894	26,871
10.0%		4,8826	3,4288	0,4174	6,888	24,7936
2.5%		0,94955	3,16165	0,137	6,88	21,77985
0.5%		0,38505	2,82966	0,0561	6,85435	18,09403
0.0%	minimum	0,244	2,575	0,024	6,797	9,229

Summary Statistics

	Filling finished to dismantle	Return hose	Hose returned to arm going up	arm going up	Equipment return
Mean	30,50825	4,3580669	0,7600624	6,9014674	28,176618
Std Dev	18,812095	0,876803	0,4681358	0,0124388	2,8517093
Std Err Mean	0,5618681	0,0261878	0,013982	0,0003715	0,0851731
Upper 95% Mean	31,610682	4,4094496	0,7874963	6,9021964	28,343735
Lower 95% Mean	29,405817	4,3066842	0,7326286	6,9007385	28,009501
N	1121	1121	1121	1121	1121

Total (C1-C4) – Large system

Car arrival



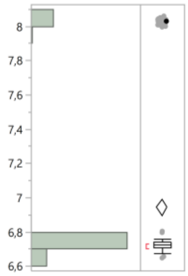
Quantiles

100.0%	maximum	56,16
99.5%		49,11575
97.5%		38,98675
90.0%		30,17
75.0%	quartile	21,89475
50.0%	median	14,294
25.0%	quartile	8,3195
10.0%		3,201
2.5%		0,56625
0.5%		0,045375
0.0%	minimum	0,027

Summary Statistics

Mean	15,737222
Std Dev	10,169844
Std Err Mean	0,4938913
Upper 95% Mean	16,708009
Lower 95% Mean	14,766435
N	424

Arm going down



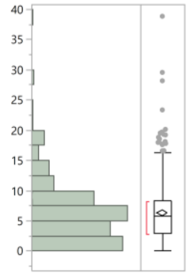
Quantiles

100.0%	maximum	8,058
99.5%		8,049875
97.5%		8,039375
90.0%		8,0275
75.0%	quartile	6,741
50.0%	median	6,725
25.0%	quartile	6,709
10.0%		6,6975
2.5%		6,684625
0.5%		6,65675
0.0%	minimum	6,646

Summary Statistics

Mean	6,9410377
Std Dev	0,4925932
Std Err Mean	0,0239224
Upper 95% Mean	6,9880594
Lower 95% Mean	6,8940161
N	424

Arm down to hose taken



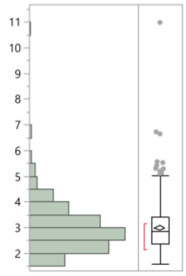
Quantiles

100.0%	maximum	38,779
99.5%		29,318125
97.5%		18,77375
90.0%		12,799
75.0%	quartile	8,28275
50.0%	median	5,7265
25.0%	quartile	2,886
10.0%		0,873
2.5%		0,18875
0.5%		0,0135
0.0%	minimum	0

Summary Statistics

Mean	6,2878585
Std Dev	4,979263
Std Err Mean	0,2418144
Upper 95% Mean	6,7631659
Lower 95% Mean	5,812551
N	424

Assemble hose



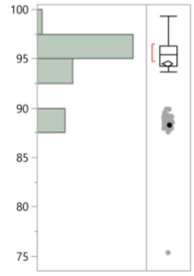
Quantiles

100.0%	maximum	10,972
99.5%		6,70375
97.5%		5,10075
90.0%		4,0705
75.0%	quartile	3,429
50.0%	median	2,8595
25.0%	quartile	2,35375
10.0%		2,0075
2.5%		1,78025
0.5%		1,638
0.0%	minimum	1,566

Summary Statistics

Mean	2,9764127
Std Dev	0,9164472
Std Err Mean	0,0445066
Upper 95% Mean	3,0638944
Lower 95% Mean	2,8889311
N	424

Equipment filling



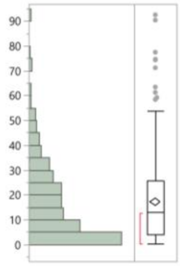
Quantiles

100.0%	maximum	99,284
99.5%		99,2195
97.5%		97,6885
90.0%		96,915
75.0%	quartile	96,2765
50.0%	median	95,426
25.0%	quartile	94,24325
10.0%		88,6185
2.5%		88,022875
0.5%		87,565125
0.0%	minimum	75,326

Summary Statistics

Mean	94,459045
Std Dev	3,0001716
Std Err Mean	0,1457012
Upper 95% Mean	94,745433
Lower 95% Mean	94,172656
N	424

Filling finished to dismantle



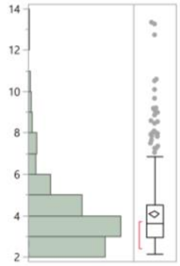
Quantiles

100.0%	maximum	92,416
99.5%		88,6755
97.5%		55,593625
90.0%		39,1995
75.0%	quartile	25,555
50.0%	median	12,8835
25.0%	quartile	4,209
10.0%		1,292
2.5%		0,530625
0.5%		0,299125
0.0%	minimum	0,244

Summary Statistics

Mean	17,277212
Std Dev	16,093065
Std Err Mean	0,7815483
Upper 95% Mean	18,813414
Lower 95% Mean	15,74101
N	424

Return hose



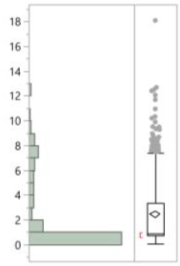
Quantiles

100.0%	maximum	13,33
99.5%		13,18525
97.5%		9,013375
90.0%		5,971
75.0%	quartile	4,53925
50.0%	median	3,6135
25.0%	quartile	2,929
10.0%		2,5515
2.5%		2,34875
0.5%		2,144625
0.0%	minimum	2,138

Summary Statistics

Mean	4,0553208
Std Dev	1,7031231
Std Err Mean	0,082711
Upper 95% Mean	4,2178964
Lower 95% Mean	3,8927451
N	424

Hose returned to arm going up



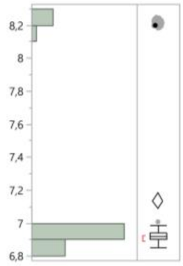
Quantiles

100.0%	maximum	18,068
99.5%		12,64425
97.5%		9,882
90.0%		7,585
75.0%	quartile	3,383
50.0%	median	0,8785
25.0%	quartile	0,713
10.0%		0,6005
2.5%		0,250375
0.5%		0,112875
0.0%	minimum	0,086

Summary Statistics

Mean	2,4274222
Std Dev	2,9762453
Std Err Mean	0,1445392
Upper 95% Mean	2,7115268
Lower 95% Mean	2,1433176
N	424

arm going up



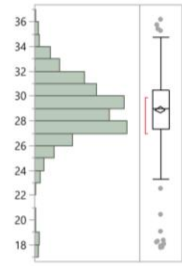
Quantiles

100.0%	maximum	8,246
99.5%		8,241375
97.5%		8,225
90.0%		8,2095
75.0%	quartile	6,943
50.0%	median	6,917
25.0%	quartile	6,90125
10.0%		6,893
2.5%		6,88
0.5%		6,85525
0.0%	minimum	6,849

Summary Statistics

Mean	7,1346887
Std Dev	0,4884083
Std Err Mean	0,0237192
Upper 95% Mean	7,1813109
Lower 95% Mean	7,0880665
N	424

Equipment return



Quantiles

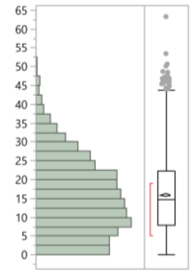
100.0%	maximum	36,163
99.5%		35,689125
97.5%		33,687625
90.0%		32,0205
75.0%	quartile	30,44375
50.0%	median	28,9955
25.0%	quartile	27,357
10.0%		26,163
2.5%		22,992375
0.5%		17,7925
0.0%	minimum	17,749

Summary Statistics

Mean	28,866946
Std Dev	2,736338
Std Err Mean	0,1328883
Upper 95% Mean	29,128149
Lower 95% Mean	28,605742
N	424

Total (C1-C4) – Small system

Car arrival



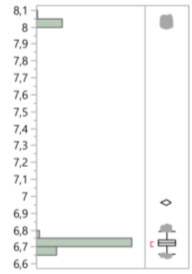
Quantiles

100.0%	maximum	63,172
99.5%		45,495575
97.5%		37,31655
90.0%		29,2953
75.0%	quartile	22,29525
50.0%	median	14,826
25.0%	quartile	7,93075
10.0%		3,3934
2.5%		0,907075
0.5%		0,214425
0.0%	minimum	0

Summary Statistics

Mean	15,822557
Std Dev	9,884465
Std Err Mean	0,162368
Upper 95% Mean	16,140896
Lower 95% Mean	15,504217
N	3706

Arm going down



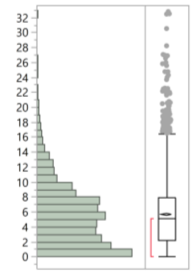
Quantiles

100.0%	maximum	8,059
99.5%		8,048
97.5%		8,037
90.0%		8,025
75.0%	quartile	6,742
50.0%	median	6,722
25.0%	quartile	6,707
10.0%		6,696
2.5%		6,686
0.5%		6,676
0.0%	minimum	6,64

Summary Statistics

Mean	6,9580534
Std Dev	0,507465
Std Err Mean	0,0083359
Upper 95% Mean	6,9743969
Lower 95% Mean	6,94171
N	3706

Arm down to hose taken



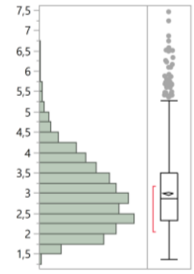
Quantiles

100.0%	maximum	32,75
99.5%		22,48525
97.5%		16,424175
90.0%		11,416
75.0%	quartile	7,88825
50.0%	median	5,078
25.0%	quartile	2,17925
10.0%		0,771
2.5%		0,207
0.5%		0,035
0.0%	minimum	0

Summary Statistics

Mean	5,6677326
Std Dev	4,4049914
Std Err Mean	0,072359
Upper 95% Mean	5,8095999
Lower 95% Mean	5,5258653
N	3706

Assemble hose



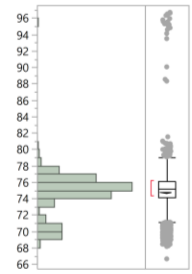
Quantiles

100.0%	maximum	7,45
99.5%		5,82597
97.5%		4,857625
90.0%		4,0953
75.0%	quartile	3,50725
50.0%	median	2,87
25.0%	quartile	2,325
10.0%		1,9637
2.5%		1,733
0.5%		1,581
0.0%	minimum	1,361

Summary Statistics

Mean	2,9733146
Std Dev	0,8449833
Std Err Mean	0,0138802
Upper 95% Mean	3,0005282
Lower 95% Mean	2,9461011
N	3706

Equipment filling



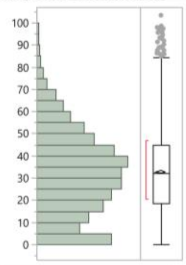
Quantiles

100.0%	maximum	96,684
99.5%		88,400045
97.5%		78,097925
90.0%		76,9116
75.0%	quartile	76,06875
50.0%	median	75,152
25.0%	quartile	74,079
10.0%		70,189
2.5%		69,367075
0.5%		68,68833
0.0%	minimum	66,622

Summary Statistics

Mean	74,661661
Std Dev	2,77051
Std Err Mean	0,04551
Upper 95% Mean	74,750888
Lower 95% Mean	74,572433
N	3706

Filling finished to dismantle



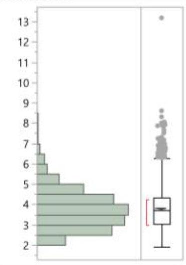
Quantiles

100.0%	maximum	103,256
99.5%		87,994165
97.5%		72,20605
90.0%		57,6295
75.0%	quartile	44,76625
50.0%	median	32,134
25.0%	quartile	18,32875
10.0%		6,3791
2.5%		1,01935
0.5%		0,393605
0.0%	minimum	0,06

Summary Statistics

Mean	32,54827
Std Dev	19,085119
Std Err Mean	0,3135033
Upper 95% Mean	33,162926
Lower 95% Mean	31,933614
N	3706

Return hose



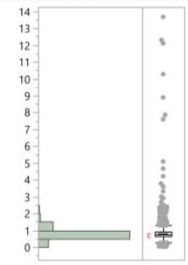
Quantiles

100.0%	maximum	13,17
99.5%		7,22644
97.5%		6,0849
90.0%		4,9973
75.0%	quartile	4,34125
50.0%	median	3,687
25.0%	quartile	3,05
10.0%		2,6317
2.5%		2,347675
0.5%		2,164535
0.0%	minimum	1,905

Summary Statistics

Mean	3,7806495
Std Dev	0,9761813
Std Err Mean	0,0160353
Upper 95% Mean	3,8120884
Lower 95% Mean	3,7492106
N	3706

Hose returned to arm going up



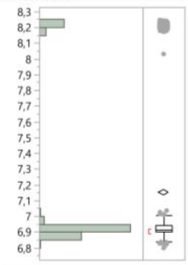
Quantiles

100.0%	maximum	13,675
99.5%		2,747255
97.5%		1,47285
90.0%		1,0893
75.0%	quartile	0,896
50.0%	median	0,752
25.0%	quartile	0,638
10.0%		0,517
2.5%		0,256675
0.5%		0,098535
0.0%	minimum	0,013

Summary Statistics

Mean	0,8082342
Std Dev	0,5299112
Std Err Mean	0,0087046
Upper 95% Mean	0,8253006
Lower 95% Mean	0,7911679
N	3706

arm going up



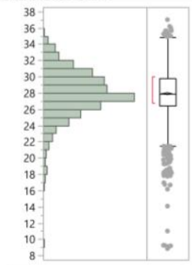
Quantiles

100.0%	maximum	8,245
99.5%		8,235
97.5%		8,225
90.0%		8,209
75.0%	quartile	6,942
50.0%	median	6,916
25.0%	quartile	6,9
10.0%		6,89
2.5%		6,88
0.5%		6,862535
0.0%	minimum	6,797

Summary Statistics

Mean	7,1507984
Std Dev	0,503645
Std Err Mean	0,0082732
Upper 95% Mean	7,1670188
Lower 95% Mean	7,134578
N	3706

Equipment return



Quantiles

100.0%	maximum	36,983
99.5%		34,725925
97.5%		33,29385
90.0%		31,4095
75.0%	quartile	29,838
50.0%	median	27,9205
25.0%	quartile	26,474
10.0%		24,5451
2.5%		21,266925
0.5%		17,87705
0.0%	minimum	8,826

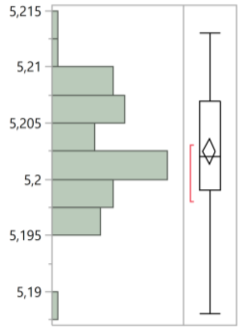
Summary Statistics

Mean	27,910894
Std Dev	2,9935761
Std Err Mean	0,0491742
Upper 95% Mean	28,007305
Lower 95% Mean	27,814482
N	3706

Appendix IV – Boxplots for equipment filling process

C1 – Large system

Initiating



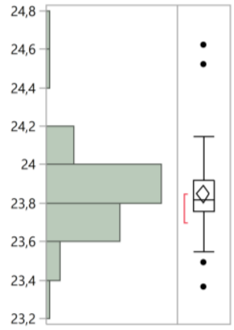
Quantiles

100.0%	maximum	5,213
99.5%		5,213
97.5%		5,21075
90.0%		5,209
75.0%	quartile	5,207
50.0%	median	5,202
25.0%	quartile	5,199
10.0%		5,197
2.5%		5,19325
0.5%		5,188
0.0%	minimum	5,188

Summary Statistics

Mean	5,2024058
Std Dev	0,0046851
Std Err Mean	0,000564
Upper 95% Mean	5,2035313
Lower 95% Mean	5,2012803
N	69

Evacuation 1



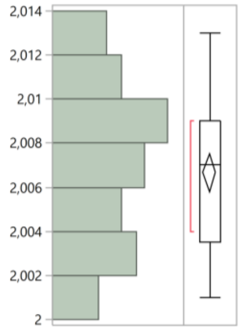
Quantiles

100.0%	maximum	24,621
99.5%		24,621
97.5%		24,54525
90.0%		24,063
75.0%	quartile	23,921
50.0%	median	23,817
25.0%	quartile	23,76
10.0%		23,647
2.5%		23,45925
0.5%		23,364
0.0%	minimum	23,364

Summary Statistics

Mean	23,845348
Std Dev	0,1918114
Std Err Mean	0,0230914
Upper 95% Mean	23,891426
Lower 95% Mean	23,79927
N	69

Vacuum test



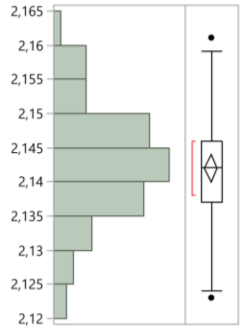
Quantiles

100.0%	maximum	2,013
99.5%		2,013
97.5%		2,013
90.0%		2,012
75.0%	quartile	2,009
50.0%	median	2,007
25.0%	quartile	2,0035
10.0%		2,002
2.5%		2,001
0.5%		2,001
0.0%	minimum	2,001

Summary Statistics

Mean	2,0066522
Std Dev	0,0035679
Std Err Mean	0,0004295
Upper 95% Mean	2,0075093
Lower 95% Mean	2,0057951
N	69

Evacuation 2



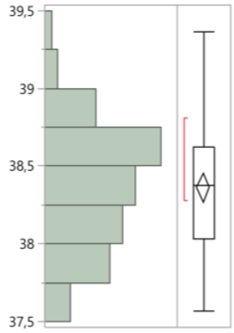
Quantiles

100.0%	maximum	2,161
99.5%		2,161
97.5%		2,1595
90.0%		2,154
75.0%	quartile	2,146
50.0%	median	2,142
25.0%	quartile	2,137
10.0%		2,13
2.5%		2,12375
0.5%		2,123
0.0%	minimum	2,123

Summary Statistics

Mean	2,1418551
Std Dev	0,0083987
Std Err Mean	0,0010111
Upper 95% Mean	2,1438727
Lower 95% Mean	2,1398375
N	69

Filling



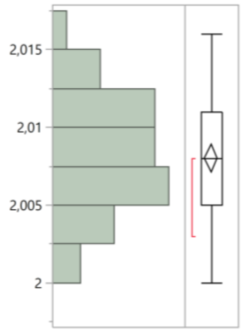
Quantiles

100.0%	maximum	39,365
99.5%		39,365
97.5%		39,14
90.0%		38,821
75.0%	quartile	38,62
50.0%	median	38,377
25.0%	quartile	38,0325
10.0%		37,797
2.5%		37,58475
0.5%		37,572
0.0%	minimum	37,572

Summary Statistics

Mean	38,359087
Std Dev	0,391867
Std Err Mean	0,0471752
Upper 95% Mean	38,453224
Lower 95% Mean	38,26495
N	69

Pressure test



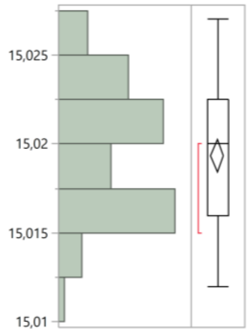
Quantiles

100.0%	maximum	2,016
99.5%		2,016
97.5%		2,01525
90.0%		2,014
75.0%	quartile	2,011
50.0%	median	2,008
25.0%	quartile	2,005
10.0%		2,003
2.5%		2,00075
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,008
Std Dev	0,0037769
Std Err Mean	0,0004547
Upper 95% Mean	2,0089073
Lower 95% Mean	2,0070927
N	69

Leveling



Quantiles

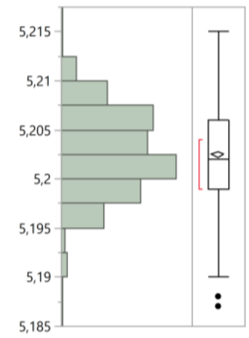
100.0%	maximum	15,027
99.5%		15,027
97.5%		15,027
90.0%		15,024
75.0%	quartile	15,0225
50.0%	median	15,02
25.0%	quartile	15,016
10.0%		15,015
2.5%		15,01275
0.5%		15,012
0.0%	minimum	15,012

Summary Statistics

Mean	15,019304
Std Dev	0,003735
Std Err Mean	0,0004496
Upper 95% Mean	15,020202
Lower 95% Mean	15,018407
N	69

C1 – Small system

Initiating



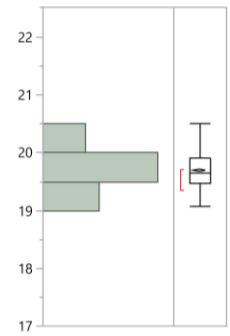
Quantiles

100.0%	maximum	5,215
99.5%		5,212515
97.5%		5,21
90.0%		5,208
75.0%	quartile	5,206
50.0%	median	5,202
25.0%	quartile	5,199
10.0%		5,197
2.5%		5,195
0.5%		5,19
0.0%	minimum	5,187

Summary Statistics

Mean	5,2024411
Std Dev	0,0042263
Std Err Mean	0,0001602
Upper 95% Mean	5,2027556
Lower 95% Mean	5,2021266
N	696

Evacuation 1



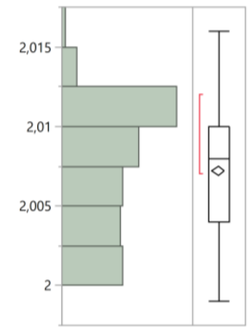
Quantiles

100.0%	maximum	20,506
99.5%		20,29217
97.5%		20,170575
90.0%		20,0846
75.0%	quartile	19,91175
50.0%	median	19,6455
25.0%	quartile	19,476
10.0%		19,3667
2.5%		19,21025
0.5%		19,122095
0.0%	minimum	19,077

Summary Statistics

Mean	19,688934
Std Dev	0,2714068
Std Err Mean	0,0102876
Upper 95% Mean	19,709133
Lower 95% Mean	19,668735
N	696

Vacuum test



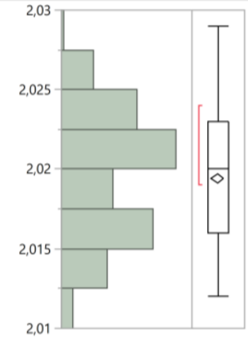
Quantiles

100.0%	maximum	2,016
99.5%		2,015515
97.5%		2,013
90.0%		2,012
75.0%	quartile	2,01
50.0%	median	2,008
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	1,999

Summary Statistics

Mean	2,0071911
Std Dev	0,0037855
Std Err Mean	0,0001435
Upper 95% Mean	2,0074728
Lower 95% Mean	2,0069094
N	696

Evacuation 2



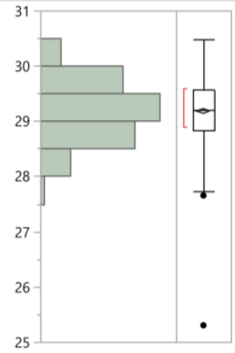
Quantiles

100.0%	maximum	2,029
99.5%		2,027515
97.5%		2,026
90.0%		2,024
75.0%	quartile	2,023
50.0%	median	2,02
25.0%	quartile	2,016
10.0%		2,014
2.5%		2,012
0.5%		2,012
0.0%	minimum	2,012

Summary Statistics

Mean	2,0193793
Std Dev	0,0039064
Std Err Mean	0,0001481
Upper 95% Mean	2,01967
Lower 95% Mean	2,0190886
N	696

Filling



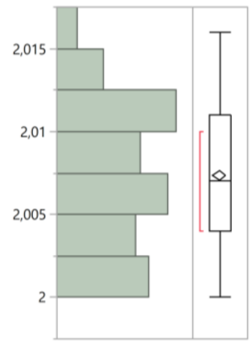
Quantiles

100.0%	maximum	30,479
99.5%		30,34612
97.5%		30,15475
90.0%		29,8795
75.0%	quartile	29,57
50.0%	median	29,211
25.0%	quartile	28,831
10.0%		28,505
2.5%		28,166925
0.5%		27,78553
0.0%	minimum	25,299

Summary Statistics

Mean	29,187075
Std Dev	0,5378777
Std Err Mean	0,0203882
Upper 95% Mean	29,227105
Lower 95% Mean	29,147045
N	696

Pressure test



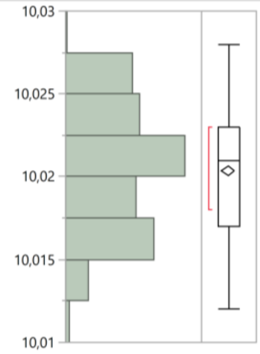
Quantiles

100.0%	maximum	2,016
99.5%		2,015515
97.5%		2,015
90.0%		2,013
75.0%	quartile	2,011
50.0%	median	2,007
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0073175
Std Dev	0,0041374
Std Err Mean	0,0001568
Upper 95% Mean	2,0076254
Lower 95% Mean	2,0070096
N	696

Leveling



Quantiles

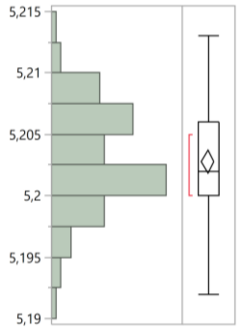
100.0%	maximum	10,028
99.5%		10,027
97.5%		10,027
90.0%		10,025
75.0%	quartile	10,023
50.0%	median	10,021
25.0%	quartile	10,017
10.0%		10,016
2.5%		10,013
0.5%		10,012
0.0%	minimum	10,012

Summary Statistics

Mean	10,020341
Std Dev	0,0036636
Std Err Mean	0,0001389
Upper 95% Mean	10,020613
Lower 95% Mean	10,020068
N	696

C2 – Large system

Initiating



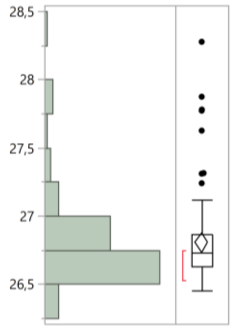
Quantiles

100.0%	maximum	5,213
99.5%		5,213
97.5%		5,2118
90.0%		5,208
75.0%	quartile	5,206
50.0%	median	5,202
25.0%	quartile	5,2
10.0%		5,198
2.5%		5,1931
0.5%		5,192
0.0%	minimum	5,192

Summary Statistics

Mean	5,2027349
Std Dev	0,0042256
Std Err Mean	0,0004638
Upper 95% Mean	5,2036576
Lower 95% Mean	5,2018123
N	83

Evacuation 1



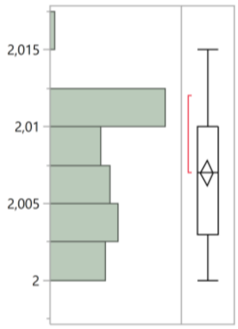
Quantiles

100.0%	maximum	28,273
99.5%		28,273
97.5%		27,8616
90.0%		27,1888
75.0%	quartile	26,862
50.0%	median	26,727
25.0%	quartile	26,627
10.0%		26,5304
2.5%		26,4686
0.5%		26,452
0.0%	minimum	26,452

Summary Statistics

Mean	26,805663
Std Dev	0,3289735
Std Err Mean	0,0361095
Upper 95% Mean	26,877496
Lower 95% Mean	26,733829
N	83

Vacuum test



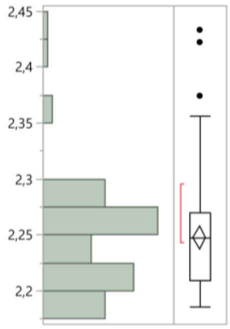
Quantiles

100.0%	maximum	2,015
99.5%		2,015
97.5%		2,012
90.0%		2,012
75.0%	quartile	2,01
50.0%	median	2,007
25.0%	quartile	2,003
10.0%		2,002
2.5%		2,0001
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0069518
Std Dev	0,0037803
Std Err Mean	0,0004149
Upper 95% Mean	2,0077772
Lower 95% Mean	2,0061264
N	83

Evacuation 2



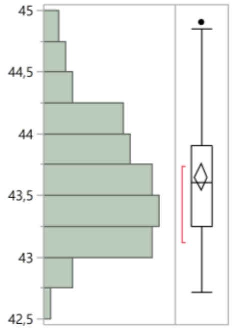
Quantiles

100.0%	maximum	2,433
99.5%		2,433
97.5%		2,4172
90.0%		2,2906
75.0%	quartile	2,27
50.0%	median	2,247
25.0%	quartile	2,209
10.0%		2,1984
2.5%		2,1881
0.5%		2,185
0.0%	minimum	2,185

Summary Statistics

Mean	2,2470602
Std Dev	0,046815
Std Err Mean	0,0051386
Upper 95% Mean	2,2572826
Lower 95% Mean	2,2368379
N	83

Filling



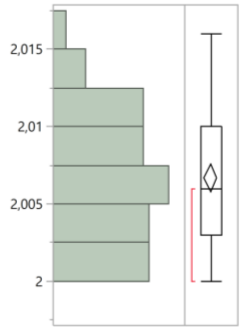
Quantiles

100.0%	maximum	44,9
99.5%		44,9
97.5%		44,8386
90.0%		44,3466
75.0%	quartile	43,906
50.0%	median	43,603
25.0%	quartile	43,25
10.0%		43,1234
2.5%		42,7544
0.5%		42,719
0.0%	minimum	42,719

Summary Statistics

Mean	43,64594
Std Dev	0,486921
Std Err Mean	0,0534465
Upper 95% Mean	43,752262
Lower 95% Mean	43,539618
N	83

Pressure test



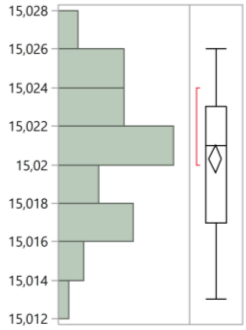
Quantiles

100.0%	maximum	2,016
99.5%		2,016
97.5%		2,0149
90.0%		2,012
75.0%	quartile	2,01
50.0%	median	2,006
25.0%	quartile	2,003
10.0%		2,001
2.5%		2,0001
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0066627
Std Dev	0,0040733
Std Err Mean	0,0004471
Upper 95% Mean	2,0075521
Lower 95% Mean	2,0057732
N	83

Leveling



Quantiles

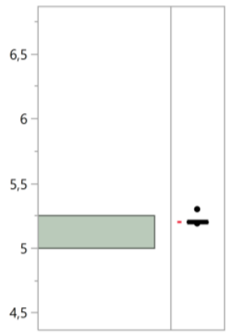
100.0%	maximum	15,026
99.5%		15,026
97.5%		15,026
90.0%		15,025
75.0%	quartile	15,023
50.0%	median	15,021
25.0%	quartile	15,017
10.0%		15,016
2.5%		15,0131
0.5%		15,013
0.0%	minimum	15,013

Summary Statistics

Mean	15,020265
Std Dev	0,0033353
Std Err Mean	0,0003661
Upper 95% Mean	15,020993
Lower 95% Mean	15,019537
N	83

C2 – Small system

Initiating



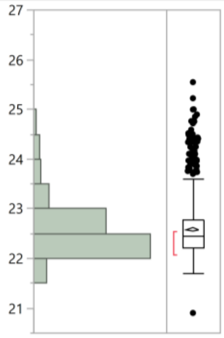
Quantiles

100.0%	maximum	5,298
99.5%		5,213765
97.5%		5,21
90.0%		5,208
75.0%	quartile	5,206
50.0%	median	5,202
25.0%	quartile	5,199
10.0%		5,197
2.5%		5,195
0.5%		5,19047
0.0%	minimum	5,188

Summary Statistics

Mean	5,2024917
Std Dev	0,0053389
Std Err Mean	0,0001836
Upper 95% Mean	5,202852
Lower 95% Mean	5,2021315
N	846

Evacuation 1



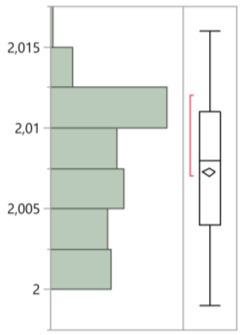
Quantiles

100.0%	maximum	25,537
99.5%		24,9625
97.5%		24,3416
90.0%		23,1421
75.0%	quartile	22,769
50.0%	median	22,438
25.0%	quartile	22,214
10.0%		22,0724
2.5%		21,92135
0.5%		21,79464
0.0%	minimum	20,894

Summary Statistics

Mean	22,573344
Std Dev	0,5596569
Std Err Mean	0,0192414
Upper 95% Mean	22,611111
Lower 95% Mean	22,535577
N	846

Vacuum test



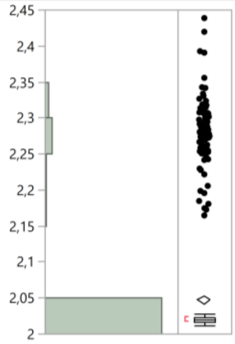
Quantiles

100.0%	maximum	2,016
99.5%		2,015
97.5%		2,014
90.0%		2,012
75.0%	quartile	2,011
50.0%	median	2,008
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	1,999

Summary Statistics

Mean	2,00724
Std Dev	0,0038391
Std Err Mean	0,000132
Upper 95% Mean	2,007499
Lower 95% Mean	2,0069809
N	846

Evacuation 2



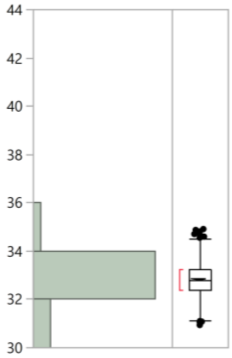
Quantiles

100.0%	maximum	2,438
99.5%		2,381775
97.5%		2,306825
90.0%		2,1873
75.0%	quartile	2,023
50.0%	median	2,02
25.0%	quartile	2,016
10.0%		2,014
2.5%		2,013
0.5%		2,012
0.0%	minimum	2,011

Summary Statistics

Mean	2,0466099
Std Dev	0,0818166
Std Err Mean	0,0028129
Upper 95% Mean	2,052131
Lower 95% Mean	2,0410888
N	846

Filling



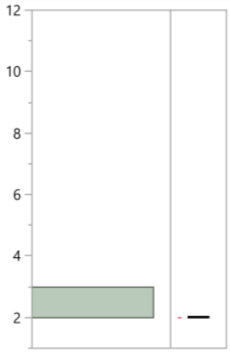
Quantiles

100.0%	maximum	34,889
99.5%		34,68071
97.5%		34,280825
90.0%		33,6341
75.0%	quartile	33,2235
50.0%	median	32,792
25.0%	quartile	32,37775
10.0%		31,9586
2.5%		31,50315
0.5%		31,089985
0.0%	minimum	30,915

Summary Statistics

Mean	32,809492
Std Dev	0,6671662
Std Err Mean	0,0229376
Upper 95% Mean	32,854513
Lower 95% Mean	32,76447
N	846

Pressure test



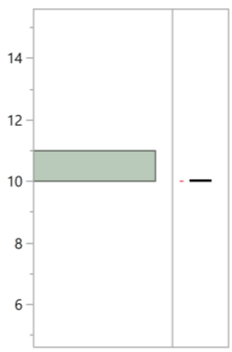
Quantiles

100.0%	maximum	2,017
99.5%		2,016
97.5%		2,015
90.0%		2,013
75.0%	quartile	2,011
50.0%	median	2,007
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0073298
Std Dev	0,0042428
Std Err Mean	0,0001459
Upper 95% Mean	2,0076161
Lower 95% Mean	2,0070435
N	846

Leveling



Quantiles

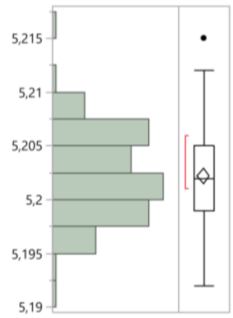
100.0%	maximum	10,028
99.5%		10,027
97.5%		10,026
90.0%		10,025
75.0%	quartile	10,023
50.0%	median	10,02
25.0%	quartile	10,017
10.0%		10,016
2.5%		10,013
0.5%		10,012235
0.0%	minimum	10,012

Summary Statistics

Mean	10,020255
Std Dev	0,0036284
Std Err Mean	0,0001247
Upper 95% Mean	10,0205
Lower 95% Mean	10,02001
N	846

C3 – Large system

Initiating



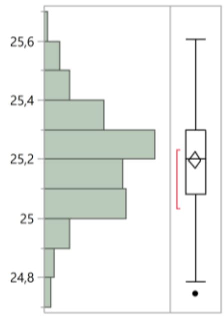
Quantiles

100.0%	maximum	5,215
99.5%		5,215
97.5%		5,209
90.0%		5,207
75.0%	quartile	5,205
50.0%	median	5,202
25.0%	quartile	5,199
10.0%		5,197
2.5%		5,195325
0.5%		5,192
0.0%	minimum	5,192

Summary Statistics

Mean	5,2021591
Std Dev	0,0039786
Std Err Mean	0,0003463
Upper 95% Mean	5,2028441
Lower 95% Mean	5,201474
N	132

Evacuation 1



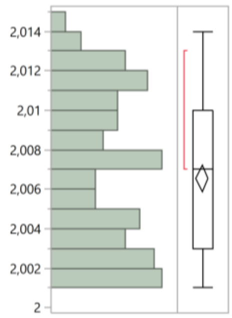
Quantiles

100.0%	maximum	25,606
99.5%		25,606
97.5%		25,536075
90.0%		25,4157
75.0%	quartile	25,30075
50.0%	median	25,201
25.0%	quartile	25,0805
10.0%		24,9993
2.5%		24,837375
0.5%		24,745
0.0%	minimum	24,745

Summary Statistics

Mean	25,195811
Std Dev	0,1636194
Std Err Mean	0,0142412
Upper 95% Mean	25,223983
Lower 95% Mean	25,167638
N	132

Vacuum test



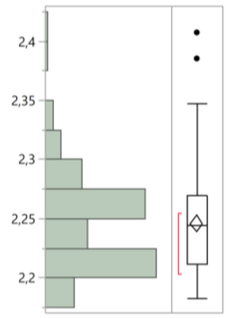
Quantiles

100.0%	maximum	2,014
99.5%		2,014
97.5%		2,013
90.0%		2,012
75.0%	quartile	2,01
50.0%	median	2,007
25.0%	quartile	2,003
10.0%		2,001
2.5%		2,001
0.5%		2,001
0.0%	minimum	2,001

Summary Statistics

Mean	2,0065303
Std Dev	0,0038906
Std Err Mean	0,0003386
Upper 95% Mean	2,0072002
Lower 95% Mean	2,0058604
N	132

Evacuation 2



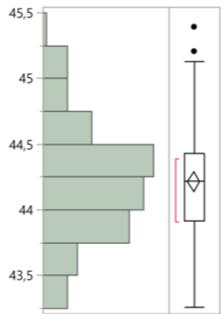
Quantiles

100.0%	maximum	2,407
99.5%		2,407
97.5%		2,34505
90.0%		2,2927
75.0%	quartile	2,27
50.0%	median	2,244
25.0%	quartile	2,21125
10.0%		2,2033
2.5%		2,18965
0.5%		2,183
0.0%	minimum	2,183

Summary Statistics

Mean	2,2456742
Std Dev	0,040484
Std Err Mean	0,0035237
Upper 95% Mean	2,2526449
Lower 95% Mean	2,2387036
N	132

Filling



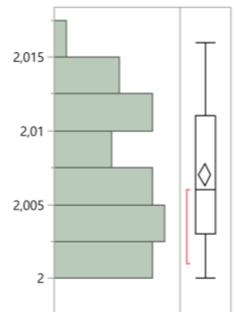
Quantiles

100.0%	maximum	45,389
99.5%		45,389
97.5%		45,1267
90.0%		44,8376
75.0%	quartile	44,4325
50.0%	median	44,2195
25.0%	quartile	43,9205
10.0%		43,6033
2.5%		43,372975
0.5%		43,262
0.0%	minimum	43,262

Summary Statistics

Mean	44,211364
Std Dev	0,4384262
Std Err Mean	0,0381601
Upper 95% Mean	44,286853
Lower 95% Mean	44,135874
N	132

Pressure test



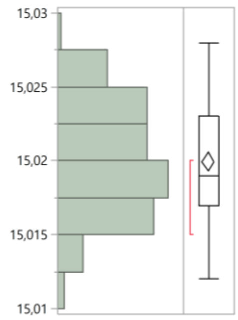
Quantiles

100.0%	maximum	2,016
99.5%		2,016
97.5%		2,014675
90.0%		2,013
75.0%	quartile	2,011
50.0%	median	2,006
25.0%	quartile	2,003
10.0%		2,002
2.5%		2,000325
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0069621
Std Dev	0,0043587
Std Err Mean	0,0003794
Upper 95% Mean	2,0077126
Lower 95% Mean	2,0062116
N	132

Leveling



Quantiles

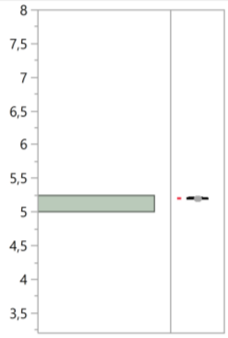
100.0%	maximum	15,028
99.5%		15,028
97.5%		15,026
90.0%		15,025
75.0%	quartile	15,023
50.0%	median	15,019
25.0%	quartile	15,017
10.0%		15,015
2.5%		15,013
0.5%		15,012
0.0%	minimum	15,012

Summary Statistics

Mean	15,019917
Std Dev	0,0037131
Std Err Mean	0,0003232
Upper 95% Mean	15,020556
Lower 95% Mean	15,019277
N	132

C3 – Small system

Initiating



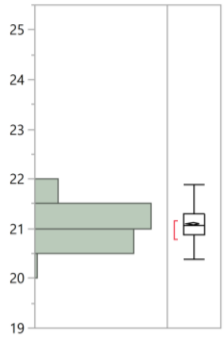
Quantiles

100.0%	maximum	5,213
99.5%		5,21226
97.5%		5,21
90.0%		5,208
75.0%	quartile	5,206
50.0%	median	5,203
25.0%	quartile	5,199
10.0%		5,197
2.5%		5,195
0.5%		5,19174
0.0%	minimum	5,188

Summary Statistics

Mean	5,2027454
Std Dev	0,0042
Std Err Mean	0,000124
Upper 95% Mean	5,2029887
Lower 95% Mean	5,2025021
N	1147

Evacuation 1



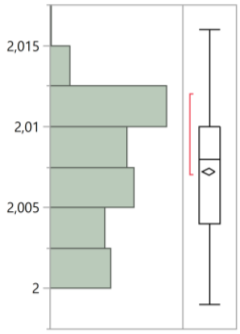
Quantiles

100.0%	maximum	21,889
99.5%		21,65704
97.5%		21,596
90.0%		21,496
75.0%	quartile	21,307
50.0%	median	21,056
25.0%	quartile	20,876
10.0%		20,7476
2.5%		20,579
0.5%		20,44876
0.0%	minimum	20,387

Summary Statistics

Mean	21,086902
Std Dev	0,2818265
Std Err Mean	0,0083215
Upper 95% Mean	21,103229
Lower 95% Mean	21,070575
N	1147

Vacuum test



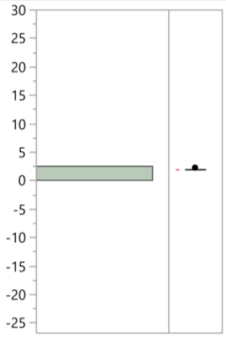
Quantiles

100.0%	maximum	2,016
99.5%		2,014
97.5%		2,013
90.0%		2,012
75.0%	quartile	2,01
50.0%	median	2,008
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	1,999

Summary Statistics

Mean	2,0072014
Std Dev	0,003707
Std Err Mean	0,0001095
Upper 95% Mean	2,0074162
Lower 95% Mean	2,0069866
N	1147

Evacuation 2



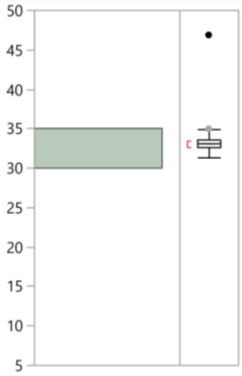
Quantiles

100.0%	maximum	2,216
99.5%		2,028
97.5%		2,026
90.0%		2,024
75.0%	quartile	2,023
50.0%	median	2,02
25.0%	quartile	2,016
10.0%		2,014
2.5%		2,012
0.5%		2,012
0.0%	minimum	2,012

Summary Statistics

Mean	2,0195632
Std Dev	0,0070317
Std Err Mean	0,0002076
Upper 95% Mean	2,0199706
Lower 95% Mean	2,0191558
N	1147

Filling



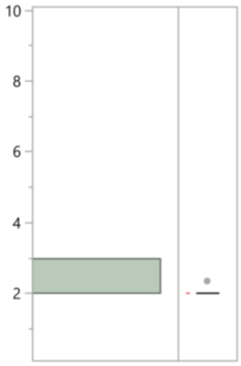
Quantiles

100.0%	maximum	46,818
99.5%		34,67406
97.5%		34,3492
90.0%		33,9784
75.0%	quartile	33,551
50.0%	median	33,09
25.0%	quartile	32,657
10.0%		32,2446
2.5%		31,8445
0.5%		31,48816
0.0%	minimum	31,368

Summary Statistics

Mean	33,107544
Std Dev	0,7665283
Std Err Mean	0,0226332
Upper 95% Mean	33,151951
Lower 95% Mean	33,063137
N	1147

Pressure test



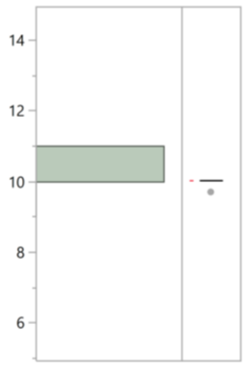
Quantiles

100.0%	maximum	2,337
99.5%		2,016
97.5%		2,015
90.0%		2,013
75.0%	quartile	2,011
50.0%	median	2,007
25.0%	quartile	2,003
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	1,999

Summary Statistics

Mean	2,0075981
Std Dev	0,0106368
Std Err Mean	0,0003141
Upper 95% Mean	2,0082143
Lower 95% Mean	2,0069819
N	1147

Leveling



Quantiles

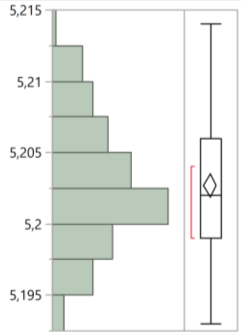
100.0%	maximum	10,028
99.5%		10,027
97.5%		10,027
90.0%		10,025
75.0%	quartile	10,023
50.0%	median	10,02
25.0%	quartile	10,017
10.0%		10,015
2.5%		10,013
0.5%		10,012
0.0%	minimum	9,691

Summary Statistics

Mean	10,02002
Std Dev	0,0104246
Std Err Mean	0,0003078
Upper 95% Mean	10,020624
Lower 95% Mean	10,019416
N	1147

C4 – Large system

Initiating



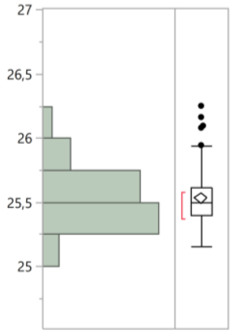
Quantiles

100.0%	maximum	5,214
99.5%		5,214
97.5%		5,211
90.0%		5,209
75.0%	quartile	5,206
50.0%	median	5,202
25.0%	quartile	5,199
10.0%		5,197
2.5%		5,194
0.5%		5,193
0.0%	minimum	5,193

Summary Statistics

Mean	5,2026325
Std Dev	0,0043462
Std Err Mean	0,0004018
Upper 95% Mean	5,2034283
Lower 95% Mean	5,2018366
N	117

Evacuation 1



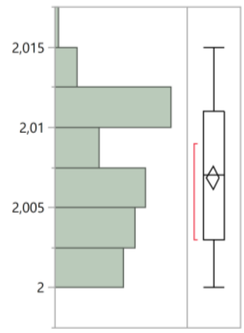
Quantiles

100.0%	maximum	26,249
99.5%		26,249
97.5%		26,09735
90.0%		25,8354
75.0%	quartile	25,614
50.0%	median	25,5
25.0%	quartile	25,396
10.0%		25,2956
2.5%		25,1599
0.5%		25,152
0.0%	minimum	25,152

Summary Statistics

Mean	25,529111
Std Dev	0,2125196
Std Err Mean	0,0196474
Upper 95% Mean	25,568025
Lower 95% Mean	25,490197
N	117

Vacuum test



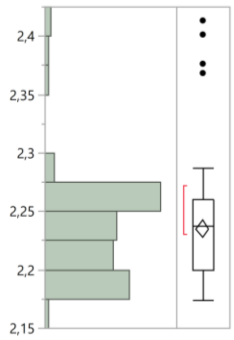
Quantiles

100.0%	maximum	2,015
99.5%		2,015
97.5%		2,01305
90.0%		2,012
75.0%	quartile	2,011
50.0%	median	2,007
25.0%	quartile	2,003
10.0%		2,0018
2.5%		2,00095
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0068034
Std Dev	0,0039419
Std Err Mean	0,0003644
Upper 95% Mean	2,0075252
Lower 95% Mean	2,0060816
N	117

Evacuation 2



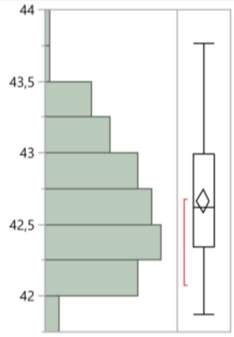
Quantiles

100.0%	maximum	2,413
99.5%		2,413
97.5%		2,37725
90.0%		2,2702
75.0%	quartile	2,2605
50.0%	median	2,237
25.0%	quartile	2,2
10.0%		2,189
2.5%		2,1798
0.5%		2,174
0.0%	minimum	2,174

Summary Statistics

Mean	2,2347949
Std Dev	0,0424925
Std Err Mean	0,0039284
Upper 95% Mean	2,2425756
Lower 95% Mean	2,2270141
N	117

Filling



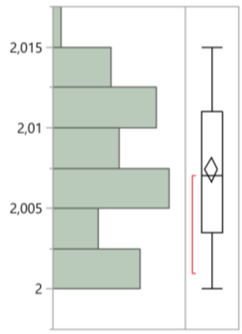
Quantiles

100.0%	maximum	43,766
99.5%		43,766
97.5%		43,4949
90.0%		43,2614
75.0%	quartile	42,9935
50.0%	median	42,622
25.0%	quartile	42,341
10.0%		42,0994
2.5%		41,96155
0.5%		41,871
0.0%	minimum	41,871

Summary Statistics

Mean	42,660325
Std Dev	0,425843
Std Err Mean	0,0393692
Upper 95% Mean	42,7383
Lower 95% Mean	42,582349
N	117

Pressure test



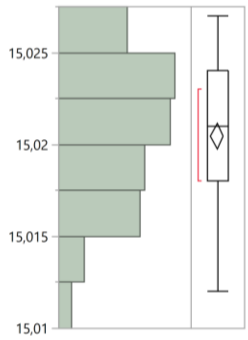
Quantiles

100.0%	maximum	2,015
99.5%		2,015
97.5%		2,01405
90.0%		2,013
75.0%	quartile	2,011
50.0%	median	2,007
25.0%	quartile	2,0035
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0073761
Std Dev	0,0041559
Std Err Mean	0,0003842
Upper 95% Mean	2,008137
Lower 95% Mean	2,0066151
N	117

Leveling



Quantiles

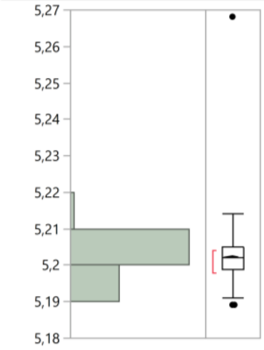
100.0%	maximum	15,027
99.5%		15,027
97.5%		15,02605
90.0%		15,025
75.0%	quartile	15,024
50.0%	median	15,021
25.0%	quartile	15,018
10.0%		15,015
2.5%		15,012
0.5%		15,012
0.0%	minimum	15,012

Summary Statistics

Mean	15,02041
Std Dev	0,0037946
Std Err Mean	0,0003508
Upper 95% Mean	15,021105
Lower 95% Mean	15,019715
N	117

C4 – Small system

Initiating



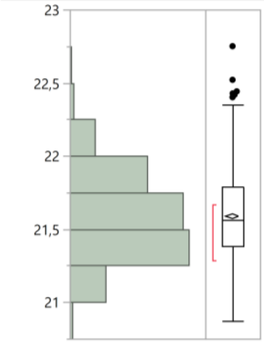
Quantiles

100.0%	maximum	5,268
99.5%		5,212
97.5%		5,20905
90.0%		5,208
75.0%	quartile	5,205
50.0%	median	5,202
25.0%	quartile	5,199
10.0%		5,197
2.5%		5,195
0.5%		5,191
0.0%	minimum	5,189

Summary Statistics

Mean	5,2022481
Std Dev	0,0045528
Std Err Mean	0,0001338
Upper 95% Mean	5,2025107
Lower 95% Mean	5,2019854
N	1157

Evacuation 1



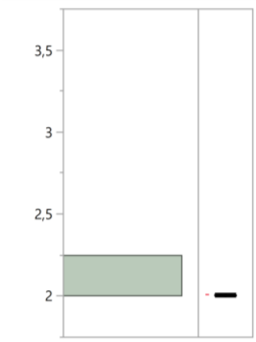
Quantiles

100.0%	maximum	22,749
99.5%		22,40357
97.5%		22,13305
90.0%		21,9584
75.0%	quartile	21,7915
50.0%	median	21,563
25.0%	quartile	21,387
10.0%		21,242
2.5%		21,0798
0.5%		20,98416
0.0%	minimum	20,873

Summary Statistics

Mean	21,58704
Std Dev	0,2800598
Std Err Mean	0,0082335
Upper 95% Mean	21,603194
Lower 95% Mean	21,570885
N	1157

Vacuum test



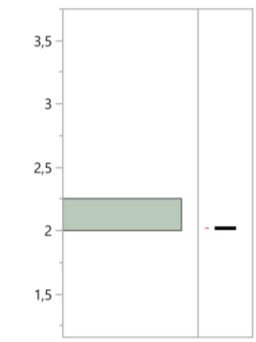
Quantiles

100.0%	maximum	2,015
99.5%		2,015
97.5%		2,014
90.0%		2,012
75.0%	quartile	2,01
50.0%	median	2,007
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	1,999

Summary Statistics

Mean	2,0071115
Std Dev	0,0038086
Std Err Mean	0,000112
Upper 95% Mean	2,0073312
Lower 95% Mean	2,0068918
N	1157

Evacuation 2



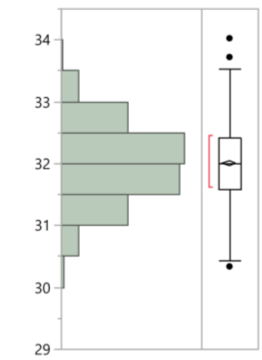
Quantiles

100.0%	maximum	2,028
99.5%		2,027
97.5%		2,026
90.0%		2,024
75.0%	quartile	2,023
50.0%	median	2,02
25.0%	quartile	2,016
10.0%		2,014
2.5%		2,012
0.5%		2,012
0.0%	minimum	2,011

Summary Statistics

Mean	2,0193656
Std Dev	0,00395
Std Err Mean	0,0001161
Upper 95% Mean	2,0195934
Lower 95% Mean	2,0191378
N	1157

Filling



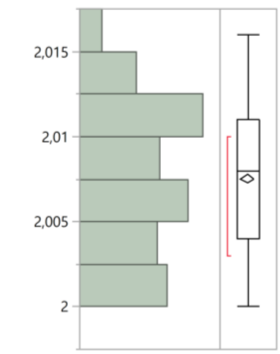
Quantiles

100.0%	maximum	34,017
99.5%		33,44567
97.5%		33,1103
90.0%		32,7744
75.0%	quartile	32,415
50.0%	median	32,003
25.0%	quartile	31,582
10.0%		31,232
2.5%		30,75995
0.5%		30,46685
0.0%	minimum	30,33

Summary Statistics

Mean	31,996628
Std Dev	0,5992532
Std Err Mean	0,0176175
Upper 95% Mean	32,031194
Lower 95% Mean	31,962063
N	1157

Pressure test



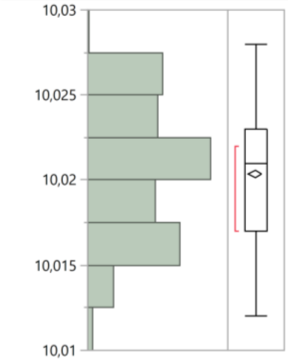
Quantiles

100.0%	maximum	2,016
99.5%		2,01521
97.5%		2,015
90.0%		2,013
75.0%	quartile	2,011
50.0%	median	2,008
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0074866
Std Dev	0,0042383
Std Err Mean	0,0001246
Upper 95% Mean	2,0077311
Lower 95% Mean	2,0072421
N	1157

Leveling



Quantiles

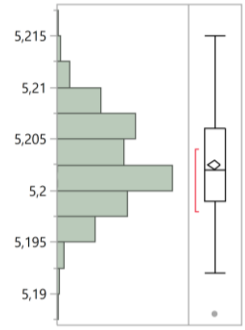
100.0%	maximum	10,028
99.5%		10,027
97.5%		10,026
90.0%		10,025
75.0%	quartile	10,023
50.0%	median	10,021
25.0%	quartile	10,017
10.0%		10,015
2.5%		10,013
0.5%		10,012
0.0%	minimum	10,012

Summary Statistics

Mean	10,020341
Std Dev	0,0037713
Std Err Mean	0,0001109
Upper 95% Mean	10,020558
Lower 95% Mean	10,020123
N	1157

Total (C1-C4) – Large system

Initiating



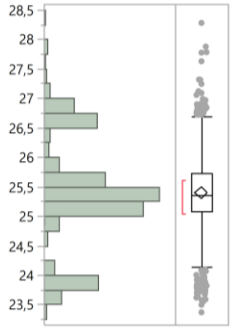
Quantiles

100.0%	maximum	5,215
99.5%		5,21399
97.5%		5,21
90.0%		5,208
75.0%	quartile	5,206
50.0%	median	5,202
25.0%	quartile	5,199
10.0%		5,197
2.5%		5,195
0.5%		5,192
0.0%	minimum	5,188

Summary Statistics

Mean	5,2024589
Std Dev	0,0042555
Std Err Mean	0,0002125
Upper 95% Mean	5,2028766
Lower 95% Mean	5,2020411
N	401

Evacuation 1



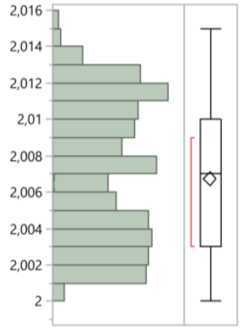
Quantiles

100.0%	maximum	28,273
99.5%		27,87006
97.5%		27,1002
90.0%		26,7328
75.0%	quartile	25,731
50.0%	median	25,355
25.0%	quartile	25,078
10.0%		23,8376
2.5%		23,6942
0.5%		23,4916
0.0%	minimum	23,364

Summary Statistics

Mean	25,393895
Std Dev	0,946479
Std Err Mean	0,0472649
Upper 95% Mean	25,486814
Lower 95% Mean	25,300977
N	401

Vacuum test



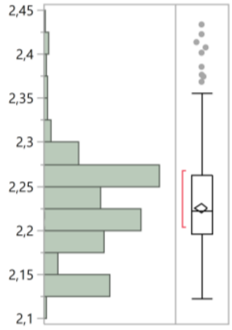
Quantiles

100.0%	maximum	2,015
99.5%		2,01499
97.5%		2,013
90.0%		2,012
75.0%	quartile	2,01
50.0%	median	2,007
25.0%	quartile	2,003
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0067182
Std Dev	0,0038188
Std Err Mean	0,0001907
Upper 95% Mean	2,0070931
Lower 95% Mean	2,0063433
N	401

Evacuation 2



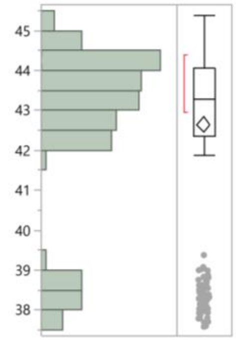
Quantiles

100.0%	maximum	2,433
99.5%		2,42191
97.5%		2,35555
90.0%		2,279
75.0%	quartile	2,2625
50.0%	median	2,222
25.0%	quartile	2,1955
10.0%		2,144
2.5%		2,13305
0.5%		2,12402
0.0%	minimum	2,123

Summary Statistics

Mean	2,2249227
Std Dev	0,0546283
Std Err Mean	0,002728
Upper 95% Mean	2,2302857
Lower 95% Mean	2,2195597
N	401

Filling



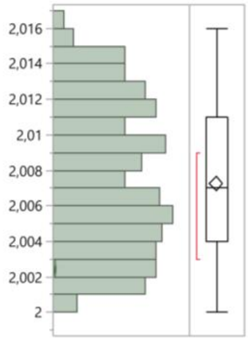
Quantiles

100.0%	maximum	45,389
99.5%		45,20225
97.5%		44,97125
90.0%		44,4328
75.0%	quartile	44,054
50.0%	median	43,294
25.0%	quartile	42,3435
10.0%		38,499
2.5%		37,9223
0.5%		37,58995
0.0%	minimum	37,572

Summary Statistics

Mean	42,634783
Std Dev	2,0919891
Std Err Mean	0,104469
Upper 95% Mean	42,84016
Lower 95% Mean	42,429406
N	401

Pressure test



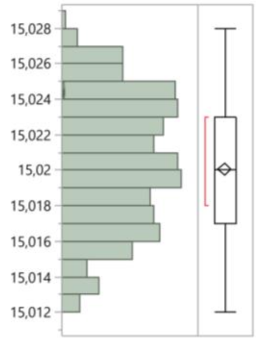
Quantiles

100.0%	maximum	2,016
99.5%		2,016
97.5%		2,014
90.0%		2,013
75.0%	quartile	2,011
50.0%	median	2,007
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	2

Summary Statistics

Mean	2,0071995
Std Dev	0,0041539
Std Err Mean	0,0002074
Upper 95% Mean	2,0076073
Lower 95% Mean	2,0067917
N	401

Leveling



Quantiles

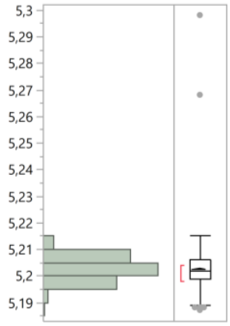
100.0%	maximum	15,028
99.5%		15,027
97.5%		15,026
90.0%		15,025
75.0%	quartile	15,023
50.0%	median	15,02
25.0%	quartile	15,017
10.0%		15,015
2.5%		15,013
0.5%		15,012
0.0%	minimum	15,012

Summary Statistics

Mean	15,020027
Std Dev	0,0036731
Std Err Mean	0,0001834
Upper 95% Mean	15,020388
Lower 95% Mean	15,019667
N	401

Total (C1-C4) – Small system

Initiating



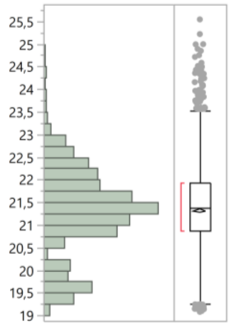
Quantiles

100.0%	maximum	5,298
99.5%		5,212
97.5%		5,21
90.0%		5,208
75.0%	quartile	5,206
50.0%	median	5,202
25.0%	quartile	5,199
10.0%		5,197
2.5%		5,195
0.5%		5,191
0.0%	minimum	5,187

Summary Statistics

Mean	5,2024849
Std Dev	0,0045847
Std Err Mean	7,3928e-5
Upper 95% Mean	5,2026299
Lower 95% Mean	5,20234
N	3846

Evacuation 1



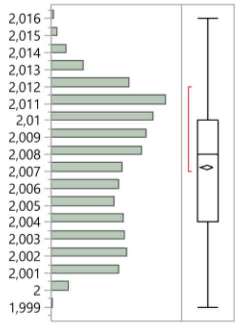
Quantiles

100.0%	maximum	25,537
99.5%		24,374715
97.5%		23,0915
90.0%		22,4856
75.0%	quartile	21,93625
50.0%	median	21,389
25.0%	quartile	20,864
10.0%		19,685
2.5%		19,405
0.5%		19,21888
0.0%	minimum	19,077

Summary Statistics

Mean	21,311344
Std Dev	0,9970923
Std Err Mean	0,016078
Upper 95% Mean	21,342866
Lower 95% Mean	21,279822
N	3846

Vacuum test



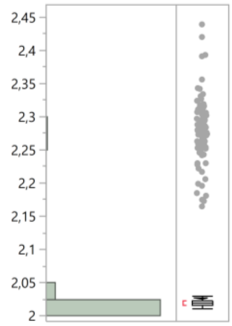
Quantiles

100.0%	maximum	2,016
99.5%		2,015
97.5%		2,013
90.0%		2,012
75.0%	quartile	2,01
50.0%	median	2,008
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	1,999

Summary Statistics

Mean	2,007181
Std Dev	0,00378
Std Err Mean	6,0953e-5
Upper 95% Mean	2,0073005
Lower 95% Mean	2,0070615
N	3846

Evacuation 2



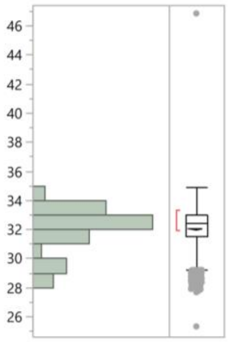
Quantiles

100.0%	maximum	2,438
99.5%		2,308765
97.5%		2,028
90.0%		2,024
75.0%	quartile	2,023
50.0%	median	2,02
25.0%	quartile	2,016
10.0%		2,014
2.5%		2,012175
0.5%		2,012
0.0%	minimum	2,011

Summary Statistics

Mean	2,0254199
Std Dev	0,0402486
Std Err Mean	0,000649
Upper 95% Mean	2,0266923
Lower 95% Mean	2,0241475
N	3846

Filling



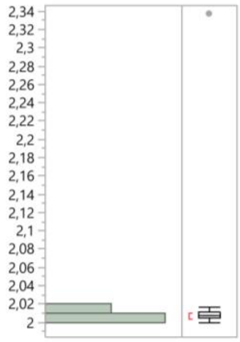
Quantiles

100.0%	maximum	46,818
99.5%		34,50271
97.5%		34,1343
90.0%		33,5643
75.0%	quartile	33,03225
50.0%	median	32,389
25.0%	quartile	31,49475
10.0%		29,2776
2.5%		28,605875
0.5%		28,18047
0.0%	minimum	25,299

Summary Statistics

Mean	31,998306
Std Dev	1,5412944
Std Err Mean	0,0248531
Upper 95% Mean	32,047033
Lower 95% Mean	31,94958
N	3846

Pressure test



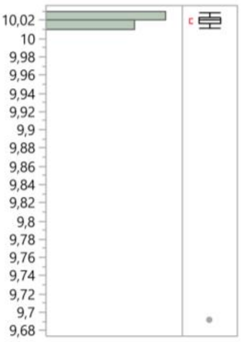
Quantiles

100.0%	maximum	2,337
99.5%		2,016
97.5%		2,015
90.0%		2,013
75.0%	quartile	2,011
50.0%	median	2,007
25.0%	quartile	2,004
10.0%		2,002
2.5%		2,001
0.5%		2
0.0%	minimum	1,999

Summary Statistics

Mean	2,0074548
Std Dev	0,006796
Std Err Mean	0,0001096
Upper 95% Mean	2,0076696
Lower 95% Mean	2,0072399
N	3846

Leveling



Quantiles

100.0%	maximum	10,028
99.5%		10,027
97.5%		10,027
90.0%		10,025
75.0%	quartile	10,023
50.0%	median	10,02
25.0%	quartile	10,017
10.0%		10,015
2.5%		10,013
0.5%		10,012
0.0%	minimum	9,691

Summary Statistics

Mean	10,020226
Std Dev	0,0064811
Std Err Mean	0,0001045
Upper 95% Mean	10,020431
Lower 95% Mean	10,020021
N	3846

Appendix V – Prediction modelling, linear regression

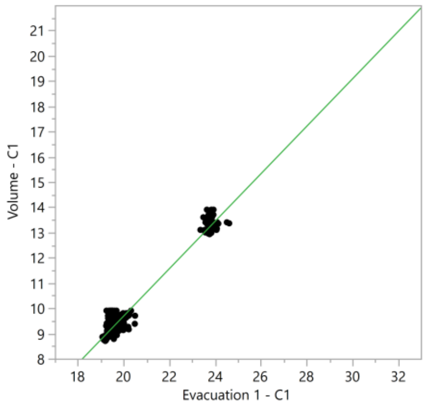
C1 Evacuation 1

Fit Curve

Model Comparison

Model		AICc	BIC	SSE	MSE	RMSE	R-Square
Linear	—	-197,1481	-183,1244	36,334287	0,0455317	0,2133816	0,9704864

Plot



Linear

Parameter Estimates

Parameter	Estimate	Std Error	Lower 95%	Upper 95%
Intercept	-9,098822	0,1168863	-9,327915	-8,869729
Slope	0,9389435	0,0057964	0,9275828	0,9503041

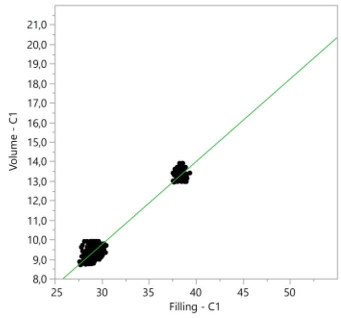
C1 Filling

Fit Curve

Model Comparison

Model		AICc	BIC	SSE	MSE	RMSE	R-Square
Linear	—	145,43788	159,46156	55,756518	0,0698703	0,26433	0,95471

Plot



Linear

Prediction Model

a + b • Filling - C1

a = Intercept

b = Slope

Parameter Estimates

Parameter	Estimate	Std Error	Lower 95%	Upper 95%
Intercept	-2,98501	0,0989856	-3,179018	-2,791002
Slope	0,4238513	0,003268	0,4174462	0,4302564

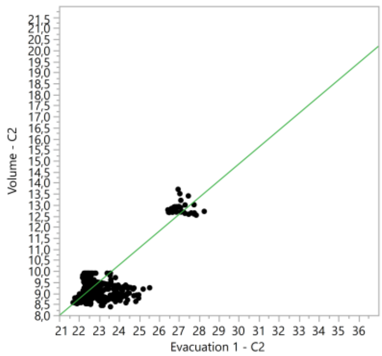
C2 Evacuation 1

Fit Curve

Model Comparison

Model		AICc	BIC	SSE	MSE	RMSE	R-Square
Linear	—	1350,3382	1364,9359	227,35461	0,2356006	0,4853871	0,8361893

Plot



Linear

Parameter Estimates

Parameter	Estimate	Std Error	Lower 95%	Upper 95%
Intercept	-8,035086	0,2508851	-8,526812	-7,543361
Slope	0,7625298	0,0108646	0,7412357	0,783824

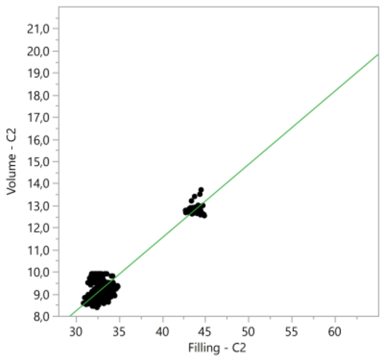
C2 Filling

Fit Curve

Model Comparison

Model		AICc	BIC	SSE	MSE	RMSE	R-Square
Linear	—	614,11002	628,70769	106,18238	0,1100335	0,3317131	0,9234948

Plot



Linear

Parameter Estimates

Parameter	Estimate	Std Error	Lower 95%	Upper 95%
Intercept	-1,753076	0,1051699	-1,959205	-1,546947
Slope	0,3319402	0,0030756	0,3259123	0,3379682

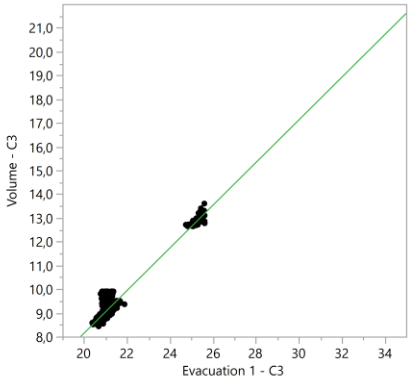
C3 Evacuation 1

Fit Curve

Model Comparison

Model	AICc	BIC	SSE	MSE	RMSE	R-Square
Linear	-237,6249	-222,0688	64,721025	0,0488092	0,2209281	0,9685198

Plot



Linear

Parameter Estimates

Parameter	Estimate	Std Error	Lower 95%	Upper 95%
Intercept	-9,828026	0,0961618	-10,0165	-9,639552
Slope	0,8981641	0,0044468	0,8894486	0,9068797

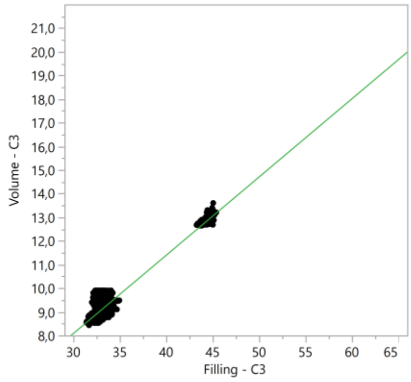
C3 Filling

Fit Curve

Model Comparison

Model	AICc	BIC	SSE	MSE	RMSE	R-Square
Linear	467,45539	483,01155	110,05938	0,083001	0,288099	0,9464672

Plot



Linear

Parameter Estimates

Parameter	Estimate	Std Error	Lower 95%	Upper 95%
Intercept	-1,812585	0,074669	-1,958933	-1,666236
Slope	0,3301549	0,0021563	0,3259287	0,3343811

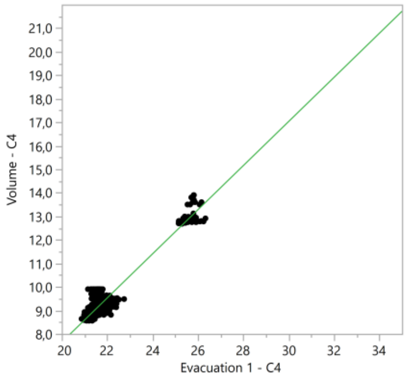
C4 Evacuation 1

Fit Curve

Model Comparison

Model	AICc	BIC	SSE	MSE	RMSE	R-Square
Linear	-103,2403	-87,69778	71,263024	0,0539871	0,2323513	0,9607027

Plot



Linear

Parameter Estimates

Parameter	Estimate	Std Error	Lower 95%	Upper 95%
Intercept	-11,11196	0,1149953	-11,33735	-10,88658
Slope	0,9379955	0,0052216	0,9277614	0,9482296

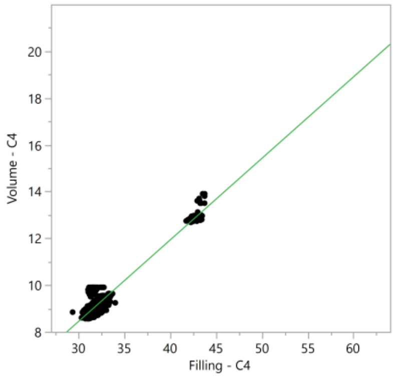
C4 Filling

Fit Curve

Model Comparison

Model	AICc	BIC	SSE	MSE	RMSE	R-Square
Linear	180,89764	196,43785	88,292164	0,0669387	0,2587252	0,9513026

Plot



Linear

Parameter Estimates

Parameter	Estimate	Std Error	Lower 95%	Upper 95%
Intercept	-2,018426	0,0721971	-2,159929	-1,876922
Slope	0,3486121	0,0021718	0,3443555	0,3528687