EXAMENSARBETE - MASKINTEKNIK

Time optimization of volume conversion on TPR1 machine

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Preface

This thesis is a result from an examination project, on bachelor level, for Mechanical engineer program on Halmstad University. This project is issued in collaboration with Tetra Recart that is a company within Tetra Pak, Lund. The duration of the project stretched over 5 months, from January 2012 to May 2012, - and comprises 15 hp.

I would like to thank Tetra Pak and Tetra Recart especially Tomas Nilén and Dan Haldeborg for all of their support in terms of time and resources as well as a priceless commitment. I would also like to thank my adviser at Halmstad University, Pär-Johan Lööf for his advice and excellent feedback.

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Abstract

This thesis has been issued in collaboration with Tetra Recart that is a company within Tetra Pak, Lund. Tetra Recart is a cardboard-based processing and packaging system for food such as tomatoes, beans, soups and sauces, that are traditionally packed in glass jars, cans or pouches.

Tetra Recart's machine *TPR1* form and seals packages in three different sizes; 340 ml, 390 ml and 500 ml. Inorder to produce these different volumes, there needs to be a conversion of the machine. This is time consuming because it comprises both adjustments as well as exchanging of whole units.

The purpose of this project is to find problem areas in the volume conversion and see how to optimize the rebuilding time with 1, 2, 3 or 4 operators.

This thesis includes mapping of rebuilding steps and identification of which steps that is the most time consuming. A working method has been developed with help from tools in Lean production and other literature that is found suitable. This working method is in this project tested on the TPR1 machine.

The findings were that the aggregate work time for one versus four operators is that it differs with 103 minutes on total work time when rebuilding from 390 ml to 500 ml. In this rebuilding there is a machine stop on 6 hours and 41 minutes with one operator and 2 hours and 6 minutes with four operators.

Volume conversion from 340 ml to 390 ml or 500 ml by one operator is not recommended because of the heavy lifting.

The report also includes an investigation of the most critical aspects of the conversion process, and suggestions for further study.

Sammanfattning

Detta examensarbete har utförts i sammarbete med Tetra Recart som är del av Tetra Pak, Lund. Tetra Recart är ett kartongbaserad process och förpackningssytem avsett för livsmedel som traditionellt sett är förpackade i glasburkar, konservburkar och så kallade pouches. Allt ifrån tomater, bönor, såser till soppor kan förpackas i förpackningen Tetra Recart.

Tetra Recarts maskin TPR1 tillverkar förpackningar i tre olika storlekar; 340 ml, 390 ml och 500 ml. För att det ska vara möjligt att producera olika volymer krävs det att maskinen byggs om vid byte av volym. Det innebär både justeringar och byte av hela enheter vilket idag är tidskrävande.

I projektarbetet ingår det att kartlägga vilka delar som ingår i en volym ombyggnation och identifiera vilka områden som är kritiska ur ett tidsperspektiv. Med hjälp av verktyg inom Lean Produktion och annan lämplig litteratur har en arbetsmetodik skapats för att hitta möjligheter till en kortare omställningstid.

Rapporten klargör arbetsmetodiken och verifierar denna under arbetets gång och ser hur ombyggnadstiden kan optimeras genom att vara 1, 2, 3 eller 4 operatörer.

Skillnaden på total arbetstid mellan en operatör och med fyra operatörer är 103 minuter vid ombyggnad från 390 ml till 500 ml. Maskinen står stilla 6 h och 41 minuter vid den förstnämnda och endast 2 h och 6 minuter med fyra operatörer.

När det gäller ombyggnad från 340 ml till 390 ml eller 500 ml är detta inte att rekommendera med en operatör på grund av tunga enheter.

I rapporten framgår det även vilka områden som är mest kritiska och bör ses över för vidare studier.

Terminology

Conversion – The act or process of changing something into a different form

Volume conversion – In this report meaning changing the machine for producing different volumes.

Changeover – is a change from activity, system or way of working to another one. (Set up)

Retort process – aseptic packages, using a special process, retort process to sterilize the package

Machine platform – Means the whole machine including all parts available such as fillers and retort process.

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1. Project organization

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2. Introduction

Here follows a brief company presentation as well as the background, purpose and goal of this project. It also defines its limitations and problem definition.

2.1 Company presentation

Tetra Recart AB is a company within Tetra Pak, which is a worldwide company within processing, packaging and distribution of food. Tetra Recart is a cardboard-based processing and packaging system for food such as tomatoes, beans, sauces and soups, -food that are traditionally packaged in glass jars and tins. Tetra Recart launched its first packaging system in 2003 for their retorted carton packages. Using a retorting process, the filled product can be sterilized within the package which extends shelf-life of up to two years. Today, Tetra Recart has two packaging platforms: Tetra Pak R1 (TPR1) and Tetra Pak R2 (TPR2). They are machines that produce packages at different speed and different package volumes. TPR1 is a machine designed for high volume capacity and can produce up to 24,000 packages per hour. TPR2 is designed to produce up to 6,000 packages per hour. (Tetra Pak, 2012, Tetra Recart 2012)

2.2 Background

Tetra Recart's TPR1 machine currently has three different package volumes: 340 ml, 390 ml and 500 ml. To make this possible, a volume conversion is needed between the current volume being produced to the new desired volume. The volume conversion combines both adjustments with tools as well as the changing of whole units. Today Tetra Recarts packages can be enjoyed by consumers in about 40 countries around the world, see figure 2.2. (Tetra Recart, 2012)

Figure 2.2 Shows where in the world you can find canned food in Tetra Recart packages. (Tetra Recart, 2012)

2.3 Purpose

The main purpose of this project is to shorten the conversion time between different package volumes on Tetra Recart's machine TPR1.

This implies:

- Finding potential development areas that could reduce conversion time and reduced costs for the customer.
- Examining ways to optimize the conversion by being one, two, three or four operators during the conversion.

2.4 Goal

The goal is to find the problem areas in the volume conversion and identify which is most time consuming and why.

Be able to present documentation for Tetra Recart on which areas that should be improve as well as guidelines for conversion time and machine stops with different number of operators.

2.5 Problem definition

When volume conversion is made on TPR1 machine there are different steps to go through.

Since Tetra Recart and their customers would like to have as high production level as possible, it is essential that it optimize the machine rebuilding time and minimizes machine stop and changeover.

Tetra Recart would like to have guidelines for volume conversions with three and four operators to complement its current guideline for two persons. It would be desirable for Tetra Recart to have a working schedule when several technicians are working during a volume conversion for the most efficient conversion.

To shorten the time on different volume conversions requires that problem areas will be identified. These areas should be further studied after this project.

2.6 Limitations

This project affects those parts in the machine that are adjusted in a volume conversion and only those parts that are the same for all customers.

Thus, the limitations of the project are the following:

- It is only concerned with the conversion in regard to time, not cost.
- It assumes that all people who are working in the conversion have technical background.
- It only looks on the main machine:
    - FFU – Final Folder Unit
    - FSM – Form and Seal Machine
    - ACL – Automatic Carton Loader
- The retort process is not included in the project.
- The project follows the information that is given in the conversion manual; there will not be any subject outside of the manual.
- Filler is not included because they are very different depending on the individual customers.

3. Theoretical framework

This chapter covers different theories that are suitable for this project and theories that have been rejected. An extensive literature search produced the following assessment.

3.1 Lean Production

Lean Production consists of comprehensive approaches and philosophies regarding how a business is operated in a resource efficient and customer oriented approach.

In Lean Production there are different tools available that are helpful when making assumptions on how to analyze flow oriented manufacturing to achieve high efficiency. (L. Sörqvist, 2004)

The tools that are used from Lean Production in this project are: process mapping and the SMED-method. (Quest Worldwide Education Ltd, 1999)

3.1.1 Process mapping

Process mapping provide an overview (see figure 3.1 for example) on different steps and in which order these are done. Different aspects on process mapping gives different results, it is possible to make different process maps

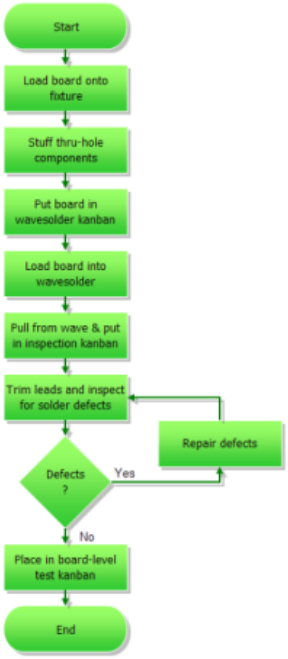


Figure 3.1Example on process map

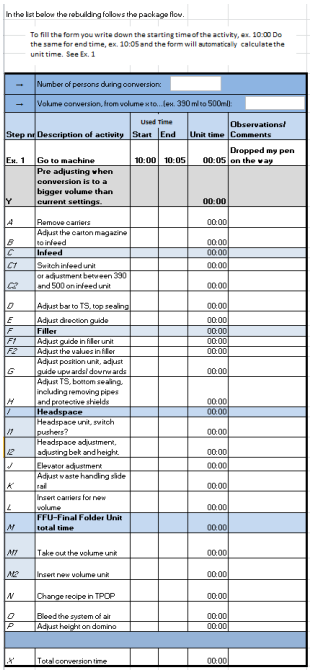
depending on how many people that are making the conversion. It is possible to make a process map with aspects on time and on what kind of information that is needed and there can be decision stops. (Quest Worldwide Education Ltd, 1999)

3.1.2 SMED-method

A systematic method for reducing changeover time is the SMED-method (-Single-digit Minute Exchange of Die) which was, developed within Toyota. It is divided in to eight steps which are:

1. Separate internal from external setup operations
2. Convert internal to external setup
3. Standardize (standardize tools shape and dimensions for easier work.)
4. Design functional fasteners
5. Use pre adjusted fixtures that can be set outside of the machine.
6. Adopt parallel operations (have more staff to work with changeover)
7. Eliminate adjustments
8. Mechanization
   (L. Sörqvist, 2004)

The SMED-method is compatible with any type of industry. SMED should only be implemented to changeovers with bottlenecks resources that have lower capacity than desired. After identifying the bottleneck machine or equipment it is necessary to analyze the different steps and recourses that exist in the today's changeover. (B. Jit Singh, D. Khanduja, 2009)



In the list below the rebuilding follows the package flov.

To fill the form you write down the starting time of the activity, ex. 10:00 Do the same for end time, ex. 10:05 and the form will automatically calculate the unit time. See Ex. 1

→	Number of persons during conversion:				
→	Volume conversion, from volume x to... (ex. 330 ml to 500ml):				
Step nr	Description of activity	Used Time Start	End	Unit time	Observations/ Comments
Ex. 1	**Go to machine**	10:00	10:05	00:05	**Dropped my pen on the way**
Y	**Pre adjusting when conversion is to a bigger volume than current settings.**			00:00	
A	Remove carriers			00:00	
B	Adjust the carton magazine to infeed			00:00	
C	**Infeed**			00:00	
C1	Switch infeed unit			00:00	
C2	or adjustment between 330 and 500 on infeed unit			00:00	
D	Adjust bar to TS, top sealing			00:00	
E	Adjust direction guide			00:00	
F	**Filler**			00:00	
F1	Adjust guide in filler unit			00:00	
F2	Adjust the values in filler			00:00	
G	Adjust position unit, adjust guide upwards/ downwards			00:00	
H	Adjust TS, bottom sealing, including removing pipes and protective shields			00:00	
I	**Headspace**			00:00	
I1	Headspace unit, switch pushers?			00:00	
I2	Headspace adjustment, adjusting belt and height.			00:00	
J	Elevator adjustment			00:00	
K	Adjust waste handling slide rail			00:00	
L	Insert carriers for new volume			00:00	
M	**FFU-Final Folder Unit total time**			00:00	
M1	Take out the volume unit			00:00	
M2	Insert new volume unit			00:00	
N	Change recipe in TPOP			00:00	
O	Bleed the system of air			00:00	
P	Adjust height on domino			00:00	
X	Total conversion time			00:00	

Figure 3.2 Form for changeover review

The changeover time is the time it takes to make all the adjustments in the machine from the end of one production until the first approved product in the next production. The meaning with SMED is to reduce the changeover time to make it possible to run the machine as long as possible to make it more profitably for the customer. To make the changeover time shorter, use a method that strives after as much external setup time as possible, this because all internal adjustments forces the operators to stop the machine. To get an overview and do a mapping on changeover times is there example for forms in the SMED-method, se figure 3.2 and for a closer look, appendix 1. (Quest Worldwide Education Ltd, 1999)

3.2 Changeover reduction

A research report called “Ställtidsreduktion: Aspekter och Effekter” written by Jan Ohlhager and Birger Rapp describes how to minimize the adjustment time in a machine. The process in this report is divided in three steps: planning, investment and education when striving for “momentary changeover”.

3.2.1 Planning

The first step is to analyze the conversion and divide it in to different steps. These steps should be separated into internal and external adjustments and find out the dependency between the different steps. Internal changeover time is the one that requires that the machine is stopped and minimize the production time and machine capacity. External adjustments are those adjustments that can be done without stopping the machine. Another fact that has impact on changeover is if there are bottlenecks and how these affect the changeover.

3.2.2 Investment

Reducing the internal adjustments often requires high production techniques solutions that probably lead to investments of different kinds. It could be modification of parts, fixtures and development of new measurement tools. The conversion time could maybe reduce by making standardization or invest in modularization and better interfaces.

3.2.3 Education

All the operators should have education in the volume conversion to get the most effective conversions. With more places you have to make adjustments the more knowledge is needed by the operators.

3.3 Modularization of the product

The book “Modulindela Produkten” written by Erixon, Erlandsson, von Yxkull and Mo Östergren is about how to think about modularization on products and how this affects the assembly. It also concerns how manufacture of products should be done and how they should be developed at an overall level for an optimal assembly. Another important fact on module thinking is that all different modules need to be compatible and have the same interface.

3.4 Rejected Theories

Theories in the beginning of the work that the author thought was suitable but later on showed that these were not.

- David G. Ullmans “The mechanical design process”
  The mechanical design process is assumed more suitable for product development. This book is focused on designing new products and how it to work with the right design.

- Freddy Olssons “Principkonstruktion and primärkonstruktion”
  This is a theory that is applicable on product development and evaluation of constructions. The theory is working with product requirements that are supposed to be satisfied when designing a new product. In this product there is no design, this is the next step when you know where you would like to improve.

- Six Sigma Methodic
  Six Sigma works with dispersion values and error free products. The following project does not include the results of the products; the project is instead focused on the volume conversion and adjustment times.

- Jan-Eric Ståhls “The development of NEXT STEP beyond Lean Production”
  This report is affecting a brief presentation of different production philosophies and development trends. Then there is a detailed cost model to work with, but this is not suitable for this project because it aims to time and not costs.

4. Method

The author, Ellen Lindewall, have integrated mentioned theories in chapter 3.1 to 3.3 which provide the working method that the project is based on. With “Ställtidsreduktion: Aspekter och Effekter” (J.Olhager, B.Rapp 1987) as base with the other tools and theories integrated will give the following working method. The eight steps that are presented in chapter 3.1.2 in SMED-method are similar to the theories in chapter 3.3, modularization where interfaces and modules are regarded in both. To follow this working method there are a couple of questions that is to be answered during the project. This is inspired by Lean Production where there are often forms with questions that need to be checked.

Planning

- Internal setup (SMED)
    - Which modules/units exist in the machine today that is adjusted in a volume conversion?
    - Which of these are fully changeable units?
    - Which modules are most time consuming and why? Use form for changeover review from SMED.
    - Which units are modules and should there be greater modularization?
    - Is there a possibility to simplify interfaces for shorter adjustment time?

- External setup (SMED)
    - Tools
    - Preparation
- Bottlenecks
    - Which dependencies are there between the modules, include a process map to get an overview.
    - Is there a particular system for the conversion?

Investment

- Tools and standards
    - What kind of investment should be considered? Can there be chosen a standard and do you need to buy new tools?
    - Do you have to rebuild or modify the machine or parts in the machine?

Education

- Operators
    - What requirements are needed for education level of technicians/operators?
    - With several operators, how can they work together for optimal changeover time?
    - How many operators are most beneficial?

This working method is a tool to easily find critical areas which are the most time consuming and to get an overview over what is really done, as well as what are internal and external adjustments.

This working method is divided in to different steps, planning is looking primarily at today's situation and investment looks on what should be done in the future. The step education looks on how the operators work and if they need any education.

With this working method the first step is to start with SMED and make a changeover reduction form to fill out time for the different steps.

The working method that is presented in part 4 will be tested and analyzed in the following chapter.

5. Result

The machine is divided in to the following main modules, see figure 5.1: FFU - Final folder unit, FSM – Form and seal machine and ACL – Automatic carton loader.

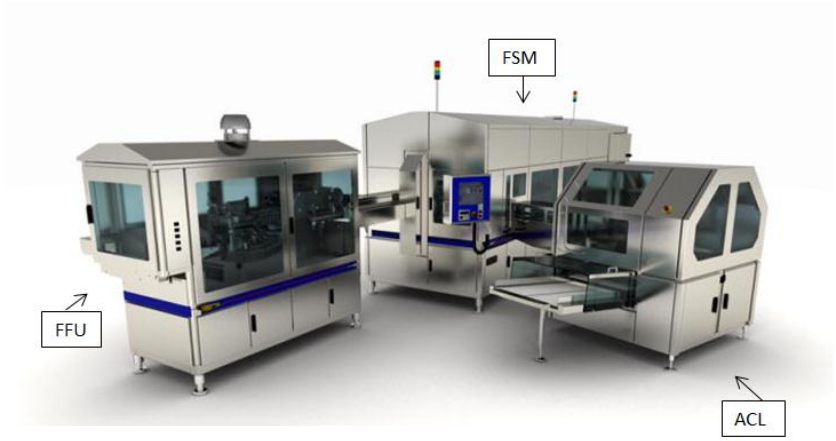


Figure 5.1, TPR1 main machine parts: ACL, FFU and FSM.

These parts will be further studied and a mapping of all different volume conversion steps will be done. Using a form for changeover reduction, all times will be studied and compiled. All dependencies in the volume conversion will be studied and an optimization of different number of operators will be done.

5.1 Existing units today that are adjusted

To know what different parts there are in a conversion a mapping is done by participating in several volume conversions. After separating different parts in the conversion there are seventeen groups. These groups in the list (table 5.1) below follow the package flow as shown in figure 5.2. All units are internal adjustments which mean that the machine needs to be stopped.

Y – Pre adjusting

A – Remove carriers

B – Adjust the carton magazine to infeed

C – Infeed

C1 – Switch infeed unit

C2 – or adjustment between 390 and 500 on infeed unit

D – Adjust bar to TS (transversal sealing), top sealing

E – Adjust direction guide

(F – Filler)

(F1 – Adjust guide in filler unit)

(F2 – Adjust values in filler)

G – Adjust position unit, adjust guide upwards/ downwards

H – Adjust TS, bottom sealing, including removing pipes and

I – Headspace

I1 – Headspace unit, switch pushers?

I2 – Headspace adjustment, adjusting belt and height

J – Elevator adjustment

K – Adjust waste handling slide rail

L – Insert carriers for new volume

M – FFU, Final folder unit, total time

M1 – Take out the volume unit

M2 – Insert new volume unit

N - TPOP

O – Bleed the system of air

(P – Adjust height on domino)

Table 5.1, content of steps in volume conversion (author, 2012)

5.1.1 Overview

Figure 5.2 shows the same machine as in figure 5.1 but from above and with the different conversion steps marked out. The red line with arrows is to mark the way a package moves in the machine.

A box with dashed lines is outside the main machine and not included in this project. These external equipments are F – Filler and P – Domino. The reason why this are considered outside the machine are that the filler station may be designed different for various customers. They can have more than one filler and longer conveyor track.P – Domino is a label writer designed for high speed. The

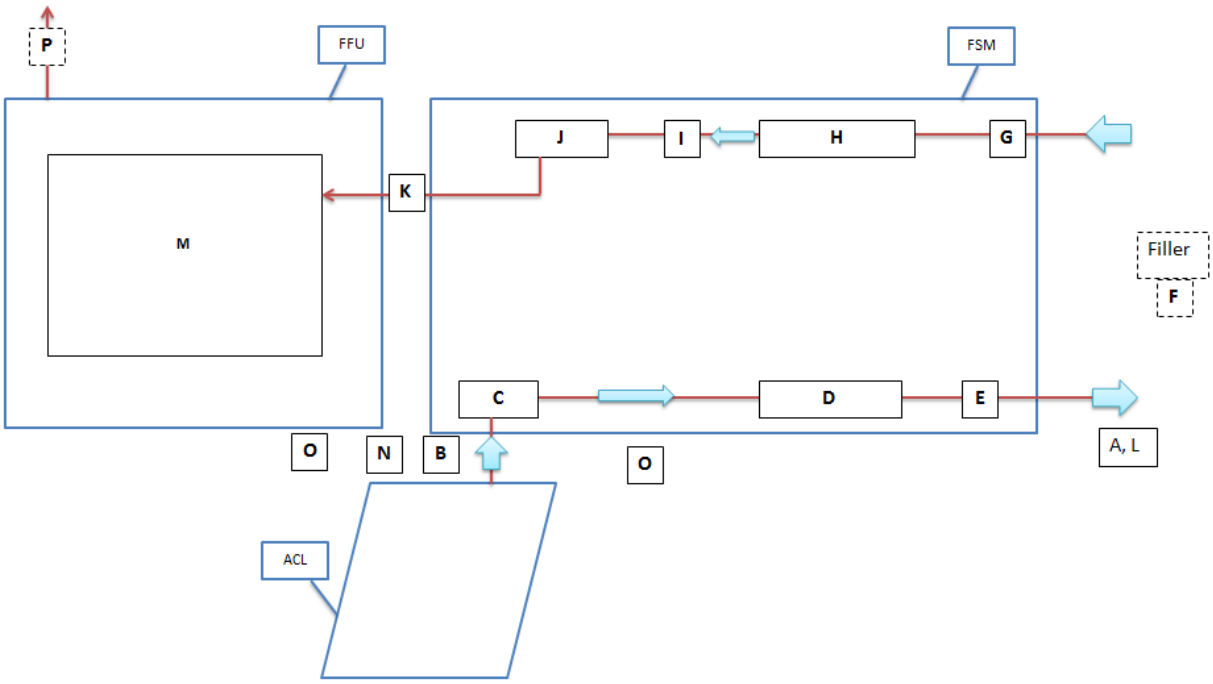


Figure 5.2 TPR1, overview with marks for the different conversion steps.

adjustment done here are to lower/higher the writer otherwise the print will be blurry. Domino is outside of the main machine and will not be considered in this project.

5.1.2 Modules

According to Erixon et al. (1994) is the definition of a module: a product divided in building blocks (modules) with fixed interfaces, driven and selected by company specific reasons. With this meaning that if modular subdivision is made it is important to make sure that it is adapted for the specific company.

To get an overview of which different steps there are in the machine today and how many of these that qualifies as modules a table has been done. In this table (see appendix 9) there is one group that is adjustable units that have been combined because they are very similar.

These groups that are combined with the new name BK are:

B – Adjust the carton magazine to infeed

D – Adjust bar to TS (transversal sealing), top sealing

E – Adjust direction guide

G – Adjust position unit, adjust guide upwards/ downwards

H – Adjust TS, bottom sealing, including removing pipes and

K – Adjust waste handling slide rail

BK

In appendix 9 there is very clearly shown how many of today's units that meet the requirement for being a module, as well as why some don't and some are not suitable for module thinking.

Those units that requires as modules todays are the units that are fully changeable and presented in chapter 5.2. The other adjustable units are presented in chapter 5.3. All the regarded units are observed with basis from the conversion manual (Tetra Recart AB, 2008) and participating on several volume conversions at Tetra Recart.

5.2 Fully changeable units

From the existing conversion groups in the machine there are four groups that are fully changeable units. These are:

- Remove carriers (A)
- Insert carriers (L)
- Infeed unit (C1)
- FFU/Volume unit (M)

5.2.1 Remove carriers (A)

For each package volume there are specific carriers that need to be switched when changing to a new package volume. There are no adjustments needed on the carriers.

Removing carriers are done by hand (see figure 5.3) and the carriers are loaded in to a wooden pallet. It requires running the machine repeatedly to pick all carriers from the same place on the conveyor band.

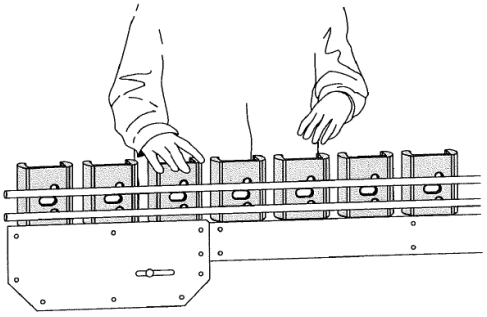


Figure 5.3 pick carriers

5.2.2 Insert new carriers (L)

This is to be done when you have taken out all carriers for the present volume and if the conversion is made to a bigger volume then the current you have to pre adjust (Y) to make sure that it is possible to put in the bigger carriers without collision with parts in the machine.

To fill the machine with carriers for the desirable volume start filling the line with carriers and run the machine a little bit so there is space for more carriers. It is important that the carriers are in right position for the position unit (G) otherwise it will be wrong input in the rest of the machine.

5.2.3 Infeed unit (C1)

There are two different conversions on this unit depending on what volume you desire and which the actual is.

There are two units, one for 340 ml and one that is designed for both 390 ml and 500 ml with some changes. Between 340 ml and 390/500 ml the whole unit has to be changed. See section 5.3.8 for infeed adjustments (C2) when conversion is between 390 ml and 500 ml.

When the whole unit is needed to be switched you have to be two persons because this is very heavy equipment and if possible use an overhead crane.

5.2.4 Volume unit (M)

This part is the most time consuming in the volume conversion. There are three different units, one per volume. To switch these you have to use special made equipment as you see in figure 5.4.

Figure 5.4 Volume unit switch

With this unit there is a lot of different steps to make for example remove a couple of screws, disconnect a number of wires and hoses and release a shaft from a coupling.

The unit is positioned on a steel stand that is made for the volume unit where the unit is slowly lowered to get in the right position.

5.3 Adjustable units

This paragraph regards parts and units in the machine that can be adjusted for the right volume during conversion.

5.3.1Transversal sealing, top sealing (D)

There are two places for transversal sealing, top and bottom seal. The first place in the machine is top seal though the package is transferred upside down and is sealed in the top at first.

Here is the folding bar adjusted upwards or downwards to fit the new volume settings. If the volume conversion is to a bigger volume than the current the bar needs to be lifted to its top and then in the end of the conversion be adjusted to the new carriers to avoid collision. To make the adjustment so precisely as possible there is measurements to place between carrier and bar when adjusting.

5.3.2 Transversal sealing, bottom sealing (H)

Bottom sealing is to be done when the package have been filled with content and needs to be sealed in the bottom which is upwards because the package goes upside down. The sealing equipment is attached on the bar that needs to be adjusted. This leads to a very long bar and it is attached with three screws that needs to be screwed a little at time to make sure that the whole unit is in line and horizontal.

The equipment has protective shields and pipes that are coupled to the sealing unit that needs to be removed.

Here are marks but only on the bar so you have nothing to match them with.

5.3.3 Headspace unit (I1)

This unit has two different cushions for different volumes, one cushion for 340 ml and another one for 390 ml and 500 ml. If you are switching between volumes that have different cushions you have to switch all the cushions on the belt which

is very time consuming. When this is done you have to lower or higher the unit depending on volume.

When volume conversion is between 390 ml and 500 ml there is no adjustment on the headspace.

5.3.4 Headspace adjustment (I2)

Adjust the cushions to carriers to make sure that they have the right pressure on the packages in operation. Make sure that the belt is right tightened.

Volume conversion between 390 ml and 500 ml there is no adjustment on the headspace.

Figure 5.5 Template for measure.

5.3.5 Elevator (J)

In this unit there is adjustment on each part, see figure 5.6, of a total of twelve places. This adjustments needs use of a template, see figure 5.5, that is adjustable for the different volumes. You can only adjust 4 places at time because you do not reach the other ones and some are open which makes it impossible to adjust. And then you have to run the machine to make it spin to four new ones to adjust. This is repeated until all parts are adjusted.

Figure 5.6 Elevator, parts that are adjusted.

5.3.6 Carton magazine (B)

This is the part that feeds the cartons from ACL to FSM machine for producing. These need to be in the right height for the current package and need to be adjusted downwards or upwards. There are fixed holes for different volumes but no labeling at the holes.

5.3.7 Direction guide (E)

This guide is positioning the packages in right height for the filler. This need to be adjusted up or down for the right height for the new package volume.

5.3.8 Infeed adjustment (C2)

If the conversion is between 390 ml and 500 ml there are spacers that needs to be added or removed. In this adjustment there is a possibility to turning the device out of the machine for better access and therefore no heavy lifting of equipment and it is accepted with one operator.

5.3.9 Position unit (G)

This unit has a feeding screw that creates the right space between the carriers after filling and before the sealing part. This unit has a bar that needs to be regulated up or down to make sure that the carriers do not tilt when the machine is running.

5.3.10 Waste handling (K)

After the elevator in the machine the packages are moving forward to the final folder unit. The path between these parts is a haste handling rail where not approved packages are wasted. Here is a rail that needs to be adjusted up- or downwards.

5.3.11 Bleed the system of air (O)

When conversion is made there is air in the cooling system that needs to be filled with water instead. To do this there is a place where the air is vented and a place for a water tap. These are not at the same place which makes this a little difficult because if the system gets too little of water when air is removed, the system will lose pressure. When there are two persons making the conversion, one can keep track of the air and one on the water.

5.3.12 TPOP (N)

When conversion is made the recipe needs to be changed for settings for the new volume.

5.3.13 Pre adjusting (Y)

When conversion is made for a bigger package volume than the current there needs to be a pre adjustment of following steps:

- D – adjust bar to top sealing, TS
- E – adjust direction guide
- F – filler
- G – position unit
- H – adjust bar bottom sealing, TS

These steps are all some kind of bar that needs to be raised to make sure that there is no collision between the bigger carriers and any bar. When the new carriers have been inserted there is the real adjustment left, meaning precise adjustments.

5.4 Time for different steps

The result after observation and participation when rebuilding the machine between different volumes is time for all units. These times are necessary to have to continue the work with optimization of volume conversion. All times have been filled in the "form for conversion time" which is based on a tool in SMED (Quest Worldwide Education Ltd, 1999). The form is filled in from the second volume conversion see appendix 1. There are also times from the first opportunity as well as the time roof that is used in the rest of the project. It means that the times that has been worked with is the highest times to make sure that there are some space for not underestimating the conversion time. All times between first and second changeover is quite similar which makes it more appropriate to choose the highest time because both conversion times is similar. Below in table 5.4 are the times for all different conversion steps.

Used times:		Time:	Comments			Time	Comments
Y	**Pre adjusting when conversion is to a bigger volume than current settings.**	**30 min**	When 2 persons are operating, one person 45 min.	***I***	**Headspace**		
A	Remove carriers	15 min	When 2 persons are operating, one person 20 min.	*I1*	Headspace unit, switch pushers?	40 min	
B	Adjust the carton magazine to infeed	5 min		*I2*	Headspace adjustment, adjusting belt and height.	15 min	
C	**Infeed**			*J*	Elevator adjustment	50 min	
C1	Switch infeed unit	55 min	With two persons	*K*	Adjust waste handling slide rail	5 min	
C2	or adjustment between 390 and	25 min		*L*	Insert carriers for	15 min	When 2 persons are

	500 on infeed unit				new volume		operating, one person 20 min.
D	Adjust bar to TS, top sealing	3 min		*M*	**FFU-Final Folder Unit total time**		
E	Adjust direction guide	2 min		*M1*	Take out the volume unit	40 min	With two persons, one person can be nearly 50 min
F	**Filler**			*M2*	Insert new volume unit	50 min	With two persons, one person can be nearly 90 min
F1	Adjust guide in filler unit	5 min		*N*	Change recipe in TPOP	3 min	
F2	Adjust the values in filler	1 min		*O*	Bleed the system of air	5 min	When 2 persons are operating, one person 10 min.
G	Adjust position unit, adjust guide upwards/ downwards	5 min		*P*	Adjust height on domino	3 min	
H	Adjust TS, bottom sealing, including removing pipes and protective shields	25 min					

Table 5.4, unit times

In table 5.4 it is very clearly to see what conversion units that are the most time consuming and the critical areas, those areas that take longer than 30 minutes are:

- **C1 switch whole infeed unit –** 55 min
  This time is when two persons are helping each other with getting the unit in right angle and position. Switching infeed unit requires two persons because the heavy equipment.
- **M2 insert new volume unit –** 50 min

This time is when this conversion step is made by two persons. This reduces the time significant in this step. If M2 is made by one person you can assume that the time will be a lot more, something near 90 minutes in due the difficulties of getting shaft correctly in coupling.

- **M1 take out volume unit –** 40 min
  This time is when this conversion step is made with two persons. This reduces the time significant in this step and if it is made by one person it is assumed that the time will be a lot longer, near 50 min. Technicians need to be caution when taking out volume unit because of mentioned shaft.
- **I1 headspace, switch pushers –** 40 min
  There are a lot of pushers to switch and it may be desirable to have the possibility to change all at once.
- **J Elevator –** 50 min
  In the elevator there are a lot of adjustment places and the machine needs to run a little bit between all adjustable sections.

5.5 Conversion flow

During a volume conversion the shortest time is desirable. To make it as short as possible it is needed to know what to do and in what order, what is needed to be done at first and what dependencies are there?

There are different parts in the conversion that is depended on each other. These vary between the different volume conversions. This because headspace and the infeed units adjustments vary depending on which volume that is the current and which the desired volume is.

5.5.1 Dependencies in conversion

Figure 5.7 shows what dependencies there are in a volume conversion. The first four steps needs to be done after each other. As said before there needs to be a pre adjustment when conversion is made to a bigger package volume than the current to prevent collision in the machine with the new carriers. The reason why the guide in the filler needs to be adjusted before the new carriers are inserted is that if the guide is not in right height carriers will tilt and may cause machine stop. All steps in the green square are not depending of each other and can be done in which order you wish except for headspace in the red box. Those two steps need to be done after each other as shown. Otherwise the only requirement of the green

box is that it follows the four beginning steps: remove carriers, pre adjusting if needed, adjust guide in filler and insert carrier.

The orange box is switch of volume unit which needs to be done after each other, insert the new volume is impossible if the new volume is not removed as well as the system cannot be bleeded until the volume unit is inserted and all the hoses and wires are connected (see 5.3.11). These steps can be done anywhere in the volume conversion and are not depending on anything else. This means that the bottlenecks in a volume conversion are the steps above the green box, which needs to be done to complete the rest.

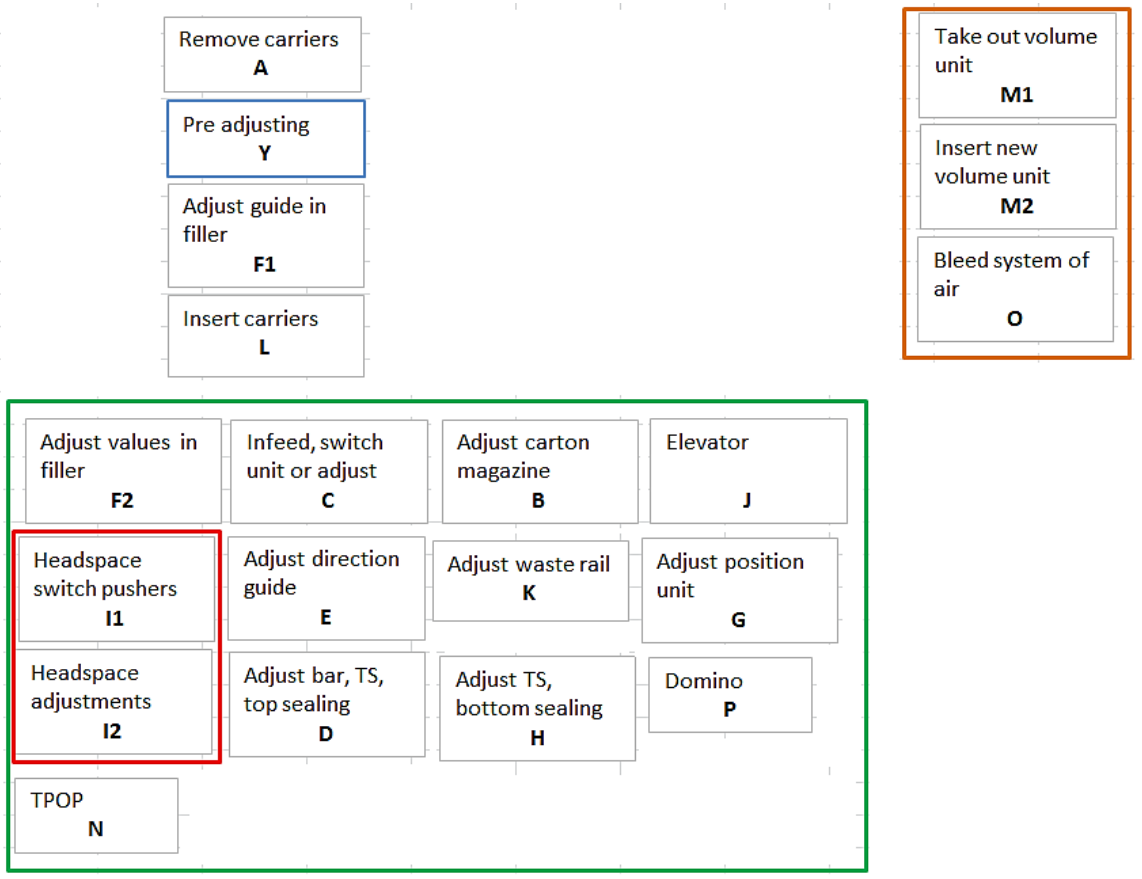


Figure 5.7 Dependencies in conversion

5.6 Optimization 1 to 4 operators

To make it possible to optimize the conversion time and in what order the different part should be done the time study presented in part 5.4 is used as an base as well as dependencies in section 5.5.1. All unit times are without time for fetching tools and movement time. Therefore when optimizing there has been

added two minutes between all steps to make sure that there is time to fetch tools and moving time for operators. But there is not included preparation time before start and time for cleaning, time for test drive when volume conversion is finished. In the conversion schedules there are not included pauses and lunch breaks because Tetra Recart has customers all over the world where they have different agreements on how long time a pause is and when on the day these should be take which makes in inappropriate to include these.

Things that can vary between different conversions are:

- **Pre adjustment (Y)** only if you go from a small volume to a bigger one.
- **Infeed unit,** when the adjustment is from 340 ml to 390ml or 500ml the whole unit needs to be switched. If the conversion is between 390 ml and 500 ml there is only adjustments required.
- **Headspace,** when conversion is made between 390 ml and 500 ml there is no adjustment here. When conversion is from 340 ml to 390 ml or 500 ml needs all pushers be switched and adjustments are required.

Different conversions that involves different steps:

- **340 ml to 390 ml** needs pre adjustments (Y), headspace adjustments (I2) and switch pushers on headspace (I1) and switch of the whole infeed unit (C2).
- **390 ml to 500 ml** only pre adjustments (Y) and adjustments on infeed (C1), nothing on headspace.
- **340 ml to 500 ml** needs pre adjustments (Y), headspace adjustments (I2) and switch pushers on headspace (I1) and switch of the whole infeed unit (C2).
- **500 ml to 390 ml** needs only adjustment on infeed unit.

With this information and all dependencies in the conversion it is possible to use notes to create the most time efficient volume conversion, see figure 5.8. Things that are considered is that when one person is working on for example the elevator it is good if another person is working on the other side of the machine to make it possible to crank the machine forward so the other person do not have to run to the other side and then back. Regarding the order for the different steps it is desirable to have those activities that are on the same side of the machine as close as possible to minimize running around the machine.

With the background of all the dependencies and time study it is possible to see how you can optimize the conversion time from being one to four technicians.

Figure 5.8 Volume conversion optimization

When conversion is to a smaller package volume than the current there is no pre adjust which means that all times below in the optimizations are 30 minutes shorter than the set value, except for one person when pre adjust is 45 minute.

5.6.1 Volume conversion for one person

When volume conversion is made by one person it follows longer conversion time because all critical areas take longer time. Specially demanding is the volume unit where there is a need to go around the machine a number of times to see that the volume unit is coming on the right position before you lower the equipment.

Result for optimization of volume conversion on one person.

- Conversion from 340 ml to 390/500 ml is not possible to do with one person because it needs at least two persons on this unit because the heavy equipment. See appendix 2.
- Conversion from 390 ml to 500 ml gives an effective conversion time of 6 hours and 41 minutes. See appendix 3.

5.6.2 Volume conversion for two persons

When volume conversion is made with two persons operating there is a great advantage for the critical areas because they can help each other to make it right from the beginning and have “four eyes”.

This optimization of volume conversion with two persons and from 340 ml to 500 ml is shown in figure 5.9

To make it easier to get an overview of how long time every different steps are the boxes are colored with

- Red boxes for time over 35 minutes.
- Orange boxes for time between 20 and 35 minutes.
- Blue boxes are for time between 10 and 19 minutes.
- Green boxes are for steps under 10 minutes.

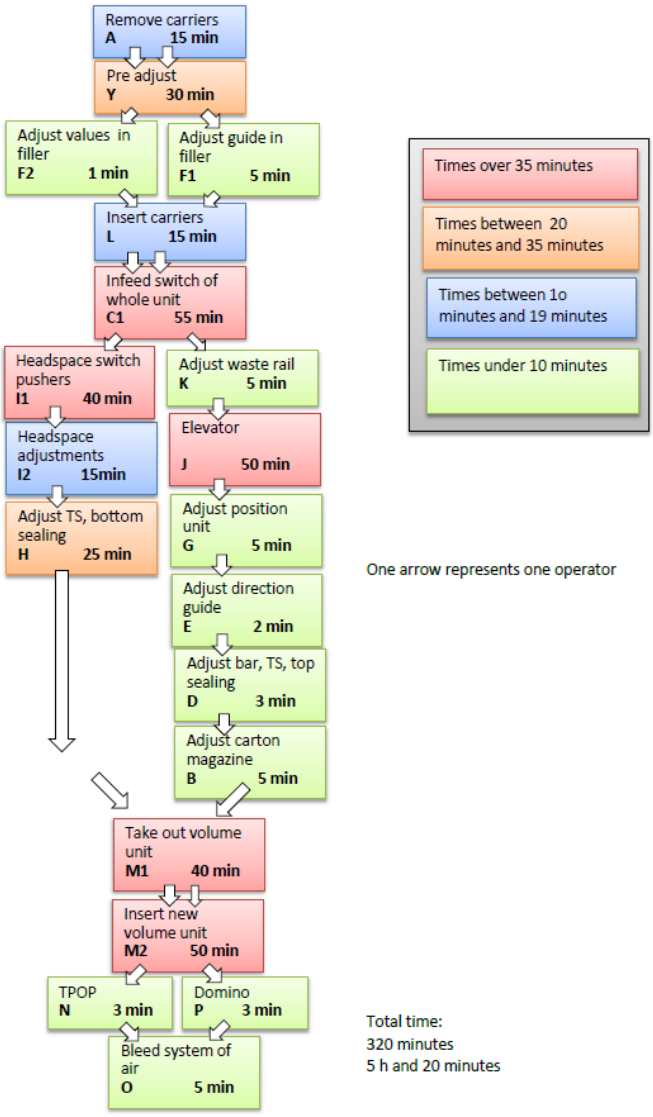


Figure 5.9 Volume conversion 2 persons 340 ml to 390 ml /500 ml

Result for effective conversion time for optimization of volume conversion on two persons:

- 340 ml to 500 ml is 5 hours and 20 minutes, se appendix 4.
- 390 ml to 500 ml is 4 hours and 7 minutes, se appendix 5.

5.6.3 Volume conversion for three persons

Advantage in this volume conversion is that when there are three persons is that it is possible to be two that works on the volume unit during whole conversion time when the third person works with all the adjustable units.

Results for optimization of volume conversion with three persons:

- 340 ml to 500 ml is 3 hours and 52 minutes. see appendix 6.
- 390 ml to 500 ml is 3 hours and 6 minutes, see appendix 7.

5.6.3 Volume conversion for four persons

Here is a possibility for two persons to work with the volume unit and the infeed unit, those parts makes a big difference in time compared to when there are two persons operating. This also makes that the other two persons can focus on the FSM, form and seal machine and all units in that area.

Results for optimization of volume conversion with four persons:

- 340 ml to 500 ml is 2 hours and 36 minutes, see appendix 8.
- 390 ml to 500 ml is 2 hours and 6 minutes, see appendix 9.

5.7 External setup

After observation and analysis of all conversion steps it shows quickly that all steps are internal setup and that it will be very hard to make any adjustments to make internal setup for external. Things that can affect the conversion time is that some tools or measurements that is used during a conversion is adjustable and can "steal" minutes by just crosschecking that it is set for the right dimensions. Also it is a lot of running around just looking for tools though they are at different places in the hall. In today's conversion manual there are some parts that refers to the Maintenance Manual which makes the operator look on different places which takes time for finding the right information.

5.8 Result of validation on theoretical reference frame

To achieve the best result it was required to create a working method for how to optimize changeover time. This working method has been tested in this project where the method strives after to answer a couple of questions. To get some questions from the beginning to work with in the method has been a good way to see on what areas to work with and what kind of tools you expect to use in this project. This method suits projects that are referring to changeover in machines and where there are both adjustments and whole unit switches and when the conversion is made just a couple of times a month and not every day. With this meaning that is not suitable for machine where it is changeover every second day. This working method could be suitable for other machines within Tetra Pak.

5.9 Operators

To strive after the most efficient volume conversion a good education on the operators is to prefer. This because if the operators know what steps that is included in a volume conversion there is no insecurity and it minimize questions. After all this is not a requirement but it is recommended and assumed that all operators have technical background.

6. Conclusion

Conclusion of working with this working method is that it is successful. The project has answered all the questions asked in the working method.

Critical areas that takes 30 minutes or more to work with are:

1) **C1 switch whole infeed unit**
2) **M2 insert new volume unit**
3) **M1 take out volume unit**
4) **I1 headspace, switch pushers**
5) **Elevator**

Regarding the working method of what number of operators that would be the most efficient from a time perspective of how long time the machine remains on hold is undoubtedly 4. If you compare all conversion times for volume conversion between 340 ml and 390/500 ml which is the most time consuming conversion, the result is that the conversion is not preferred for one operator due to the heavy equipment. Additionally, between two persons and three persons it differs 1 hour and 18 minutes. Similarly between three operators and four operators, the difference is 1 hour and 16 minutes.

Thus, from a time perspective on how long time the machine is standing still, 4 persons is the optimal number of operators. If you are examining how long the working time will be for all persons for example: volume conversion from 340 ml to 390/500 ml on 232 minutes with three persons gives a total working time for 3*232 minutes = 696 minutes. So if you compare these values for the same conversions:

- 2 persons 340 ml to 390/500 ml gives 2*320=640 minutes
  Machine stop: 5 hours 20 minutes
- 3 persons 340 ml to 390/500 ml gives 3*232= 696 minutes
  Machine stop: 3 hours 52 minutes

- 4 persons 340 ml to 390/500 ml gives 4*156 =624 minutes
  Machine stop: 2 hours 36 minutes

This shows that if you are looking on working time and not machine stop is the question what is most desirable, short machine stop or low total paid working time? If there are four operators there is approximately the same total effective working time as for two persons. There will be the same working costs because it is the same total time and when there is four people working the machine will go to production faster and Tetra Recart and their customer can use the machines capacity faster.

When comparing the other volume conversion from 390 ml to 500 ml the results are:

- 1 persons 390 ml to 500 ml gives 1*401=401 minutes
  Machine stop: 6 hours 41 minutes
- 2 persons 390 ml to 500 ml gives 2*247=494 minutes
  Machine stop: 4 hours 7 minutes
- 3 persons 390 ml to 500 ml gives 3*186= 558 minutes
  Machine stop: 3 hours 6 minutes
- 4 persons 390 ml to 500 ml gives 4*126 =504 minutes
  Machine stop: 2 hours 6 minutes

This is interesting because when the work is done by one person on this conversion there is a little more than an hour less in conversion time than the others where they are several operators. This gives that it is up to the customer what they prioritize, less working costs or shorter production stop. The production stop is only 2 hours and 6 minutes with four people compared with one person where the stop is 6 hours and 41 minutes but with 103 minutes less total working time for operators. This is to be compared with number of produced packages per hour which is between 9 000 and 24 000 packages per hour.

6.1 Modularization

The result from the time study shows that in some places there is no wish for greater modularization. For example of this is the infeed unit where it takes 30 minutes longer time to switch the infeed instead of just regulating the unit with distances and adjustments. In this case there is not preferred to have three units that are fully changeable.

Regarding the volume unit maybe the time will be shorter if there would be parts that are switched and not the whole unit. But in the current units it would be desirable to look over interfaces, especially where all wires and hoses are connected to the volume unit in the final folder unit.

6.2 Further work

After this thesis there are some areas that are suggested to work further with. These areas are in particular the critical areas that are mentioned above in the beginning of chapter 6.

Examples for simple solutions are:

Volume unit: It would be desirable to have an easier connection for wires and hoses either better mark of different hoses or a whole coupling unit that makes all hoses come together at the same time.

Look over the shaft that is fitted in the coupling which is a difficult step, is there a possibility to make a simpler connection?

When the volume unit is lowered to the special made stand when it is not in use, is there a possibility to have some direction rails to make sure that it always comes in the right position? (See figure 6.2)

Figure: 6.2 Volume unit stand

Infeed unit: Is here a possibility to work on one unit that is possible to adjust between all three volumes?

Headspace: To save a lot of time on this unit the best would be to have the same pushers to all different sizes. But that can be difficult to make the result as precise as desired. Another alternative would be an easier way to switch pushers.

BK combined units: All these units are some kind of adjustments. For faster adjustments the best would be to have fixed set points with fine adjustments. Another thing that maybe needs a new design is marks for the different volumes, where the adjusted unit is in right position for the new volume.

Tools: The best for an efficient volume conversion would be to have ready tool boxes that every operator has when working to minimize the running and looking for tools.

Measurements that are used should be one for each volume to erase double check all measurements before use and with clear volume marking on each measure.

7. Critical review

When a project plan was made (see appendix 11) for this project the thought was to optimize the volume conversion such as find problem areas and come with suggestion of modification or redesign and also see how long time in the end these redesigns can shorter the conversion time. As the project proceeded I realized that the problem was too complex and comprehensive and the project should be more focused on mapping of the conversion as well as finding critical areas and optimizing with different numbers of operators.

In the beginning of this project the thought was to base my project on theories such as Lean production and Six Sigma. Longer in to the process it showed that these theories were not suitable. This led to a comprehensive literature search and focus on generating a working method suitable for this project when working with changeover and conversion of a Tetra Recart machine. Most of the literature that was found was mostly oriented on assembly and manufacturing of thousands items which is not applicable on this projects. This gave a project with more theoretical focus than expected as well as a result that is useful for Tetra Recart though the working method is applicable on other Tetra Pak machines.

In the project plan and in the schedule (appendix 11) it also mentions that cost benefits for customers should be studied. This has been summed up to what the different time profits there are with different numbers of operators and how this affects the machine stop. What is more beneficial for the customer is not said, it depends on how there are available staff and how many packages that needs to be produced.

Overall I am very satisfied with the result of this project and I have learned a lot working with this thesis.

8. References

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Figures:

Figure 2.2, Where in the world, http://campaign.tetrapak.com/tetra-recart/how-to/ (20120318)

Figure 3.1, Process map, *http://www.breezetree.com/articles/convert-flowchart-to-process-map.htm,* (2012-04-22)

Figure 3.2 Form for changeover review, Ellen Lindewall (2012-02-10)

Figure 5.1 TPR1 machine, from Li Strandberg, Tetra Recart

Figure 5.2, TPR1 overview with conversion steps, Illustration Ellen Lindewall

Figure 5.3, Pick carriers, Conversion manual, (2012-03-10)

Figure 5.4, Volume unit switch, Photo: Ellen Lindewall (2012-04-20)

Figure 5.5, Template for measure, Photo: Ellen Lindewall (2012-02-23)

Figure 5.6, Elevator, Photo: Ellen Lindewall (2012-02-23)

Figure 5.7, Dependencies in conversion, Illustration Ellen Lindewall

Figure 5.8, Volume conversion optimization, Photo: Ellen Lindewall(2012-04-20)

Figure 5.9, Volume conversion 2 persons, Illustration: Ellen Lindewall

Figure 6.2, Volume unit stand, Photo: Ellen Lindewall (2012-04-25)

Literature search in Halmstad University Library, both articles and books and in different databases:

Search words:

- Omställning
- Maskin omställning
- Manuell montering
- Maskin montering
- Manuell assembly
- SMED
- Changeover

In the list below the rebuilding follows the package flow.

To fill the form you write down the starting time of the activity, ex. 10:00 Do the same for end time, ex. 10:05 and the form will automatically calculate the unit time. See Ex. 1

→	Number of persons during conversion:		2		
→	Volume conversion, from volume x to...(ex. 390 ml to 500ml):				390-500
Step nr	**Description of activity**	**Used Time Start**	**End**	**Unit time**	**Observations/ Comments**
Ex. 1	**Go to machine**	**10:00**	**10:05**	**00:05**	**Dropped my pen on the way**
Y	**Pre adjusting when conversion is to a bigger volume than current settings.**	**10:00**	**10:45**	**00:45**	
A	Remove carriers	08:15	08:26	00:11	
B	Adjust the carton magazine to infeed	12:20	12:25	00:05	
C	**Infeed**			00:00	
C1	Switch infeed unit			00:00	
C2	or adjustment between 390 and 500 on infeed unit	12:45	13:10	00:25	
D	Adjust bar to TS, top sealing	12:50	12:53	00:03	
E	Adjust direction guide	12:55	12:57	00:02	
F	**Filler**				
F1	Adjust guide in filler unit	12:25	12:30	00:05	
F2	Adjust the values in filler	12:35	12:36	00:01	
G	Adjust position unit, adjust guide upwards/ downwards	11:25	11:30	00:05	
H	Adjust TS, bottom sealing, including removing pipes and protective shields	11:03	11:25	00:22	
I	**Headspace**			00:00	
I1	Headspace unit, switch pushers?			00:00	
I2	Headspace adjustment, adjusting belt and height.			00:00	
J	Elevator adjustment	10:25	11:15	00:50	
K	Adjust waste handling slide rail	12:30	12:35	00:05	
L	Insert carriers for new volume	12:35	12:45	00:10	
M	**FFU-Final Folder Unit total time**				
M1	Take out the volume unit	08:45	09:25	00:40	
M2	Insert new volume unit	09:25	10:15	00:50	
N	Change recipe in TPOP	10:15	10:18	00:03	
O	Bleed the system of air	10:18	10:25	00:07	
P	Adjust height on domino	10:25	10:35	00:10	
X	Total conversion time			04:59	

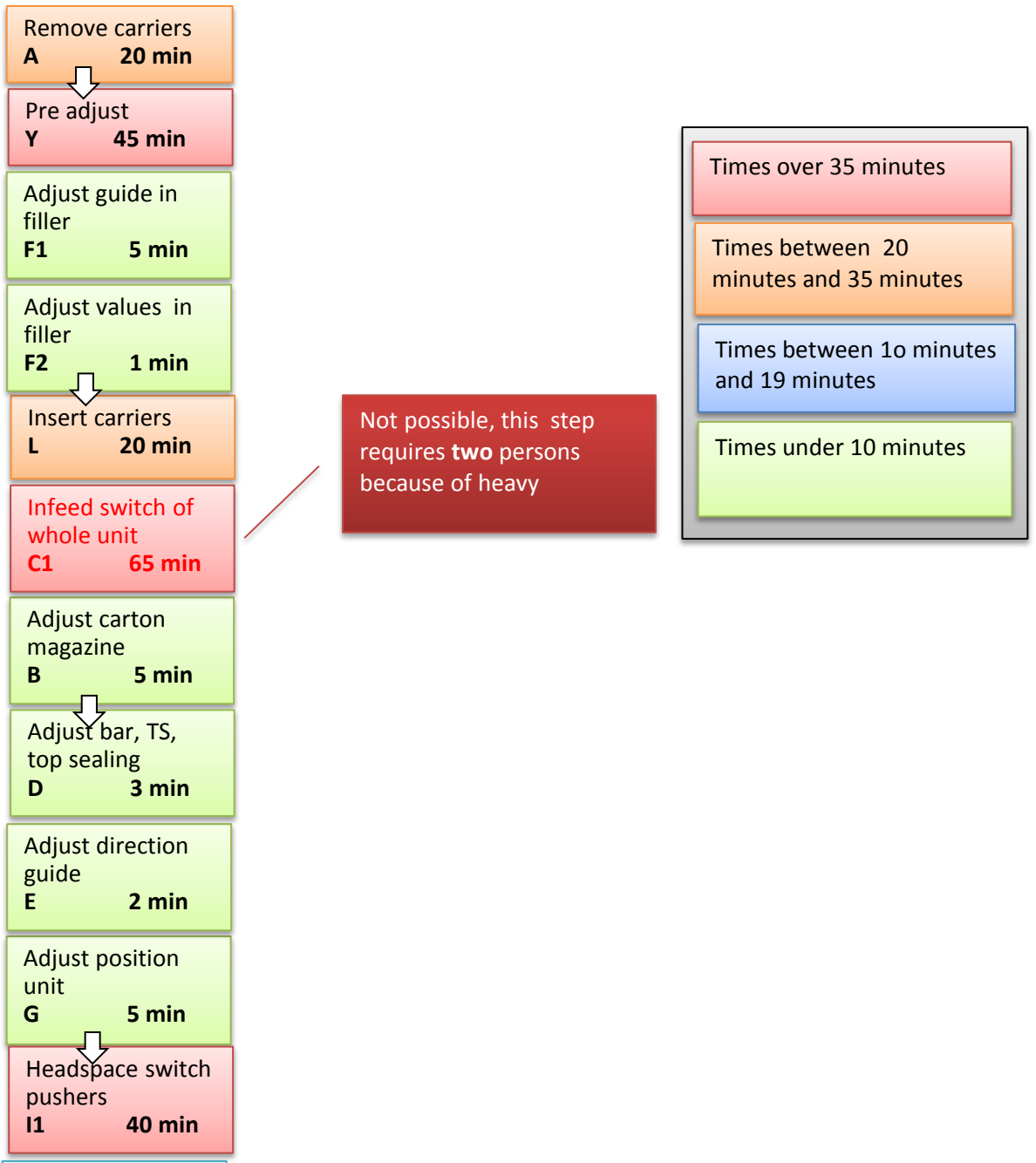
Observation one 390 - 340	Observation two 390 - 500	Time roof
	45 min	45 min
15 min	11 min	15 min
5 min	5 min	5 min
55 min		55 min
	25 min	25 min
3 min	3 min	3 min
2 min	2 min	2 min
5 min	5 min	5 min
1 min	1 min	1 min
5 min	5 min	5 min
25 min	22 min	25 min
40 min		40 min
15 min		15 min
45 min	50 min	50 min
5 min	5 min	5 min
15 min	10 min	15 min
35 min	40 min	40 min
50 min	50 min	50 min
3 min	3 min	3 min
5 min	4 min	5 min
2 min	3 min	3 min

Appendix 2, Modules

	Do the units meet the requirements for a module?	Yes	No	Comments
BK	Combined groups of adjustments		**X**	This is not a changeable component, only adjustments of a bar.
A	Remove carriers	**X**		Have the same interface and are changeable component
C	**Infeed**			
C1	Switch infeed unit	**X**		Fully changeable unit, adapted for Tetra Recart
C2	or adjustment between 390 and 500 on infeed unit		**X**	It is not a changeable component but there are parts that need to be added or removed. To become a module have to infeed units, one for 390 and one for 500 ml.
F	**Filler**			
F1	Adjust guide in filler unit		**X**	This is not a changeable component, only adjustment of a bar.
F2	Adjust the values in filler		**X**	This is not a changeable component, only changing of a value in the filler unit.
I	**Headspace**		**X**	To be a module there would have to be a whole changeable unit to switch here to get away from switching pushers and make a lot of adjustments.
I1	Headspace unit, switch pushers?		**X**	- ‖ -
I2	Headspace adjustment, adjusting belt and height.		**X**	- ‖ -
J	Elevator adjustment		**X**	Here are decided interfaces of what sizes every part should be. But every adjustment is made by hand, to become a module there should be three units, one per volume that is changeable.
L	Insert carriers for new volume	**X**		Have the same interface and are changeable component
M	**FFU-Final Folder Unit total time**	**X**		Whole unit are changeable and have three different units, one per volume.
M1	Take out the volume unit			
M2	Insert new volume unit			
N	Change recipe in TPOP		**X**	This is not a changeable component, only changing of values in machine
O	Bleed the system of air		**X**	No component
P	Adjust height on domino		**X**	There is no component that is supposed to be switched only height adjustment.

Appendix 3

Conversion with 1 person from 340 ml to 390ml/500 ml



Total conversion time
499 minutes
8 hours and 19 minutes

Appendix 4

Conversion with one person, from 390 ml to 500 ml

Remove carriers
A **20 min**

Pre adjust
Y **45 min**

Adjust guide in filler
F1 **5 min**

Adjust values in filler
F2 **1 min**

Insert carriers
L **20 min**

Infeed adjustment
C2 **25 min**

Adjust carton magazine
B **5 min**

Adjust bar, TS, top sealing
D **3 min**

Adjust direction guide
E **2 min**

Adjust position unit
G **5 min**

Adjust TS, bottom sealing
H **25 min**

Elevator
J **50 min**

Adjust waste rail
K **5 min**

Take out volume unit
M1 **50 min**

Insert new volume unit
M2 **90 min**

Bleed system of air
O **10 min**

TPOP
N **3 min**

Domino
P **3 min**

Times over 35 minutes

Times between 20 minutes and 35 minutes

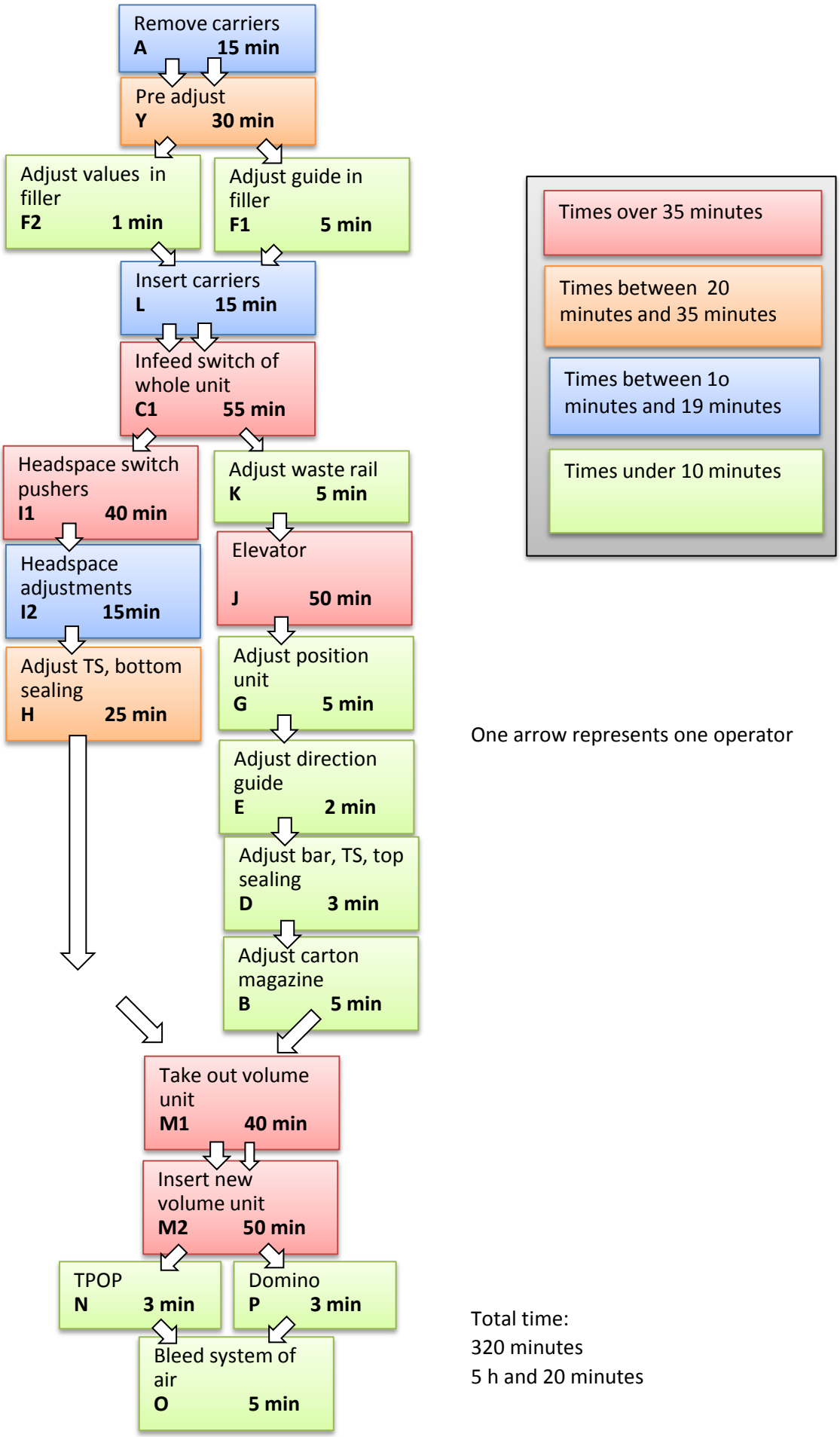
Times between 1o minutes and 19 minutes

Times under 10 minutes

Total time:
401 minutes
6 hours 41 minutes

Appendix 5

Conversion with 2 persons from 340 ml to 390 ml / 500 ml

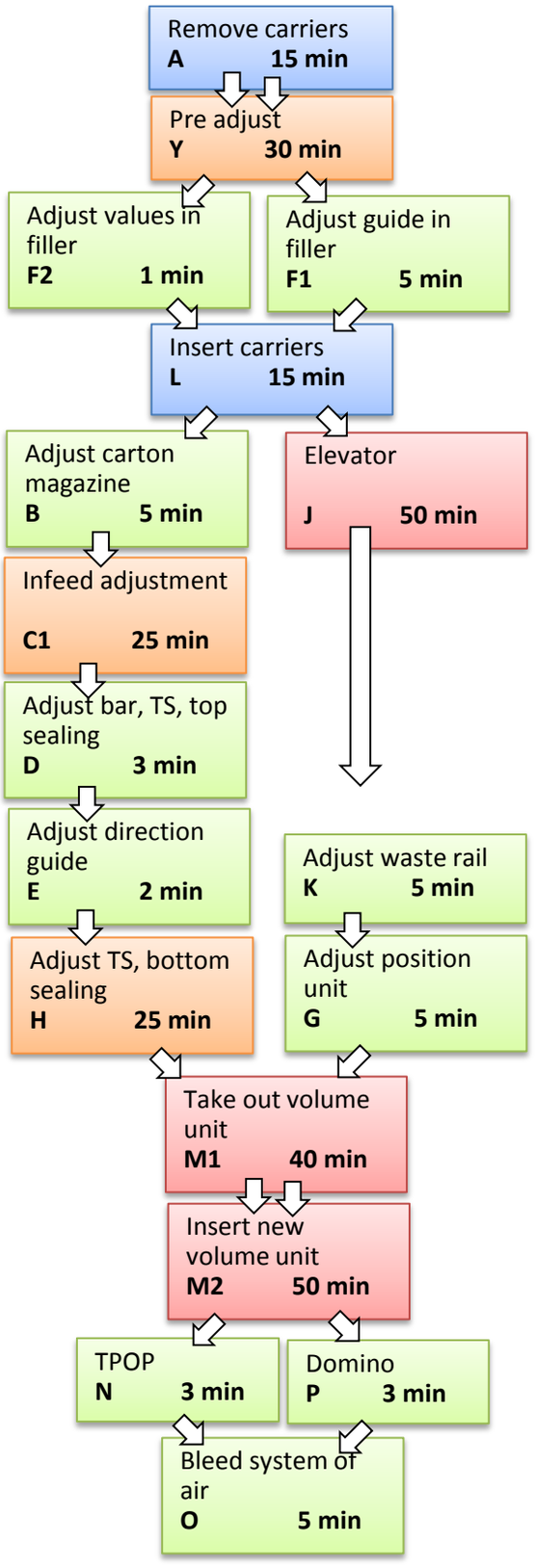


One arrow represents one operator

Total time:
320 minutes
5 h and 20 minutes

Appendix 6

Conversion with 2 persons, from 390 ml to 390 ml/500 ml.

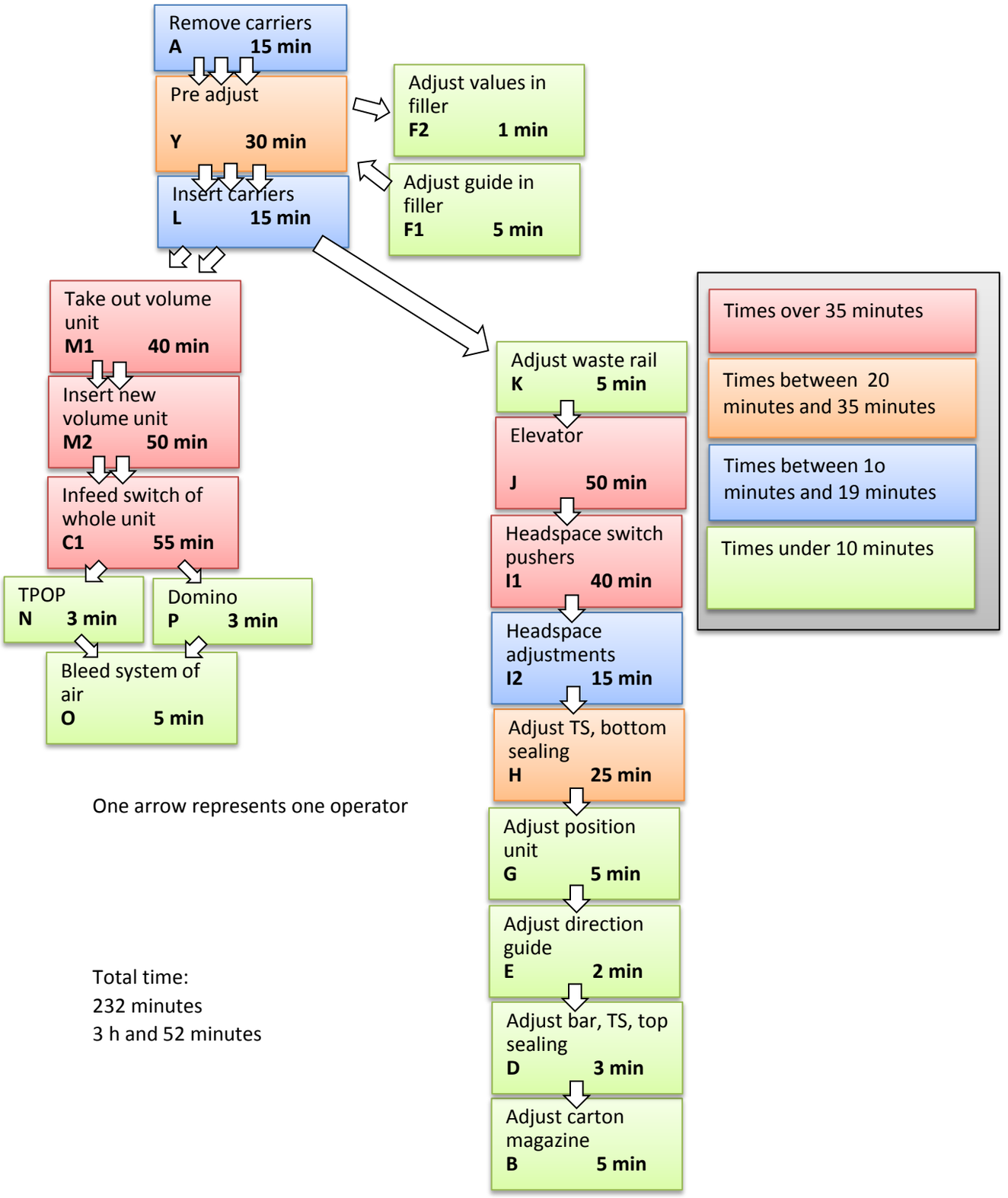


One arrow represents one operator

Total time:
247 min
4 h and 7 minutes

Appendix 7

Conversion with 3 persons from 340 ml to 390 ml/500 ml

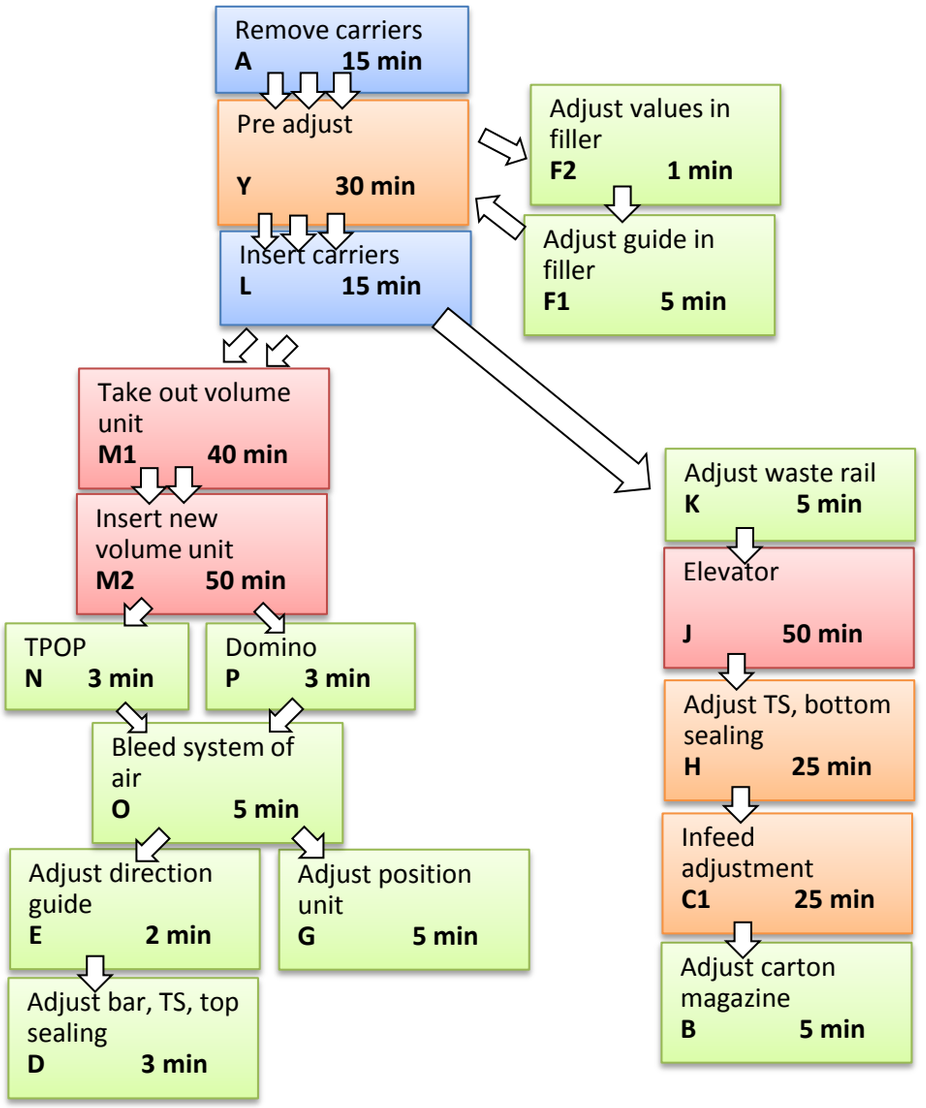


One arrow represents one operator

Total time:
232 minutes
3 h and 52 minutes

Appendix 8

Conversion with 3 persons from 390 ml to 500 ml

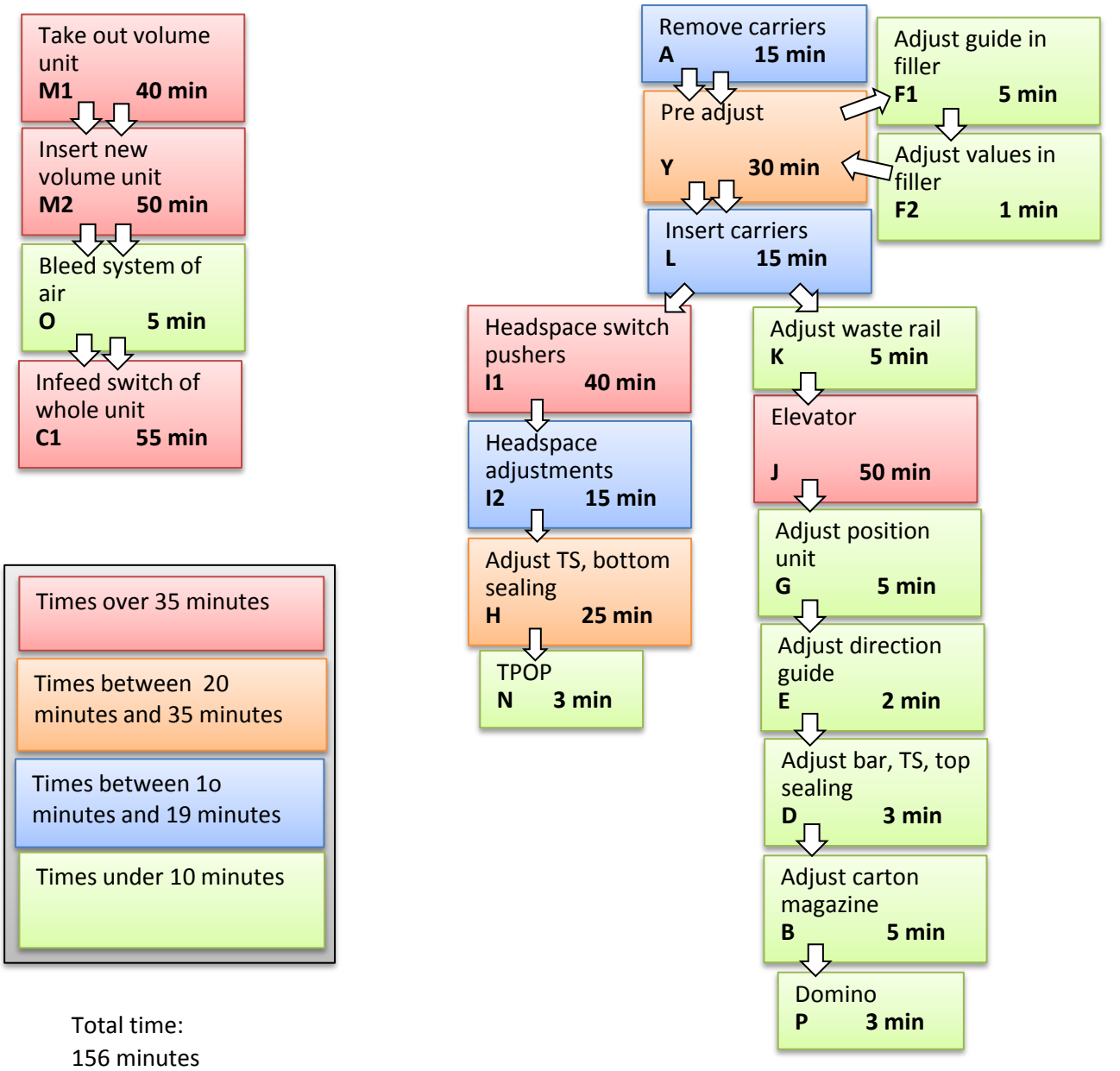


One arrow represents one operator

Total time:
184 minutes
3 hours and 4 minutes

Appendix 9

Volume conversion with 4 persons from 340 ml to 390 ml/500 ml

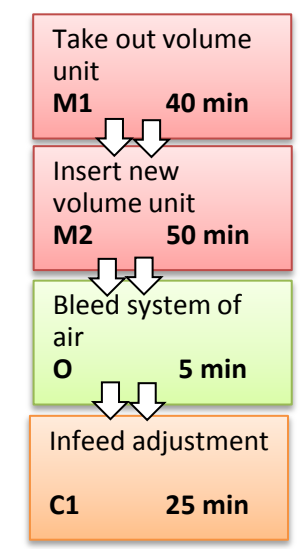


Total time:
156 minutes
2 hours and 36 minutes

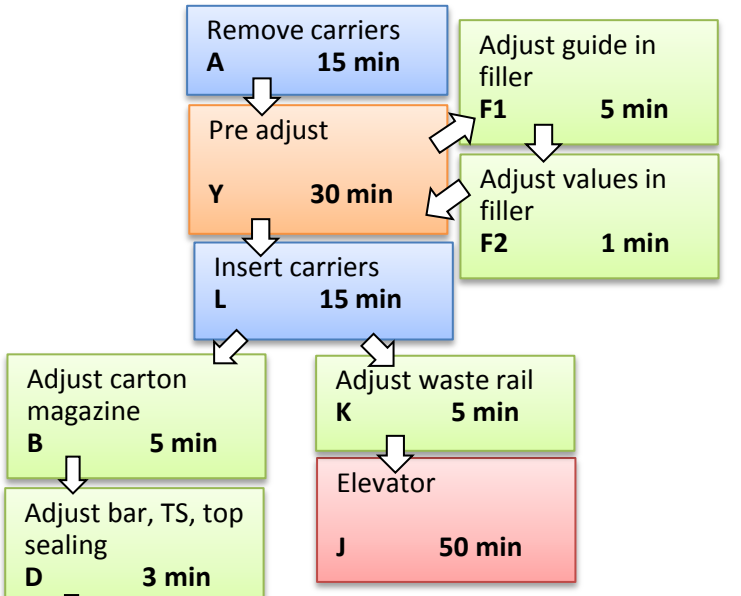
One arrow represents one operator

Appendix 10

Volume conversion with 4 persons from 390 ml to 500 ml



126 min



123 min

124 min

Total time:
126 minutes
2 hours and 6 minutes

One arrow represents one operator

Appendix 11, Project plan with GANTT-schedule

Projektbeskrivning examensarbete VT 2012

Student: Ellen Lindewall

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Titel på examensarbete: Tidsoptimering av volymombyggnation på Tetra Recarts Maskin TPR1

Uppdragsgivare: Tetra Recart

Handledare: Tomas Nilén, 046- 361529

Dan Haldeborg, 046 - 363601

Syfte med projektet:	Syftet är att effektivisera ombyggnadstiden mellan olika förpackningsvolymer på Tetra Recarts maskin TPR1. Att se var det finns utvecklingsmöjligheter samt se vilka tids och ekonomiska vinster det finns för kunderna. Även undersöka tidsåtgången med 1, 2, 3 eller 4 operatörer.
Förmodad metod:	LEAN & Six Sigma med viss anpassning för detta projektet
Kort summering av relevant litteratur:	Ombyggnadsmanual, Tetra Recart Produktionsutveckling, Monica Bellgran & Kristina Säfsten, Studentlitteratur 2005, upplaga 1:2, Ständiga förbättringar. Lars Sörqvist, Studentlitteratur, 2004, upplaga 1:5 Vad är LEAN?, Niklas Modig & Pär Åhlström, stockholm school of economics institute for research, 2011 Produktion, John Andersson, Bert Audell, Eric Giertz, Göran Reitberger. Nordstedts juridik, 1992
Tillgänglig data:	Ombyggnadsmanual, Tetra Recart. Den manual som medföljer till kund.
Nödvändiga faciliteter:	Tillgång till maskinen TPR1 krävs delvis samt närvaro vid en ombyggnation.

GANTT-schema

Vecka	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Uppstart av examensarbete																				
Ta fram preliminär rapportstruktur																				
Leta efter lämplig litteratur inom området produktionslogistik och optimering																				
Planlägg de olika ombyggningsmomenten																				
Medverka vid ombyggnation																				
Sammanställ insamlad information																				
Halvtidsredovisning																				
Uppskatta och optimera tidsåtgången för 1,2,3 & 4 operatörer.																				
Undersöka vad det finns för ekonomiska vinster för kunder genom tidsreducering																				
Rapportskrivning																				
Redovisning																				
UTEXPO																				