Reuse Concept
Vital Segments in a Clean in Place Project

by

Philip Granstrand
Alexander Werne

Department of Chemical Engineering
Lund University

June 2016

Supervisor: **Christian Hulteberg**
Co-Supervisors: **David Hellborg & Jan-Åke Nilsson, ÅF AB**
Examiner: **Professor Hans T. Karlsson**

Postal address
P.O. Box 124
SE-221 00 Lund, Sweden
Webb address
www.chemeng.lth.se

Visiting address
Getingevägen 60

Phone
+46 46-222 82 85
+46 46-222 00 00
Fax
+46 46-222 45 26

Preface

This paper is a Master's Thesis for Chemical Engineering at Lund University, Faculty of Engineering. The research was done at ÅF Food & Pharma in Malmö and carried out between January and June 2016.

First of all a special thanks to Jan-Åke Nilsson and David Hellborg at ÅF and Christian Hulteberg, assoc. prof. at Lund University for being helpful and supportive throughout the entire project. Additional gratitude to the co-workers at ÅF in Malmö for giving us a lot of joy and laughter.

Last but not least, a special thank you to Louise Olsson for being a loving other half. Philip, on the other hand, is appreciating you for being his medical guidance through thick and thin.

Abstract

The aim of this project was to examine if it is feasible to develop and apply a reuse concept regarding clean in place (CIP) processes. The concept is based on different topics such as limitation, structure, future and reliability. Three CIP processes were chosen to represent the wide variety of cleaning processes available to the food and pharmaceutical industries, Single use Food, Recovery Food and Single use Pharmaceutical. Each were developed according to a predetermined structure in order to cover all chemical engineering aspects of a project; process description, process flow diagram, calculations, heat and mass balance, piping and instrumentation diagram, component list, chemicals as well as sales and promotion.

The process description resulted in an overview of main features for each system. Heat and mass balances describes how the content and energy of the different flows are changing throughout a cleaning cycle. Differences and similarities between the examined systems are lucid through the P&IDs. The component list resulted in facilitation of documentation, design, purchasing and installation for the project. Quotation regarding the three systems were calculated and combined with reuse some costs are reduced or excluded. In order for a reuse concept to work, the CIP process must be sold in sufficient volume. Broadening the customer base from an international perspective is the best way to facilitate, maintain and sustain a recuse concept.

Time has been a limiting factor due to the versatile variation of systems included in the field of CIP. The sectioning concerning the three main systems has tough delivered a secure and fundamental base considering further work. One important segment, not included in the reuse concept is automation. The lack of automation is leading up to a reuse concept not covering the entire spectra. A corrective action is to use an automation engineer in order to get as much as possible of the software ready for being handled in a reuse concept. A CIP project have an obvious extent when studying application and area of usage compared with several other technologies. This is the logical explanation for why CIP projects are a good area trying out a reuse concept. Transferring the reuse concept to other projects could include problems not covered by this concept. A larger area of application are making unexpected events more realistic and project frames more obscure. Studying former projects in each area over time combined with inspiration from this CIP reuse concept as a foundation will hopefully generate a more efficient future way of working. A final conclusion regarding this project is in accordance to the Pareto principle, the reuse concept is making up 70 % of the results within 30 % of the time. This fact is pin pointing at the level of reliability, main segments in a CIP project are handled and included even though adaptions are requiring much time.

Table of Contents

Parameter list

m – Mass (kg)

A – Area (m^2)

z – Residue thickness (m)

F – Fouling factor

$\dot{m}$ – Mass flow (kg/s)

t – Time (min)

Q – Energies (kW, kWh)

$\dot{V}$ – Volumetric flow rate (dm^3/min)

ρ – Fluid density (kg/dm^3)

T – Temperature ($°C$)

Cp – Specific heat capacity ($kJ/kg°C$)

C – Cost (kr)

P – Price (kr)

f – Scale factor

V – Volume (dm^3)

Re – Reynolds number

d – Diameter (m)

v – Velocity (m/s)

μ – Dynamic viscosity ($Pa \cdot s$)

ΔP – Pressure (Pa)

λ – Moody's friction factor

L – Tube length (m)

ε – Pressure drop constant

X – Distribution factor

x – Fraction content

W – Required energy (kW)

E – Pump energy (kW)

1 Introduction

Today’s society is strongly influenced and affected by competitiveness within all branches of the industry. A vital factor is the time required to generate and submit your own company’s solution to an existing problem, especially concerning the consultancy business. The faster your proposal is delivered to the costumer, the greater is the chance your company ends up with order. This makes internal shift projects an important daily element in order to operate as efficient and proficient as possible. By starting and founding every new project upon a standard concept time and risks are reduced. A well-structured documentation will enhance the knowledge and efficiency of every participant. Clean in Place (CIP) projects are chosen to work as the experimental object due to its moderate consistent setup, the intention is to reach all vital aspects when handling a CIP project.

ÅF AB is a consultant company handling projects within energy, industry and infrastructure. There are essentially four different subdivisions within ÅF: Industry, Infrastructure, International and Technology. Each one of these divisions include a variety of more specific branches. ÅF was founded in 1895 and there are currently 8,000 people employed in 30 different countries around the world. This master thesis is carried out in the Industry division titled Food and Pharma at the ÅF office situated in Malmö.

1.1 Purpose and Aim

The aim with this master thesis is to examine if it is possible to obtain all clean in place process alternations within a standard reuse concept. The purpose of finding logical fragments, when put together covers a wide range perspective concerning knowledge and sales of a CIP system, is to help ÅF Industry match the unwritten laws of competitiveness. A future aim, if this concept works, is to base all projects in different divisions upon a standard concept.

By finding project fragments vital for giving correct and blanket information regarding CIP systems one will be able to answer the main problem statements in the project:

- Is it possible to cover all different CIP systems when handling a standard concept?
- How many different segments will this concept be based upon?
- How could a standard concept be transferred into the daily work of all different projects?
- Is the concept suggested reliable? If not, how should it be improved?

1.2 Scope

Since this project is carried out as a master thesis there is a fundamental time restriction, a master thesis shall correspond to twenty weeks of full time studies, which have been set as the period for this project.

Due to the predetermined time frame a scope concerning the amount of systems was set to three different versions; Single use Food, Recovery Food and Single use Pharmaceutical. These fixed systems will be further discussed in chapter 3 and 4.

One part of every industrial project today consists of automation. Through various control systems automation runs everything from lightning to valves, ventilation, machines and advanced industrial processes. The field of automation becomes constantly larger. Intelligent control of different systems is the best and easiest way to reduce energy consumption, environmental impact and optimize processes. Since automation is performed by automation-engineers with a background in electrical engineering this aspect is not included other than recovered costs regarding addressed CIP processes.

The various quotations and calculations are based on internal estimations regarding rates. These estimations are used to give a sales price comparable to previously sold processes.

Heat and mass balances as well as pressure drop calculations are performed only for the recovery system. Time was not enough for investigating small differences in this area. Consumptions calculations have been considered from both a Single use and a Recovery perspective. This is due to the fact of chemical reuse, this will have a large impact on the operation cost.

1.3 Disposition

The report begins in chapter two with a theoretical background covering the aspects of a CIP system that will be addressed in the project. Next chapter refers to how the problem statements will be solved through methodology, examined systems, calculations as well as heat and mass balances. Studied CIP processes combined with calculations and results regarding the overall reuse concept are presented and discussed in chapter four. Lastly a conclusion of the project and future work is presented in chapter five. Information that is relevant to the project but which is too large for the report are found in Appendix A – I.

2 Background

2.1 Cleaning In Place

2.1.1 Historical review

Clean In Place, or CIP, is a cleaning process that was first implemented in the late 1940s on farms and in larger process plants such as dairy plants in the 1950s (Seiberling 2007). During the past two decades, both the pharmaceutical and food industries have shifted towards CIP because of demands such as validation and verification regarding final product, durability and plant hygiene. CIP is therefore used in most dairies, breweries and processed food plants. CIP offers an identical cleaning each time it's used compared to manual cleaning (Seiberling 2007). To possess the highest standard of hygiene is the perquisite for any high quality product that will be consumed by humans.

2.1.2 Definition

There are several definitions of CIP, the National Dairyman's Association (Linda and Jay) defines CIP as:

The cleaning of complete items of plants or circuits without dismantling or opening of the equipment and with little or no manual involvement on the part of the operator. The process involves the jetting or spraying of surfaces or circulation of cleaning solutions through the plant under conditions of increased turbulence and flow velocity. (Tamime 2009)

2.2 Design

A CIP process with all its equipment and apparatus has the task of cleaning an object during a sequence consisting of different steps. The object is able to vary from a single piece of equipment to a whole up scaled process, below is a description of typical equipment included in a CIP process.

2.2.1 Structure

Depending on the object there are various constructions for a CIP process. It's up to each individual case to design the cleaning process in an optimal way. Characteristic parts that make up the body of the process and also generates different CIP sequences are tanks, heat-exchangers, pumps, control system and various measuring instruments.

Tanks

The purpose of storage tanks is to store raw material, reused solutions or any residual solutions. The number of storage tanks necessary depends largely on the number of substances used in the cleaning process along with the reuse of chemicals which in turn will need one storage tank per substance, A in figure 2.1. This means that in a system where no substance is reused only one storage tank is required, figure A in figure 2.2. The storage tank volume have an effect on pump and tube options since different amounts of liquid is supplied and returned through the system, thus the size of the storage tank has a great impact on the rest of the system.

Tubes

Tubes can vary in material depending on the area of application. For example is the hygiene requirements higher in the pharmaceutical industry compared to the food industry. The most common material is stainless steel, AISI304 or AISI316. An important factor is where the CIP process in placed related to the cleaning object because of the volume in the tubes. This affects the pumps and tank volume. A comparison between the cross sectional area of the CIP tubes and object tubes are performed. The tubes must be the same size to obtain the right turbulent velocity.

Heat exchangers

It is usually two different kinds of heat exchangers that is used in a CIP process, plate- or tube-in-shell heat exchanger. There is a large variety of different heat exchangers that is designed to maximize the heat transfer. Based on content plate or tube-in-shell heat exchanger is chosen. Usually only a small fraction of the flow contains particles which favors the plate heat exchangers (B in figure 2.1). Depending on availability, hot water or steam is used as a heating medium.

Pumps

Centrifugal- or liquid ring pumps are normally used in the process. The centrifugal pump use the centrifugal force in the liquid and requires a fluid pressure in order to work. The liquid ring pump works as a vacuum pump and has the ability to pump without any fluid pressure. Thus, the centrifugal pump is placed before the object and the liquid ring pump is placed after (C in figure 1.1).

Valves

The most commonly used valves are butterfly, seat and mix proof valves (D in figure 2.2). Valves is often a vital aspect due to hygienic demands. Butterfly valves are the least expensive but cannot guarantee equal safety as the expensive mix proof valves.

Control system

A well-suited control system is critical for a CIP process, without it managing the process the idea of CIP is difficult to uphold. The computer containing the different process sequences is called Programmable Logic Controller (PLC).

Measuring instruments

In order to control parameters and verify different conditions in the process various measuring instruments are used (E in figure 2.2). Controlled parameters are temperature, conductivity, flow, turbidity and fluid levels. (Hellborg 2016)

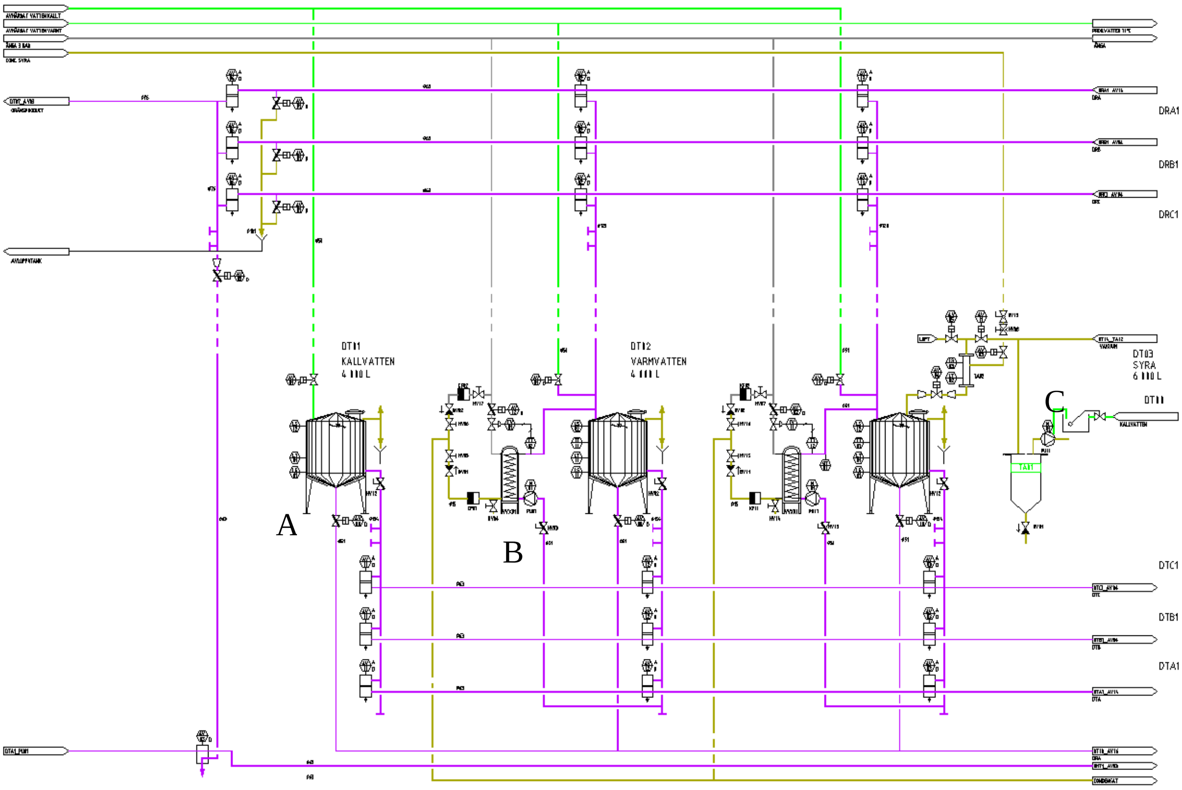


Figure 2.1. Full recovery (Nilsson 2016)

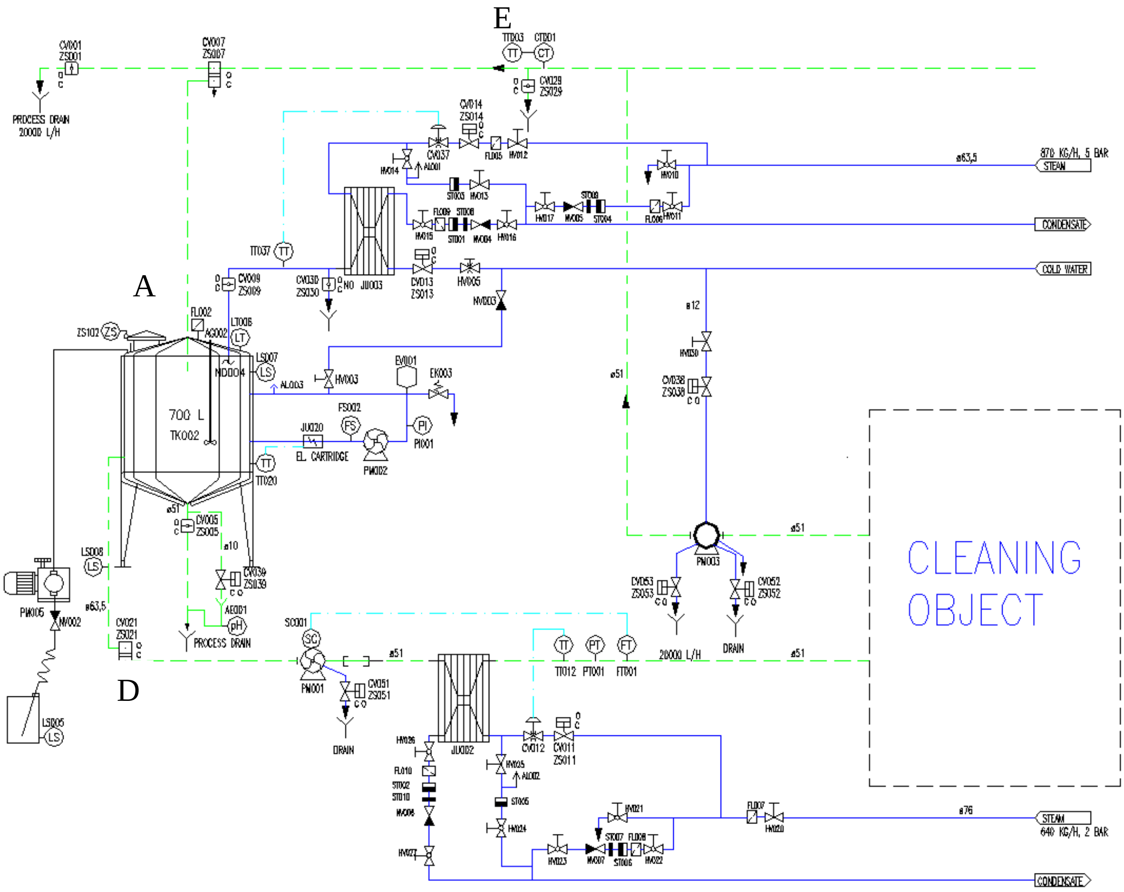


Figure 2.2. Single use (Nilsson 2016)

2.2.2 Hygienic design principals

Hygienic design principals are divided into three subgroups:

- Materials, refers to the CIP arrangement and must be resistant against both the product and the cleaning solutions at their efficient temperature, pressure and concentration. The material must not be toxic as well as smooth, non-porous and free from cracks.
- Equipment and fabrication, comprises of equipment specifications such as draining, avoiding stagnant points and sharp corners where product can accumulate. The equipment should also be designed to protect the product from external contaminations.
- Cleaning demands regarding CIP consists of being able to demonstrate that desired results have been achieved without dismantling the equipment.

It is difficult to fulfill the design principals when they are implemented in a CIP process and limitations often occur. The principals are defined separate from the production and they relate only to the CIP equipment. It is therefore important to understand the product; e.g. its thermophysical properties and how it interact with the equipment's geometry. (CCFRA 1983) (Holah 1998)

2.2.3 Construction material

The construction material must attain certain demands and be inert against the product during all of the different conditions during the process.

2.2.3.1 Stainless steel

There is a large variety of stainless steel used as construction material. The selection depends largely on how corrosive the product or the cleaning chemicals are. The most common is to use austenitic stainless steel that inhabits good mechanical properties, different varieties are:

- American International Standard Institute (AISI) 304, is economical and used in several different applications within the pharmaceutical- and food industry. It's corrosion resistant in most environments and is easy to weld and form.
- AISI 316, is of better than AISI 304 quality since molybdenum has been added to increase the corrosion resistance.
- AISI316L, has a reduced amount of carbon compared to AISI 316 which facilitates welding.

All types of stainless steel is sensitive towards corrosion in the presence of chlorine (Tuthill 2000). Corrosion occur in various forms but is generally located and affected by different factors such as chemical environment, pH, temperature, fabrication method, oxygen concentration, surface finish and shear stress.

2.2.3.2 Plastics

Various forms of plastics are used in the CIP process and must be approved to handle different conditions such as pressure, temperature, concentration. (Tamime 2009) An example of a plastic material is polytetrafluoroethylene (PTFE), an attractive material due to its high chemical resistance.

2.2.3.3 Elastomers

There are different kinds of elastomers used in gaskets, joints and fastenings. These rubber based components are widely used for their high elasticity and ability to return to its original form after being exposed to stress. (H. L. M. Lelieveld 2014) Commonly used elastomer are fluoroelastomers, nitril- or silicone rubber. All elastomers have to eventually be replaced depending on usage, increased temperatures and aggressive chemicals in the cleaning process affect the durability.

2.2.3.4 Surface finish

The surface that the product comes in contact with must be non-porous, smooth, easy to clean and be free of irregularities such as crevices, folds and pits (Cocker 2003). It's widely accepted that a rough surface contributes to a longer cleaning time.

2.2.3.5 Joints

Joints can be broken down into permanent joints and dismountable joints, for example welds and tube couplings. A general rule regarding CIP design is to use welding where it's possible and to use tube couplings only when it's necessary, for example where components need to be removed for repair or inspection.

2.2.4 Construction features

This section aims to briefly discuss general construction features regarding drainage, corner angles and dead spaces.

All surfaces in the process needs to be able to drain since remaining liquids lead to bacterial growth or contamination of cleaning solutions. Insufficient draining can also lead to increased corrosion, especially if there is heat involved in the process.

Corners and angles ought to be radiussed (smooth-edged) in order to facilitate cleaning. The minimal radius of a corner is 3 mm but should be larger or equal to 6 mm. If the process requires a smaller radius than 3 mm must the other design compensate for the reduced level of cleanability (Tamime 2009)

Dead spaces are areas outside the primary flow where fluids accumulate and remain during a longer period of time and result in microbial growth as well as contamination of the flow. It is hard to clean dead spaces due to the lack of fluid motion within. The part of a tube that constitutes a dead space cannot be longer than three times the diameter of the tube. (Pak 2015) (Brolund 2016)

2.3 CIP Process

A cleaning cycle consist of several steps: product recovery, pre-rinse, circulation of detergent, intermediate rinse, final rinse and disinfection.

2.3.1 Product recovery

The aim of this step is to remove remaining large residues in the process. The idea is to facilitate the remaining cleaning steps and be able to use detergents more efficiently. Minimization of product loss and a reduction concerning the load on the sewer system are two additional reasons product recovery is important to perform (Bylund 2015). The procedure is carried out by using water or compressed air. The residues from the process can either be pumped to the sewer or to a storage tank for further process into new products or animal feed.

2.3.2 Pre-rinse

Rinsing with water is commonly the first step in the official cleaning cycle. The water can either be fresh or recovered from a previous cleaning cycle (Nilsson 2016) . Pre-rinsing occurs after finished production in order to reduce the amount of residue that otherwise would attach to the process equipment. Hot or cold water is normally used depending on the cleaning object. (IDF 1979) The pre-rinse stands for a large part of the overall cleaning process. Up to 90% of the uncrusted residues and 99% of the total residues can be removed through pre-rinsing. (Bylund 2015)

2.3.3 Circulation of detergent

In order obtain the right degree of purity regarding particles and contaminations, lye and acid are used. If the surface is warm lye is circulated followed by acid, meanwhile for cold a surfaces, only circulation of lye is necessary. Concentration, temperature, mechanical force and time are four parameters that needs to be controlled in order to obtain sought cleaning results (Sinner circle 2.4.1). (IDF 1979) As a general rule, lye should have the same temperature as the product or at least 70 ˚C. The acid should be used between 68-70˚C (Bylund 2015).

When detergents are reused, the concentration is important and is measured through conductivity. When the right concentration interval is obtained, the detergent is circulated over the object and CIP unit before it is pumped back to the CIP unit for reuse. (Nilsson 2016)

2.3.4 Intermediate rinse

Since lye and acid are used, a cleaning cycle is requiring an intermediate rinse with water. The reasons are increased efficiency in each individual cleaning and increased purity in reused cleaning solutions. The water can be either new or reused from a previous step.

2.3.5 Final rinse

The final rinse aim to remove all remaining detergent and the conductivity is measured in order to obtain how clean the water is. At the end of the cycle when the water is clean it can either be discarded or collected in a pre-rinse tank until following cycle. (SPX 2014) A final drainage of the process is performed in order to guaranty the removal of water and chemicals. To prevent bacterial growth, phosphoric- or citric acid can be added. By reducing pH ($pH < 5$), bacterial growth becomes inhibited. (Bylund 2015)

2.3.6 Disinfection

After the final rinse, the process is often visually, chemically and bacterially clean. Disinfection is therefore an option for processes where bacterial purity is of prime interest. Disinfection can either be thermal or chemical. Thermal disinfection involves circulation of 90-95˚C water while chemical disinfection refers to circulation of hydrogen peroxide (H_2O_2), chlorine (Cl) or iodine (I). Both alternatives are followed by rinse with clean water. Disinfection is carried out before production starts and is the last stage in a CIP cleaning cycle. (Bylund 2015) (SPX 2014).

2.4 Chemicals

The cleaning process aims to remove residue, generally consisting of water scale or product residue. Residue is divided into two types, either soluble or insoluble in water. Examples of water-soluble residues are salt and sugar which are easy to remove. Water-insoluble residues are often harder to remove and can be divided into organic and inorganic residues. Organic residue are comprising of matter from animals and plants, e.g. fat, protein, starch and carbohydrates. If subjected to heat, organic solids will form carbon deposits, which can be difficult to remove. Inorganic residue are deriving from the earth's crust and the most common example is lime deposits from water. Some types of water-insoluble residues are transformed into water-soluble by changing the properties of the residue using a chemical reaction. (Romney 1990)

By far the most frequent technology regarding CIP cleaning is the use of detergents, lye and acid, through suspension cleaning: the chemical composition of the residue is not changing and a water-based solution is able to remove water-insoluble residue. The cleaning solution needs to wet the cleaning object and penetrate through the whole layer of residue. These functions are achieved through the use of chemicals, the surface tension of the water is reduced so it can spread across and through the residue. The detergent then lift the residue from the cleaning object and suspend it within the cleaning solution. This prohibit the residue from redepositing in another part of the process. (Tamime 2009)

2.4.1 Sinner Circle

In order to obtain a clean process, the adhesive forces of the residue must be overcome (figure 1.6). The four parameters that making up cleaning are:

- Mechanical force
- Thermal force
- Chemical force
- Time

These parameters are connected and depend on each other, this means that changing one will affect the cleaning result if other three isn't adjusted. This relationship is described in the so-called Sinner circle (figure 2.3).

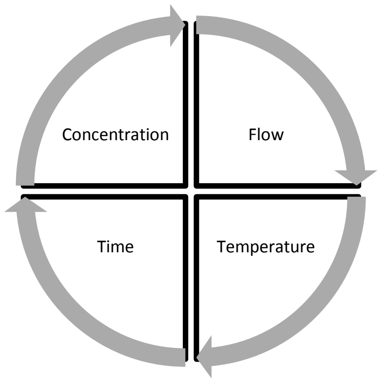


Figure 2.3. Relationship between parameters in the Sinner Circle. (Pak 2015)

Mechanical force

The mechanical force involving in a CIP process consists of shear stress. This is created by the turbulence in the flow and can be regulated through the pumps. The flow must be turbulent and with a velocity between 1.5-2 m/s in order to achieve sufficient shear stress. Velocities above 2 m/s do not contribute to a higher efficiency of the cleaning process.

Thermal force

The thermal force is based on that molecules moves faster at a higher temperature and increases the efficiency of the detergent. A general rule is to clean the process at the same temperature as during production. A too high temperature can become contra-productive to the cleaning process, the residue can cling harder to equipment and the detergent can become less effective.

Concentration

Having the right concentration of the detergent is the most crucial aspect of the cleaning process. All detergents have an optimal concentration generating the best cleaning result. A lower concentration facilitates inferior results; a higher concentration facilitates unnecessary detergent loss.

Time

The time it takes for other parameters to be affective determine the efficiency of the cleaning process. Most surfaces eventually become clean using all parameters, but neglecting optimal flow, temperature or concentration have a great impact on the cleaning time. (Pak 2015)

2.4.2 Water

Water works in many ways as a universal solvent; it can suspend, disperse or dissolve organic and inorganic material. It can also dissolve chemicals and residues, contributing the use of water as a carrier and a medium in a CIP process. The water carries energy (thermal and mechanical) and detergent to the residue and removes it. Thus, the water becomes a very important part of the cleaning solution and act almost as a chemical within the cleaning solution. Because excellent solvent properties of water it is rarely found accessible in its pure form. It is often containing impurities or contaminations such as gases, liquids, solids or micro- and macro organisms. These components can, in combination or individually, cause problems during a CIP process.

2.4.3 Lye

Sodium hydroxide (NaOH) is a strong alkaline frequently used in CIP processes due to its low cost and high strength. NaOH removes fatty oils and proteinaceous residues through saponification but is corrosive to many surfaces and has a deleterious effect on soft metals. Dilution in hard water will contribute to calcium and magnesium scale. NaOH does not inhibit good free-rinsing features and is difficult to remove from surfaces after cleaning. Despite these drawbacks NaOH are used in many industries where cleaning solutions is applied by spray or circulation. (Tamime 2009)

2.4.4 Acid

There are several different acids used in CIP processes compared to lye where NaOH is predominantly used. The most commonly used acids are nitric and phosphoric acid. The aim is to remove scale, often in diaries and at a lower operational temperatures compared to lye. Nitric and Phosphoric acid have a degrading on pumps and valves seals. (Stephan 2011)

2.4.5 Disinfection

The aim of disinfectants are to remove and destroy microorganisms, which are either contaminations or product residue, in order to ensure hygiene demands. Temperature and pH are two parameters that affect the disinfection result, higher temperature and lower pH increase the efficiency. A third parameter is initial degree of purity, if there is any organic residues, the disinfectant effectiveness will be greatly reduced. By performing disinfection as the last stage in a CIP cleaning cycle the highest initial degree of purity is ensured.

In order to be active, the disinfectants must be effective against a variety microorganism in low concentration. It must also be non-corrosive, odorless, stabile during storage and bactericidal within the predetermined time frame. The disinfectant must not be deactivated by other process equipment and have a good wetting ability. Disinfectants can be classified as either thermal or chemical.

Heat in the form of steam, water or air can be used as a thermal disinfectant. These are often more expensive than chemical disinfectants and can be difficult to use, especially in open systems. Other drawbacks with thermal disinfection is the degradation of rubber elasticity, hot equipment and requires more time. Chemical disinfectants react with the microbial cell wall through an oxidation reaction. Either the ability to absorb nutrients is reduced or the cell wall is destroyed. Both cases result in the elimination of the organism. An example of a disinfectant is Oxonia, it has a low pH and is based on Peracetic acid and Hydrogen peroxide (Ecolab 2003). (Banner 1998)

2.4.6 Additives

By adding additives the detergent properties can be improved. pH is neutral and enhances anti-foaming qualities through the use of surfactants and sequestrants (Chemex 2015). The goal of a surfactant (polyethylen glycole, PEG) is to make water-insoluble deposits soluble in water. Sequestrants (EDTA) aims to prevent the precipitation of hard water scale. (Tamime 2009)

2.5 Contaminations

The CIP unit is handling three different variations of contaminants; physical, chemical and microbiological. Fouling is defined as an accumulation of undesirable material on solid surfaces and is briefly examined in this chapter.

2.5.1 Physical contaminants

Within industry, physical contaminants are often termed physical bodies and are frequently deriving from:

- Leaves, stalk and other inessential pieces of plats material.
- Residue and stone associated with harvested fruit and vegetables.
- Bone and tissue from raw meat
- Insect and animal parts or residues in ram material or resulting from infestation during processing.

Synthetic material as glass, metal and plastic fragment are also included in physical contaminants. By having a god praxis concerning suppliers both the variation and number of physical contaminants could be reduced. (C 2000)

2.5.2 Chemical contaminants

These pollutants are sharing three features; they are not deliberately added to product, contamination could occur at one or several steps in the process and illness development if enough amount of the product is consumed. Different chemical pollutants are usually deriving from either naturally occurring toxicants, chemical formed during processing, migration from packaging or residues of cleaning and sanitation chemicals.

2.5.3 Microbiological contamination

A microbiological pollutant is generally undetectable by the human senses due to no product change in whether color, taste or smell. Microbiological pollutants are multiplying exponentially under correct conditions and the growth rate is depending on several factors:

- Temperature
- Humidity
- Water activity
- pH
- Access to nutrients
- Aerobic or anaerobic factors

These factors are more or less vital depending on specific microbiological growth and depend on each other. (H. L. M. Lelieveld 2014)

2.5.4 Fouling

The problem surrounding the degree of purity regarding CIP processes are often based on fouling, without fouling the need for cleaning would be small. This process involves a number of steps:

- Surface conditioning
- Mass transfer of species to the surface
- Surface deposition
- Deposit aging
- Possible removal

A lot of different kinds of process industries have fouling problems. The most usual are stated below.

- Protein and mineral deposition in heat exchanges
- Ice buildup in freezers
- Scale buildup in cooling water systems
- Fat burn-on in ovens
- Product solidification
- Growth of biofilm
- Accumulation of material in stagnant of low-flow areas of equipment
- Loss of membrane activity

(Kylee R. Goode 2013)

2.6 Regulations

To facilitate cross-border regulations EU legislation is used. Hygiene legislation and other vital regulations are described in the *General Food Law* (GFL) from 2002. The private sector has its own interpretation concerning legislation within the food industry, these document are similar to the GFL and includes:

- International Featured Standard (IFS)
- International Organization for Standardization (ISO 22000)
- Food Safety System Certification (FSSC 22000)

(H. L. M. Lelieveld 2014)

The EU legislation 2001/83 are mediating guidelines within the pharmaceutical industry by regulating registration and production regarding pharmaceuticals. Good Manufacturing Practice (GMP) is an important document controlling manufacturing including packing, personnel education and working conditions. EU is constantly making new updates of the GMP to assure it is keeping up with society and its development. (Albrecht and Joachim 2007)

3 Method

A description of the project sectioning as well as calculations are described below and are divided into five segments:

- Methodology
- Standard systems
- System boundaries
- Calculations
- Heat and Mass balances

3.1 Methodology

The first part of the project consisted of research around CIP and writing a literature review. The research is focusing on the food- and pharmaceutical industry. It was conducted by reading and compiling information from scientific articles, textbooks and interviews. The interviews was carried out with staff from ÅF and the Institution of Food Technology at LTH. The aim of the research was to understand the overall CIP process and parts within the process that could be altered for a reuse purpose.

Three study visits were conducted to gain an insight regarding design and operation. The visits covered two pharmaceutical industries and one food industry: McNeil, Christian Hansen and Unilever. McNeil and Christian Hansen operate smaller Single use CIP processes and is subjected to GMP while Unilever operates a large, less regulated recovery CIP process. The focus of the visits were to examine differences and similarities between the processes and discuss the extent of variations.

How to approach the Reuse project was discussed and agreed upon by the projects supervisor and co-supervisor. Three different CIP processes were chosen in order to gain large variations and applications for the project; Single use Food, Recovery Food and Single use Pharmaceutical. Single use Food and Recovery Food covers the food industry while Single use Pharmaceutical covers the pharmaceutical industry. In order to obtain a logical structure for the project eight steps for each of the three addressed CIP processes were included:

1. Process description
2. Process flow diagram (PFD)
3. Calculations
4. Heat and mass balance
5. Piping and instrumentation diagram (P&ID)
6. Component list
7. Chemicals
8. Sales and promotion

The PFDs and P&IDs was created in AutoCAD. This is a computer-aided design program that is used to produce drafting and design in 2D and 3D. The P&IDs was drawn with different layers, meaning that the processes can change to a customer's specification. This facilitate how a process is presented to a promising customer. Calculations were made in Microsoft Excel to simplify modifications and providing a consistent structure.

Interviews were conducted throughout the project, both with relevant employees and external companies. During the first five parts (1-5), interviews included co-supervisors and supervisor. Knowledge about chemicals was gained through interviews with an external company focusing on the subject. The sales documentation was created by spreadsheets combined with interviews with co-supervisors, automation, installation and sales personnel.

3.2 Standard systems

As discussed previously, by trying to reach a reasonable project scope three main systems has been chosen to handle. In similar projects the long-term ambition is always to include all variations and differences. In an early stage with a restricted time frame it is though more important getting through all project steps and taking analysis into account. For this reason, a basic sectioning using three fixed systems to start from was feasible. The choice with reference to standard systems are made in order to meet as much of the variations as possible.

3.2.1 Single use Food

The first system is small handling the food industry and its demands regarding CIP. It is based upon one tank and one circuit. A small single use system is usually placed at small capacity production sites, for example dairies operated by local farmers.

3.2.2 Recovery Food

Using a system more complex and larger includes a lot of variations not covered by a Single use system. The basic configuration is including six tanks and three circuits in order to clean several objects simultaneously. If there is a high frequency regarding cleaning i.e. a large usage of chemicals and water, a system taking recycling into account is most suitable. The Recovery system is primarily utilized in the food industry concerning large production sites.

3.2.3 Single use Pharmaceutical

The other sector often handling CIP systems are the pharmaceutical sector. Due to higher regulation, compared with the food sector, there are no need of Recovery systems but only single use. There are differences relating to the single uses systems chosen to be a part of the project even though the basic configuration is identical.

3.3 System boundaries

Calculations are based on one of the three main systems: the recovery system in figure 3.1. The configuration is furthermore to include an object, which practically is a food or pharmaceutical production process. This object is assumed to be filled with whole milk (3%).The tube diameter together with the ingoing flow are resulting in the predefined flow velocity of 2 m/s. All assumptions are produced in collaboration with ÅF personnel.

The object is based upon three main fragments:

- 100 m supply tubes
- 100 m return tubes
- 1 tank (20 m^3)

Initial system data are stated below:

- Tube diameter – 51 mm
- Ingoing flow – 14,700 dm^3/h

- Initial lye proportion – 0.015
- Initial acid proportion – 0.01
- Lye dosage pump – 0.07 kg/s
- Acid dosage pump – 0.055 kg/s
- Cleaning temperature
  - Pre-rinse 40˚C
  - Lye circulation 75˚C
  - Intermediate rinse 40˚C
  - Acid circulation 65˚C
  - Intermediate rinse 40˚C
  - Disinfection 90˚C
  - Final rinse 10˚C
- Residue temperature
  - Pre-rinse 3˚C
  - Lye circulation 40˚C
  - Acid circulation 75˚C
  - Disinfection 65˚C
- Temperature drop of 3˚C over object.
- Cycle times
  - Pre-rinse 5 min
  - Lye circulation 20 min
  - Intermediate rinse 5 min
  - Acid circulation 15 min
  - Intermediate rinse 5 min
  - Disinfection 10 min
  - Final rinse 5 min

Not all steps are assumed to clean the object. Cleaning steps regarding the calculations are pre-rinse, lye circulation, acid circulation and disinfection while the intermediate rinses and final rinse are assumed to cleanse the system from previous stage.

Calculations, based on above mentioned system boundaries, arranged later in the chapter are taking the following aspects into account:

- Amount of residue, milk
- Consumption of energy, water and chemical per cycle
- System pressure drop
- Heat and mass balances

The consumption calculation is actually including both Recovery and Single use data. This is done since the greatest divergences between Recovery and Single use systems are to be found concerning the consumption of water and chemicals and needed to be emphasized. Regarding heat and mass balances as well as pressure drop the variation of systems are not significant.

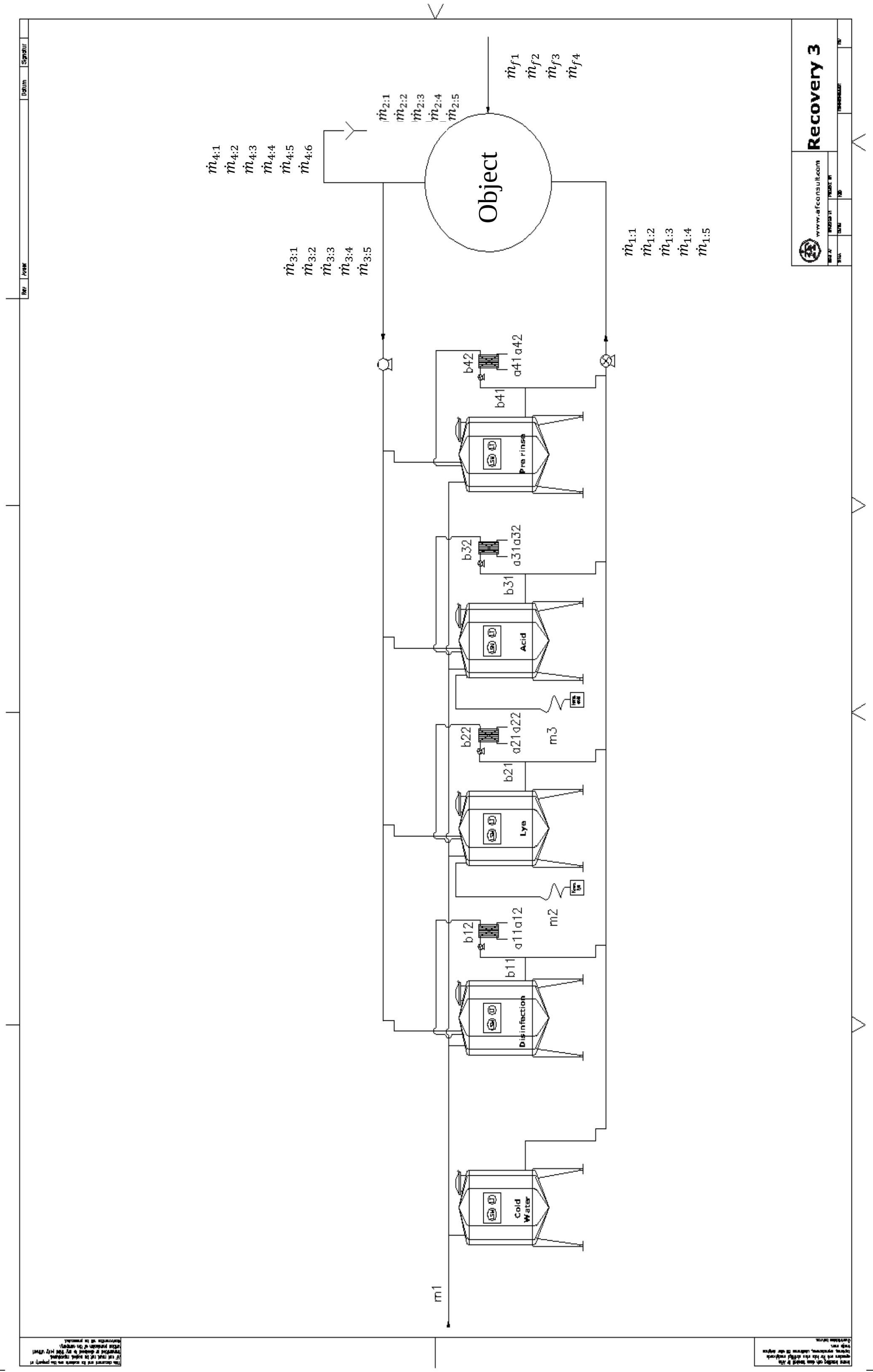


Figure 3.1. System used in calculations

3.4 Calculations

Calculations based upon the system boundaries specified in the recent section (3.3) are including estimations relating to:

- Residue quantity
- Consumption during a cycle
- System pressure drop

3.4.1 Residue

In order to perform heat and mass balances, the flow rate of residue needs to be determined. Removing residue is the main intention of the CIP cleaning and before the production process is able to start again a complete residue removal is required.

The amount of residue remaining in the system when the CIP process begins is described in equation (1), expressed in kg.

$$m_{\text{residue}} = (A_{inner\ tube} \cdot z_{\text{residue}\ thickness} + A_{inner\ tank} \cdot z_{\text{residue}\ thickness}) \cdot \rho_{\text{residue}} \qquad (1)$$

Quantity of removed residue per step in the CIP cycle is described in equation (2), expressed in kg.

$$m_{removed\ \text{residue}} = m_{\text{residue}} \cdot F_f \qquad (2)$$

The assumed flow rate of residue per step in the CIP cycle is described in equation (3), expressed in kg/s.

$$\dot{m}_{\text{residue}} = \frac{m_{removed\ \text{residue}}}{t_{stage} \cdot 60} \qquad (3)$$

3.4.1.1 Assumptions

When calculating the amount and rate of residue, assumptions has been made. Assumptions are made due to lack of process specifications as well as project time and are shown below.

- Tube length (200 m)
- Tube diameter (0,051 m)
- Tank height (3,8 m)
- Tank diameter (2,6 m)
- Tank thickness (0,002 m)
- residue thickness (0,001 m)
- Constant density within examined temperature interval.
- Residue consist of whole milk and is evenly distributed in the object.
- Terms of residue is assumed to be flows.
- CIP cycle times.
- Residue factor (0-1)

3.4.2 Consumption

Calculations are based upon Single use and Recovery data. Vital aspects handled in this chapter are consumption of energy, water and chemicals per cycle. The energy calculations consisted of two parts, heating and electricity. Heating is required to heat the fluids as well as equipment in the process. Electricity calculations describe the amount of required electricity from the pumps to circulate the fluids through the process.

The time of a CIP cycle is divided into eight steps, which in turn is consisting of three parts. The required time to heat the fluid, required time to circulate water as well as detergent and required time to heat the cleaning object, which often is cold from previous production. Required time to heat the cleaning object is often seen as an interphase that ensures as little detergent loss as possible. The mentioned times are used throughout the consumption calculations.

The volume of water used in a CIP process is calculated with different times and constants to simulate the difference between singe use and recovery. Amount of chemicals is also based on constants as well as the volume of water used in the different detergent steps.

Energy

The energy required to heat the flow in each step of the CIP cycle is described by the general equation (4), expressed in kW.

$$Q_{heating\ fluid} = \frac{\dot{V} \cdot \rho_{water} \cdot Cp_{water} \cdot (T_{initial} - T_{final})}{60} \quad (4)$$

Energy required to heat the steel in the object from its original product temperature for each step in the CIP cycle is described in equation (5), expressed in kJ/min.

$$Q_{object} = m_{steele} \cdot Cp_{steel} \cdot (T_{initial} - T_{object}) \quad (5)$$

The amount of energy that is transferred from the flow to the steel before the temperature signal send indications that the flow requires heating is described in equation (6), expressed in kJ/min.

$$Q_{loss} = \dot{V} \cdot \rho_{water} \cdot Cp_{water} \cdot \Delta T_{signal} \quad (6)$$

Required energy from the heat exchanger to heat the flow in each step is the difference in energy between equation (5) and (6). This is presented in equation (7), expressed in kW.

$$Q_{heat\ exchanger} = \frac{Q_{object} - Q_{loss}}{60} \quad (7)$$

Energy required to heat the fluid for all CIP steps is described in equation (8), expressed in kWh.

$$Q_{heating\ fluid} = \frac{Q_{heating\ fluid} \cdot t_{heating\ fluid}}{60} \quad (8)$$

Energy required to heat the equipment for all steps is described in equation (9), expressed in kWh.

$$Q_{heating\ equipment} = \frac{Q_{heat\ exchanger} \cdot t_{equipment}}{60} \quad (9)$$

Required energy demand per stage in the cycle is presented in equation (10), expressed in kWh.

$$Q_{heating\ per\ stage} = Q_{heating\ equipment} + Q_{heating\ fluid} \tag{10}$$

The cost for heating for each step is calculated in equation (11), expressed in kr.

$$C_{heating} = \left(Q_{heating\ equipment} + Q_{heating\ fluid}\right) \cdot P_{steam} \cdot f_{recovery} \tag{11}$$

Amount of electricity required for the pump to circulate the fluids from each step during heating before being forced towards the object is described in equation (12), expressed in kWh.

$$Q_{electricity-fluid} = \frac{Q_{pump} \cdot t_{heating\ fluid}}{60} \tag{12}$$

Amount of electricity required for the pump to circulate the fluids from each step to heat the equipment is described in equation (13), expressed in kWh.

$$Q_{electricity-equipment} = \frac{Q_{pump} \cdot t_{equipment}}{60} \tag{13}$$

Amount of electricity required for the pump to circulate the fluids for each step between the CIP unit to the object during the actual cleaning is described in equation (14), expressed in kWh.

$$Q_{electricity-steady} = \frac{Q_{pump} \cdot t_{stage}}{60} \tag{14}$$

Total electricity demand per stage in the cycle is presented in equation (15), expressed in kWh.

$$Q_{electricity\ per\ stage} = Q_{electricity-fluid} + Q_{electricity-equipment} + Q_{electricity-steady} \tag{15}$$

Total electricity cost for each step in the cycle is presented in equation (16), expressed in kr.

$$C_{electricity} = Q_{electricity\ per\ stage} \cdot P_{electricity} \tag{16}$$

The total energy demand in the cycle comprises of both heating and electricity, this is presented in equation (17) expressed in kWh.

$$Q_{total\ per\ cycle} = \sum Q_{heating\ per\ stage} + \sum Q_{electricity\ per\ stage} \tag{17}$$

The total cost for energy in the CIP cycle comprises of both heating and electricity, this is presented in equation (18) expressed in kr.

$$C_{energy\ per\ cycle} = \sum C_{heating} + \sum C_{electricity} \tag{18}$$

Water

The amount of water used in each step is described in equation (19), expressed in dm^3.

$$V_{water} = \dot{V} \cdot t_{stage} \cdot f_{reuse} \cdot f_{proportion,water} \tag{19}$$

Cost for water in each step is presented in equation (20), expressed in kr.

$$C_{water\ per\ stage} = V_{water} \cdot P_{water} \tag{20}$$

Total cost for water in the CIP cycle is presented in equation (21), expressed in kr.

$$C_{water\ per\ cycle} = \sum C_{water\ per\ stage} \tag{21}$$

Chemicals

The amount of detergents used in each step is described in equation (22), expressed in *l*.

$$V_{chemicals} = f_{proportion,chemicals} \cdot V_{total} \tag{22}$$

Total cost for detergents in each step in the CIP cycle is presented in equation (23), expressed in kr.

$$C_{chemicals\ per\ stage} = V_{chemicals} \cdot P_{chemicals} \tag{23}$$

Total cost for chemicals in the CIP cycle is presented in equation (24), expressed in kr.

$$C_{chemicals\ per\ cycle} = \sum C_{chemicals\ per\ stage} \tag{24}$$

Assumptions

When calculating the consumption of energy, water and chemicals assumptions has been made. Assumptions are made due to lack of process specification as well as project time perspective and are shown below.

- Tube length (200 m)
- Tube diameter (0,051 m)
- Tube thickness (0,0013 m)
- Tank height (3,8 m)
- Tank diameter (2,6 m)
- Tank thickness (0,002 m)
- Electricity cost (1 kr/kwh)
- Water/steam cost (0,13 kr/kwh)
- Cold water price (0,01 kr/l)
- Lye price (7,35 kr/l)
- Acid price (5,25 kr/l)
- Constant flow velocity (2 m/s)
- CIP cycle times
- CIP cycle temperatures
- Temperature drop of 3˚C over object.
- No energy transfer to surroundings.
- Constant densities within examined temperature interval.
- Constant specific heat capacity within examined temperature interval.
- Reuse factor (0-1)

- Proportion factor (0-1)
- Constant pump output (6 kW)

3.4.3 Pressure drop

Pumps are essential concerning the transportation of fluids and together with ÅF Industry a section concerning pump models was agreed upon. The pressure drop is unaffected by the choice of CIP system and calculations aims to provide a general basis for how the pressure drops varies in tubes, tanks and components. The calculations is divided into supply, return, drainage and is based on equations below.

The dimensionless Reynolds number for the five selected tube diameters is described by equation (25).

$$Re = \frac{d \cdot v \cdot \rho}{\mu} \tag{25}$$

Pressure drop in straight tubes, bends and valves for selected dimension is described in equation (26), (27) and (28) and expressed in Pa.

$$\Delta p_{pipes} = \lambda \cdot \left(\frac{L_{supply\,/return}}{d}\right) \cdot \left(\frac{\left(\frac{\rho \cdot v^2}{2}\right)}{2}\right) \tag{26}$$

$$\Delta p_{bends} = \frac{\varepsilon_1 \cdot \rho \cdot v^2}{2} \tag{27}$$

$$\Delta p_{valves} = \frac{\varepsilon_2 \cdot \rho \cdot v^2}{2} \tag{28}$$

The total pressure drop for each dimension is described by equation (29), expressed in bar.

$$\Delta p_{total} = \Delta p_{pipes} + \Delta p_{bends} + \Delta p_{valves} + \Delta p_{tank} + \Delta p_{heat\ exhanger} \tag{29}$$

3.4.3.1 Assumptions

When calculating the pressure drop, assumptions has been made. Assumptions are made due to lack of process specification as well as project time perspective and are shown below.

- Constant flow velocity
- Tube length supply (100 m)
- Tube length return (100 m)
- Tube length drain (40 m)
- Kinematic viscosity (0,001005 kg/m·s)
- Pressure drop constant over the system (ε)
- Pressure drop over tank (2 bar)
- Pressure drop over heat exchanger (0,3 bar)
- Amount of T-sections, narrow and rounded tube bends
- Constant density

3.5 Heat and Mass balances

Heat and mass balances are done at start up in a cycle but also during operation. Balances have been calculated for each step in the recovery process. Energy balances have been arranged in two ways, one is over the CIP unit when heating and pumping fluids in the system. The other one is over the assumed object showing loss of energy.

3.5.1 Startup

Startup is representing only a small fraction of the overall process cycle. It is though requiring a large energy demand due to the low temperature of the commodities.

Mass balance

The general mass balance is found in equation (30).

$$Input = Output + Accumulation - Production \tag{30}$$

Since no chemical reaction is taken into account, the production term is excluded. Due to cleaning the accumulation term has the opposite sign contrary to normal balances, equation 31 and 32.

$$Input = Output - Accumulation \tag{31}$$

$$Input + Accumulation = Output \tag{32}$$

The accumulation term is set as a flow rate going into the object, m_f (33).

$$\dot{m}_{in} + \dot{m}_f = \dot{m}_{out} \tag{33}$$

The flow rate going back to the CIP unit is m_3 and is expressed in equation (34).

$$\dot{m}_3 = X_{reuse} \cdot \dot{m}_{in} + X_{reuse} \cdot \dot{m}_f \tag{34}$$

The flow rate going toward drainage is m_4 and is expressed in equation (35).

$$\dot{m}_4 = X_{drainage} \cdot \dot{m}_{in} + X_{drainage} \cdot \dot{m}_f \tag{35}$$

To get fractions after the object equations 36 and 37 are used.

$$x_{out} = \frac{\dot{m}_{in} \cdot x_{in}}{\dot{m}_{in} + \dot{m}_f} \tag{36}$$

$$\dot{m}_{in} + \dot{m}_f = \dot{m}_{out} \cdot x_{1,out} + \dot{m}_{out} \cdot x_{2,out} + \dot{m}_{out} \cdot x_f \tag{37}$$

Unit heat balance

Heat balances over the CIP unit is describing needed work concerning heating and pumping. The overall equation is stated in equation 38, and the specific balance for each step is in equation 39.

$$Input + Work = Output + Pump\ energy \tag{38}$$

$$\dot{m}_{in} \cdot Cp_{in} \cdot T_{in} + W_1 = \dot{m}_{out} \cdot Cp_{out} \cdot T_{out} + E \tag{39}$$

Object heat balance

Heat balances over the object is describing the energy loss in each step. Equation 40 is showing the overall balance. Equations 41 is referring to when no cleaning is taking place, and equation 42 is referring to when cleaning is taking place.

$$Input = Output + Energy\ loss \tag{40}$$

$$\dot{m}_{in} \cdot Cp_{in} \cdot T_{in} = \dot{m}_{out} \cdot Cp_{out} \cdot T_{out} + W_2 \tag{41}$$

$$\dot{m}_{in} \cdot Cp_{in} \cdot T_{in} + \dot{m}_f \cdot Cp_f \cdot T_f = \dot{m}_{out} \cdot Cp_{out} \cdot T_{out} + \dot{m}_{drain} \cdot Cp_{out} \cdot T_{out} + W_2 \tag{42}$$

3.5.2 Operation

The operation is representing a larger portion of the overall process cycle. Not as large temperature difference as in startup is handled concerning the operation stage.

Mass balance

The general mass balance is found in equation (43).

$$Input = Output + Accumulation - Production \tag{43}$$

Due to the assumption of neither a chemical reaction nor accumulation, the production term and the accumulation term is excluded (44).

$$Input = Output \tag{44}$$

The accumulation term, m_f, is assumed to be zero concerning the operation stages. No mass is therefore added and it is described in either equation 45 or 46 depending on the choice of circulation.

$$\dot{m}_1 = \dot{m}_2 = \dot{m}_3 \tag{45}$$

$$\dot{m}_1 = \dot{m}_2 = \dot{m}_4 \tag{46}$$

Fractions in all stream are assumed not to differ from the fractions calculated in stream m_2 concerning start up (47 – 49).

$$x_{H_20} = x_{1,out} \tag{47}$$

$$x_{lye/acid} = x_{2,out} \tag{48}$$

$$x_{fouling} = x_f \tag{49}$$

Equation (45-49) is applied similarly to steps in the CIP cycle.

Unit heat balance

Equation 50 and 51 are describing the CIP unit balance when recirculation is applied.

$$Input + Work = Output + Pump\ energy \tag{50}$$

$$\dot{m}_{in} \cdot Cp_{in} \cdot T_{in} + W_1 = \dot{m}_{ut} \cdot Cp_{ut} \cdot T_{ut} + E \tag{51}$$

Object heat balance

This section describes the energy loss during circulation, cleaning effects (residue terms) are negligible. Equation 52 is the overall one and equation 53 is applied in each step.

$$Input = Output + Energy\ loss \tag{52}$$

$$\dot{m}_{in} \cdot Cp_{in} \cdot T_{in} = \dot{m}_{ut} \cdot Cp_{ut} \cdot T_{ut} + W_2 \tag{53}$$

Assumptions

When calculating heat and mass balances assumptions has been made. Assumptions are made due to lack of process specifications as well as project time perspectives and are shown below.

- Dirt and contamination are all seen as residue.
- The amount of residue in each step are removed in startup.
- Terms of residue is assumed to be flows.
- Remaining residue are heated to the temperature of the previous step.
- Residue cleaned by a process step is assumed to have equal temperature as that process step when leaving the object.
- To simplify calculations cleaning efficiency has been set to 90 % in all stages but the disinfection step which is assumed to have 100 % cleaning efficiency.
- 95 % of chemicals are reused.
- 75 % of final rinse water are reused.
- Temperature drop of 3˚C over object.
- Regarding heat balances flows are seen as 100 % water.
- No energy loss in final rinse during operation. (10˚C)
- Constant pump output (6 kW)
- Tube diameter (51 mm)
- Flow velocity (2 m/s)

4 Results and discussion

The result chapter is based upon the sectioning in chapter 3.1 (methodology):

- Process description
- Process flow diagram (PFD)
- Calculations
- Heat and mass balances
- Piping and instrumentation diagram (P&ID)
- Component list
- Chemicals
- Sales and promotion

Results, discussions and appendixes are presented in each segment. An overall discussion is found in the end of the chapter trying to provide a comprehensive rendering concerning the results.

4.1 Process description

When a selection of a process has been made, it is essential to provide a description regarding the features of the process. The piping and instrument diagram, P&ID, should be used alongside the process description. The description should be detailed but not viewed as an essay. It is mainly an engineering rapport where only the important information need to be included.

Three different process descriptions covering Single use Food, Recovery Food, Single use Pharmaceutical are found in Appendix A. Table 4.1 presents the sectioning for the Food and Pharmaceutical systems.

Table 4.1. Sectioning of the process descriptions

Food - Single use - Recovery	**Pharmaceutical** - Single use
Process	Process
Demands on CIP unit	Qualification and validation
Demands on production	Certificates
Time	Demands on CIP unit
Detergents	Demands on production
Demand on components	Time
General demands	Detergents
Specific demands	**Demand on components**
Options	General demands
Valves	Specific demands
Heat exchanger	**Options**
Sensors	Valves
Internal cleaning	Heat exchanger
Circuits	Sensors
Drainage	Internal cleaning
Control system	Circuits
	Drainage
	Control system
	Nitrogen
	Sample tap

Even though large parts are similar, there are differences between the process descriptions for the two food systems. Regarding the section demands on CIP and production (Table 4.1), the

Recovery Food system is made for reuse as well as large and advanced production processes while Single use Food is made for traceability and plain production processes. The possible options (Table 4.1) varies between the food systems as well, Recovery Food enables the possibility of an extra internal cleaning system and individual heating.

The basic configuration for the Single use Pharmaceutical is comparable to its counterpart in the food industry, but there are important differences. Because of stricter rules and regulations within the pharmaceutical industry, the Single use Pharmaceutical process description also covers qualification, validation and certificates. Qualification and validation aims to prove the authenticity of the cleaning process while the purpose of certificates is to guarantee the correct use of components and materials. Differences between food and pharmaceutical systems are also found in the sections demands on CIP unit as well as detergents and options (Table 4.1). Single use Pharmaceutical requires a margin of error within 1% for chemical dosage which is not required for the food systems. Regarding the section detergents, the Single use Pharmaceutical use different specialized detergents that are rarely changed. The pharmaceutical system offer the possibility of a sample tap and nitrogen to dry system between cycles.

The layup of the process description resulted in an overview of main features and how each process operate, various demands on the CIP unit, production and components as well as how the process might be altered. Additional sections in a description should be; advantages, disadvantages and alternative configurations. The section demands on production (Table 4.1) can be viewed as advantages, disadvantages are obtained when comparing all three process descriptions. How advantages and disadvantages affect costs are not examined due to the variations within Single use Food, Recovery Food and Single use Pharmaceutical. Alternative processes were not taken into consideration because of lack of substitute for CIP processes.

4.2 Process flow diagram

A simple flow sheet, or Process Flow Diagram (PFD), is created by drawing the main features and routes of the examined process with simple identifiable symbols. The PFD resulted in an introductory explanation of the processes and can be used as a general comparison between different cleaning processes. One PFD was created for each one of the three standard systems and is found in figures 4.1 – 4.3.

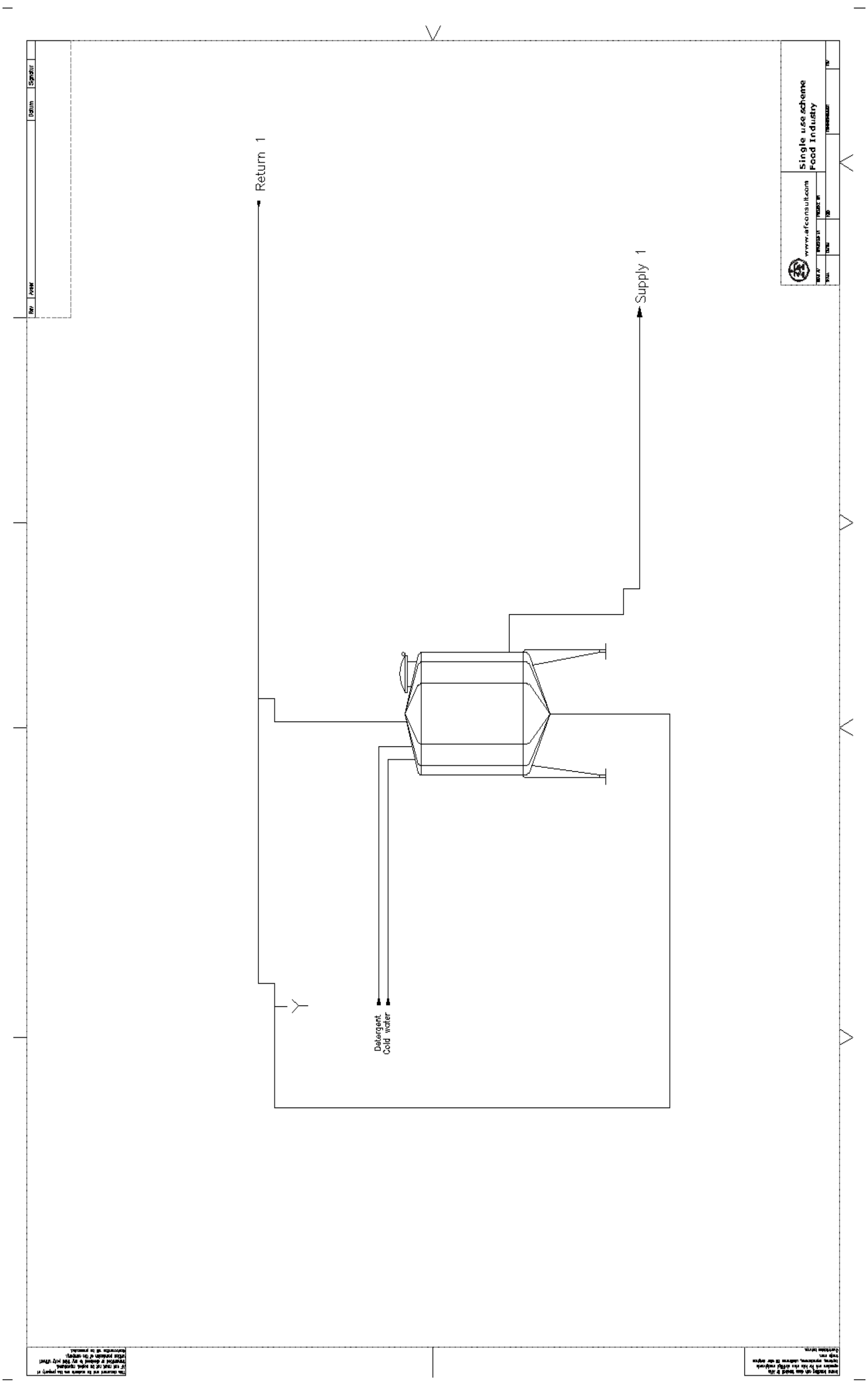


Figure 4.1. PFD Single use Food

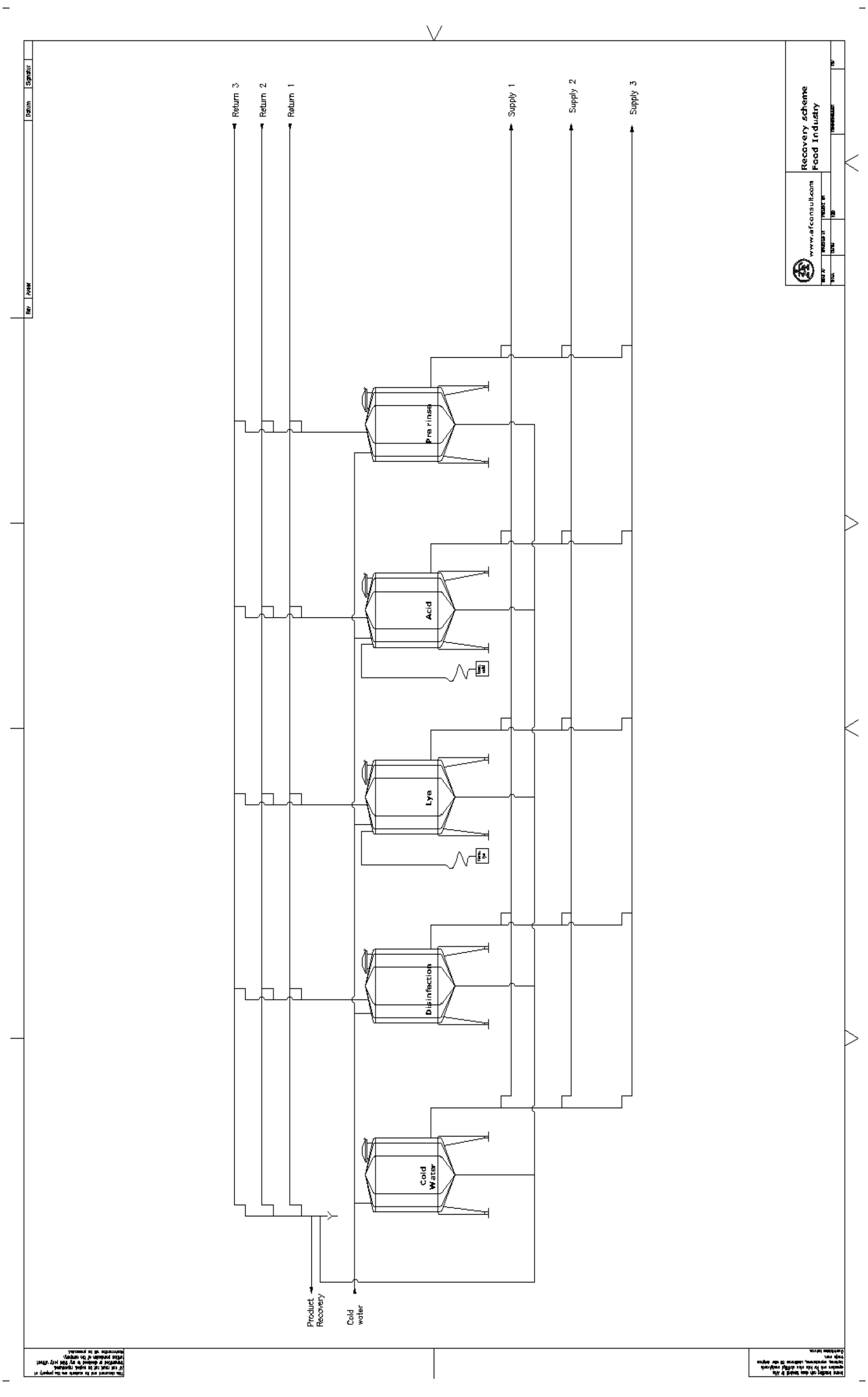


Figure 4.2. PFD Recovery Food

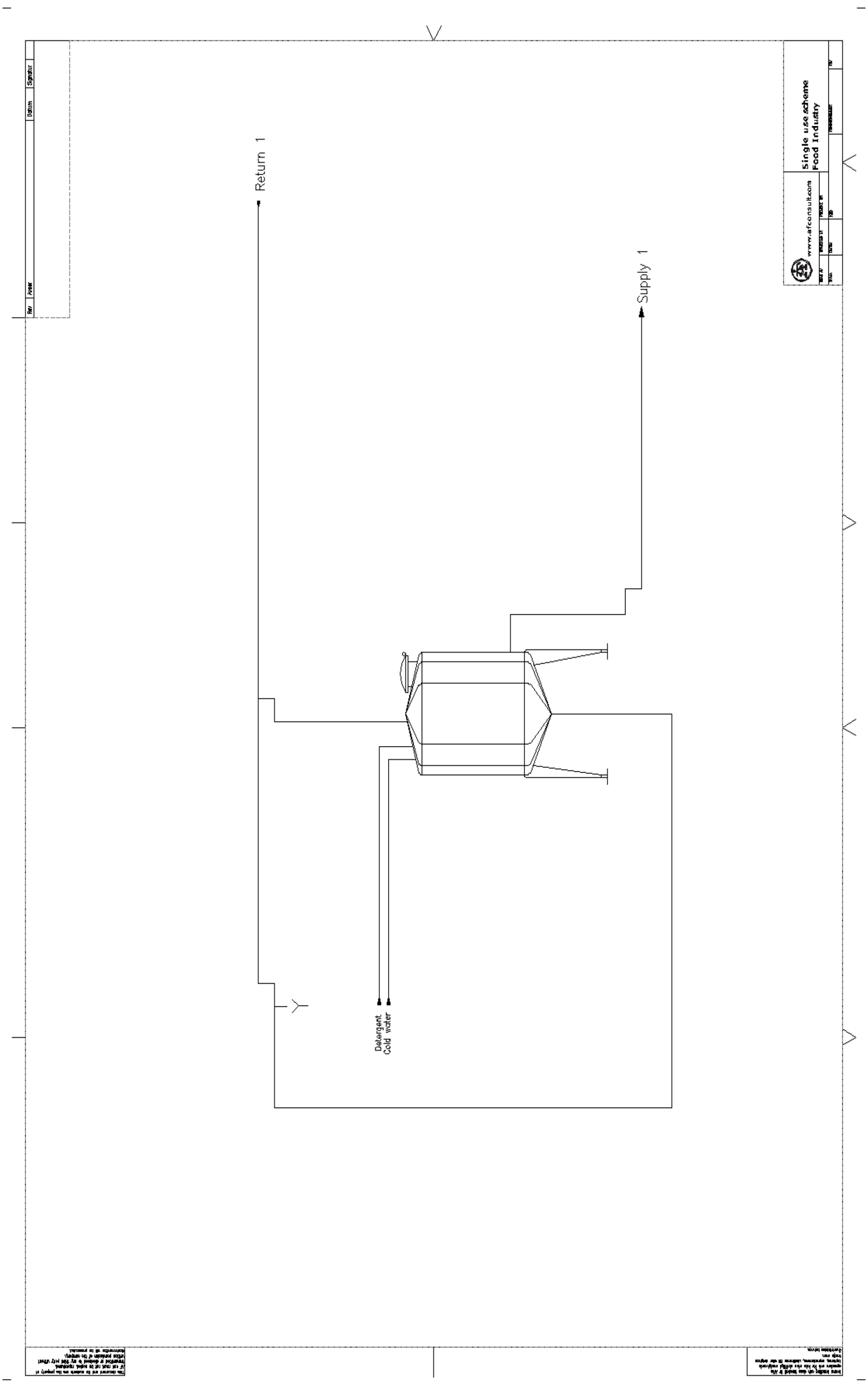


Figure 4.3. PFD Single use Pharmaceutical

Single use Food and Recovery Food contain large differences in order to meet as many of the process variations as possible. Single use Food is based on one tank and one circuit compared to Recovery Foods six tanks and three circuits. The PFDs does not contain valves, pumps or other instrumentation. The PFD for Single use Food and Single use Pharmaceutical looks the same since detailed process features is not included in PFDs.

PFDs are usually used to compare and appreciate different processes in chemical engineering projects. Since this project is focusing on three selected CIP processes and there is no relevant technique to compare it to the PFDs are only examined briefly.

4.3 Calculations

The outcome based on the calculations in method, chapter 3.4, are presented below. Segments are:

- Residue quantity
- Consumption during a cycle
- System pressure drop

4.3.1 Residue

The total amount of residue is 76.28 kg and was calculated using equation (1) based upon the predetermined object. Calculations were assumed to be primitive and was estimated only with regards to object area and an assumed thickness value. Complete calculations are found in Appendix B.

Table 4.2. Residue results

	Residue factor	Amount	Flow rate
Pre-rinse	0.9	68.65 kg	0.229 kg/s
Lye circulation	0.9	6.87 kg	0.006 kg/s
Acid circulation	0.9	0.69 kg	0.001 kg/s
Disinfection	1	0.08 kg	0.0001 kg/s

Table 4.2 is showing the residue flow rate based upon cycle times. As descried in table 4.2 the major part is removed in the pre-rinse step, the residue factor is based upon the Dairy processing handbook by Gösta Bylund writing 90 % of the residue is handled in the pre-rinse (Bylund 2015). This outcome is essentially predetermined by ourselves due to our assumptions and calculation procedures, but it was vital to get moderate values concerning residue supplements which are added into the heat and mass balances.

4.3.2 Consumption

In table 4.3 consumption costs regarding a Single use and Recovery cycle are found. Complete calculations are found in Appendix C.

Table 4.3. Comparison CIP costs

	Single use (kr)	**Recovery (kr)**	**Cost saving (%)**
Energy	45.26	14.70	68
Water	145.73	45.28	69
Chemicals	733.58	36.68	95
Total	924.57	96.67	90

One factor of four is illustrating the difference in energy costs and this is due to various initial temperatures. Concerning the Single use system every component has to be heated up from 10˚C but when it comes to the Recovery system the initial heating is not included since the storage tanks are already heated in a general Recovery cycle. One assumption is if the initial heating in the Recovery system is included, there would not be a significant difference in energy cost over time. There is tough, as table 4.3 shows, a significant difference studying a common cycle.

Water consumption described in table 4.3 is also larger for a single use cycle. This is due to the assumed reuse factor in a recovery process which is set as 0.05 – 0.25 concerning a majority of the steps. The reuse factor explains how frequent a solution is used before discarded. In a Single use process the reuse factor 1 since no reuse is handled.

The major difference is based on costs regarding chemicals, this is shown is table 4.3. The 95 % saving is based on the reuse factor here as well. The difference is also because only the lye and acid steps are taken into account. This combined with a higher volumetric price compared with water makes this cost sustainably higher regarding Single use.

One thing worth mentioning is what generates the substantial difference between Single use and Recovery concerning water and chemical consumption. This is due to when studying water consumption all seven steps are taken into account, but when studying the amount of drained chemicals only two steps (lye and acid) are considered. This generate a percentage difference between water and chemical since a lot of steps are equal regarding Single use and Recovery when studying water consumption.

4.3.3 Pressure drop

Below, in table 4.4, different pressure drops and tube diameters are visualized. Calculations and proposed pumps together with specifications are to be found in Appendix D.

Table 4.4 Pressure drop regarding supply, return and drainage

Diameter (mm)	Supply (Bar)	Return (Bar)	Drainage (Bar)
0.025	4.23	2.27	0.88
0.051	3.25	1.95	0.49
0.065	3.01	1.13	0.42
0.090	2.93	0.97	0.38
0.105	2.87	0.91	0.33

The supply column is regarding the distance from CIP unit to object, the return column is the opposite, object back to the CIP unit. Distance between the CIP unit and drain area are included in the drainage column. These are the suggested pump locations in a system. The total pressure loss in one circuit is the sum value of supply and return, which seems reasonable concerning our object after discussions together with ÅF staff. With regards to equation (26) the pressure drop is decreasing with larger diameter. Since one assumption is constant flow velocity (2 m/s) the general relation where change in pressure loss is equal to the velocity change squared is not valid.

4.4 Heat and mass balances

In tables 4.5 - 4.12 results based on equations in chapter 3.5 are visualized, complete calculations are found in appendix E.

4.4.1 Mass balance

Table 4.5 is including the outcome concerning mass balances in Pre-rinse.

Table 4.5. Flows and fractions after object in Pre-rinse

Pre-rinse	Parameters	Initial values	Start up	Operation
	$\dot{m}_{1:1}$	4.05 kg/s	4.05 kg/s	4.05 kg/s
	$\dot{m}_{3:1}$	0 kg/s	0 kg/s	0 kg/s
	$\dot{m}_{4:1}$	0 kg/s	4.28 kg/s	4.05 kg/s
	$x_{1:1}$	1	0.947	0.947

	x_{f1}	0	0.053	0.053

Table 4.6 is including the outcome concerning mass balances in Lye circulation.

Table 4.6. Flows and fractions after object in Lye circulation

Lye circulation	**Parameters**	**Initial values**	**Start up**	**Operation**
	$\dot{m}_{1:2}$	3.98 kg/s	3.98 kg/s	3.98 kg/s
	$\dot{m}_{3:2}$	0 kg/s	3.79 kg/s	3.98 kg/s
	$\dot{m}_{4:2}$	0 kg/s	0.20 kg/s	0 kg/s
	$x_{2:1}$	0.985	0.984	0.984
	$x_{2:2}$	0.015	0.015	0.015
	x_{f2}	0	0.001	0.001

Table 4.7 is including the outcome concerning mass balances in Acid circulation.

Table 4.7. Flows and fractions after object in Acid circulation

Acid circulation	**Parameters**	**Initial values**	**Start up**	**Operation**
	$\dot{m}_{1:3}$	4.01 kg/s	4.01 kg/s	4.01 kg/s
	$\dot{m}_{3:3}$	0 kg/s	3.81 kg/s	4.01 kg/s
	$\dot{m}_{4:3}$	0 kg/s	0.20 kg/s	0 kg/s
	$x_{3:1}$	0.99	0.9898	0.9898
	$x_{3:2}$	0.01	0.01	0.01
	x_{f3}	0	0.0002	0.0002

Table 4.8 is including the outcome concerning mass balances in Disinfection

Table 4.8. Flows and fractions after object in Disinfection

Disinfection	Parameters	Initial values	Start up	Operation
	$\dot{m}_{1:4}$	3.94 kg/s	3.94 kg/s	3.94 kg/s
	$\dot{m}_{3:4}$	0 kg/s	3.75 kg/s	3.94 kg/s
	$\dot{m}_{4:4}$	0 kg/s	0.20 kg/s	0 kg/s
	$x_{4:1}$	1	0.9999	0.9999
	x_{f4}	0	0.0001	0.0001

Table 4.9 is including the outcome concerning mass balances in Final rinse.

Table 4.9. Flows after object in Final rinse

Final rinse	Parameters	Initial values	Start up	Operation
	$\dot{m}_{1:5}$	4.08 kg/s	4.08 kg/s	4.08 kg/s
	$\dot{m}_{3:5}$	0 kg/s	3.75 kg/s	3.06 kg/s
	$\dot{m}_{4:5}$	0 kg/s	0.20 kg/s	1.02 kg/s

Table 4.10 is including the outcome concerning mass balances in Intermediate rinse.

Table 4.10. Flow after object in Intermediate rinse

Intermedi-ate rinse	Parameters	Initial values	Start up	Operation
	$\dot{m}_{1:1}$	4.05 kg/s	4.05 kg/s	4.05 kg/s

Table 4.5 – 4.10 are clarifying the estimated mass balances. They are presenting different flows and fractions in various steps. Fractions are denoted as x with two indices The first number is representing the relevant step and the second one is describing if it water ($x_{x:1}$) or detergent ($x_{x:2}$). The fouling proportion in each step is described by x_{f1-4}.

The initial values column represent the ingoing values before the object while the startup and operation column represent values after object.

The flow after object in especially the pre-rinse step (table 4.5) is considerably higher at startup compared to during operation. This is due to the majority of residue (69 kg) being removed here. Since the amount of residue present in the outgoing flow is decreasing for each step the fractions are altered less and less from the initial fractions. This is clear looking at the water fractions in pre-rinse (table 4.5.) and compared to disinfection (table 4.8). At a few steps the reuse of water and chemicals has been taken into consideration. The results concerning this is shown in tables 4.5 – 4.12 illustrating flows going to both drain and storage tanks. Except these small observations the CIP system is stable, no reactions are taking place and there is a steady volumetric flow going through the system. In appendix F all different flows in various steps are listed together with temperatures, pressure and fractions.

4.4.2 Unit heat balance

The energy demand at different stages when studying the CIP unit is found in table 4.11.

Table 4.11. Energy demand concerning CIP unit at start up and operation

Stage	**Start up (kWh)**	**Operation (kWh)**
Pre-rinse	42,64	42,64
Lye circulation	358,68	38,16
Intermediate rinse	42,64	42,64
Acid circulation	231,24	27,03
Intermediate rinse	42,64	42,64
Disinfection	220,97	21,28
Final rinse	0,5	0,5
Total energy demand	939,31	214,89

Table 4.11 is visualizing the energy needed for heating the fluids and pumping them through the whole system. One large difference if found concerning lye circulation, acid circulation and disinfection since he fluids has to be heated from significantly different temperatures. During operation the mean temperature difference is assumed to be 3˚C while the temperature difference is much greater in the startup phase. Basically the difference is showing a CIP cycle where heating from cold initial temperature occur and one where recycling of already heated fluids are handled. The total value is at last presenting total energy demand within equal time span; it is showing a factor of three between startup and during operation.

4.4.3 Object heat balance

The energy loss at different stages when studying the object is found in table 4.12.

Table 4.12. Energy demand concerning object at start up and operation

Stage	Start up (kWh)	Operation (kWh)
Pre-rinse	1,51	4,23
Lye circulation	16,42	16,69
Intermediate rinse	4,23	4,23
Acid circulation	12,58	12,75
Intermediate rinse	4,23	4,23
Disinfection	8,28	8,28
Final rinse	0	0
Total energy demand	47,25	50,41

Stated as an assumption, the temperature loss is 3˚C and this is the main reason for why the majority of the energies are equal in size. The only outlier is the pre-rinse step in the startup stage. This is due to the relatively high amount of residue included in the outgoing flow. Since the assumption made earlier is about the residue having equal temperature as the outgoing flow and the overall temperature is not altered due to residue this number is expected. This assumption is in this case not true, a process run made practically would verify the overall outgoing temperature not to be as high as these calculations.

4.5 Piping and instrumentation diagram

A piping and instrumentation diagram, P&ID, describes the examined process in more detail than the PFD. A P&ID is including flow directions, transmitters, indicators, sensors, tanks, pumps, valves, heat exchangers and how piping connects to other installed instrumentation and equipment. Number and letter combination appear beside every P&ID component and is defined by ÅFs internal standard system. Usually the first letter in the symbols describes the measured variables, for example flow (F) and temperature (T), the second describes the output function, such as transmitter (T) or sensor (S). P&IDs were created for Single use Food, Recovery Food as well as Single use Pharmaceutical and are presented in figure 4.1, 4.2 and 4.3. Two additional P&IDs describing two recovery systems were created in CAD to facilitate future work. Recovery 1 and Recovery 2 can be found in Appendix G and were made in the same way as other examined systems.

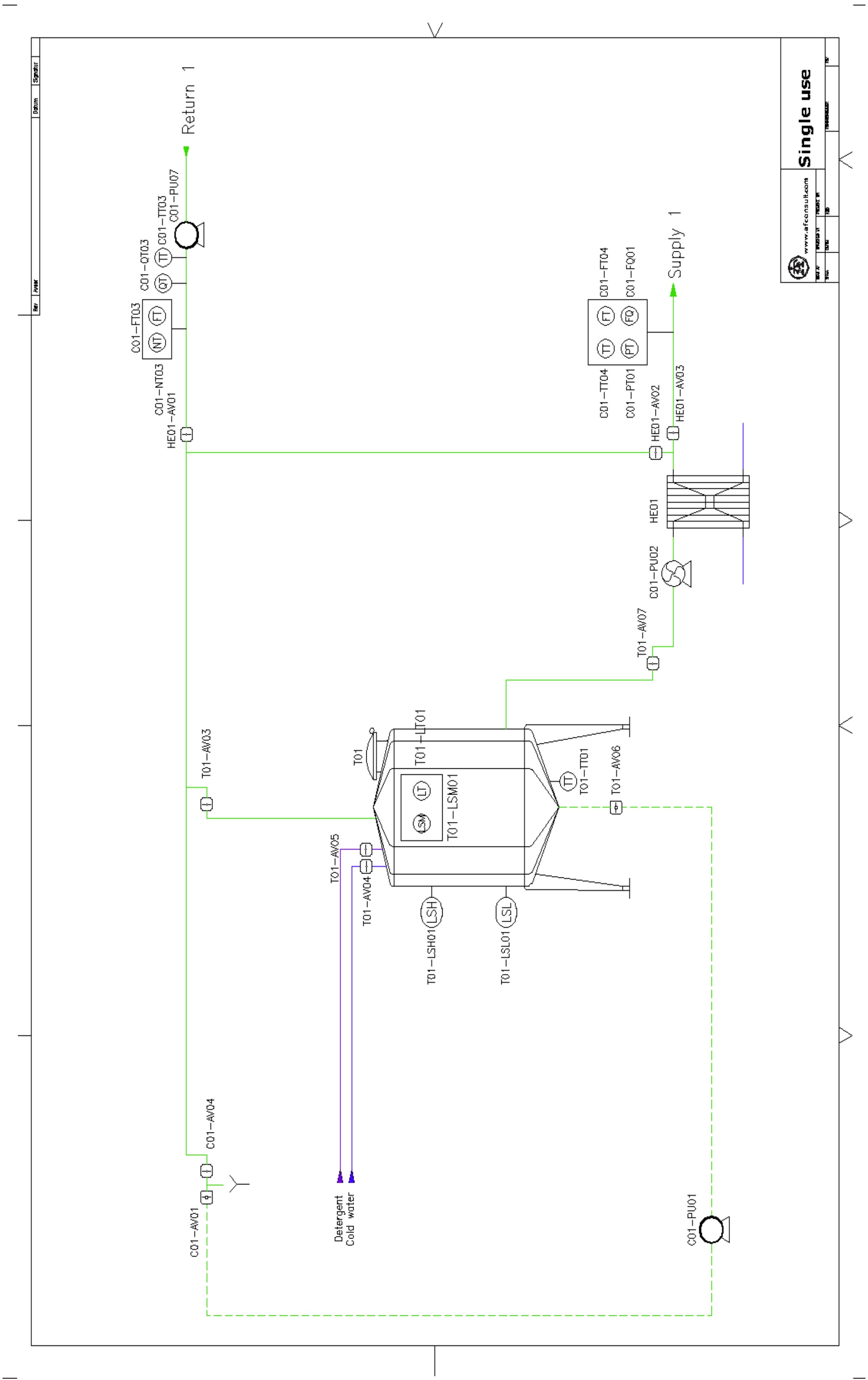


Figure 4.4. P&ID Single use Food

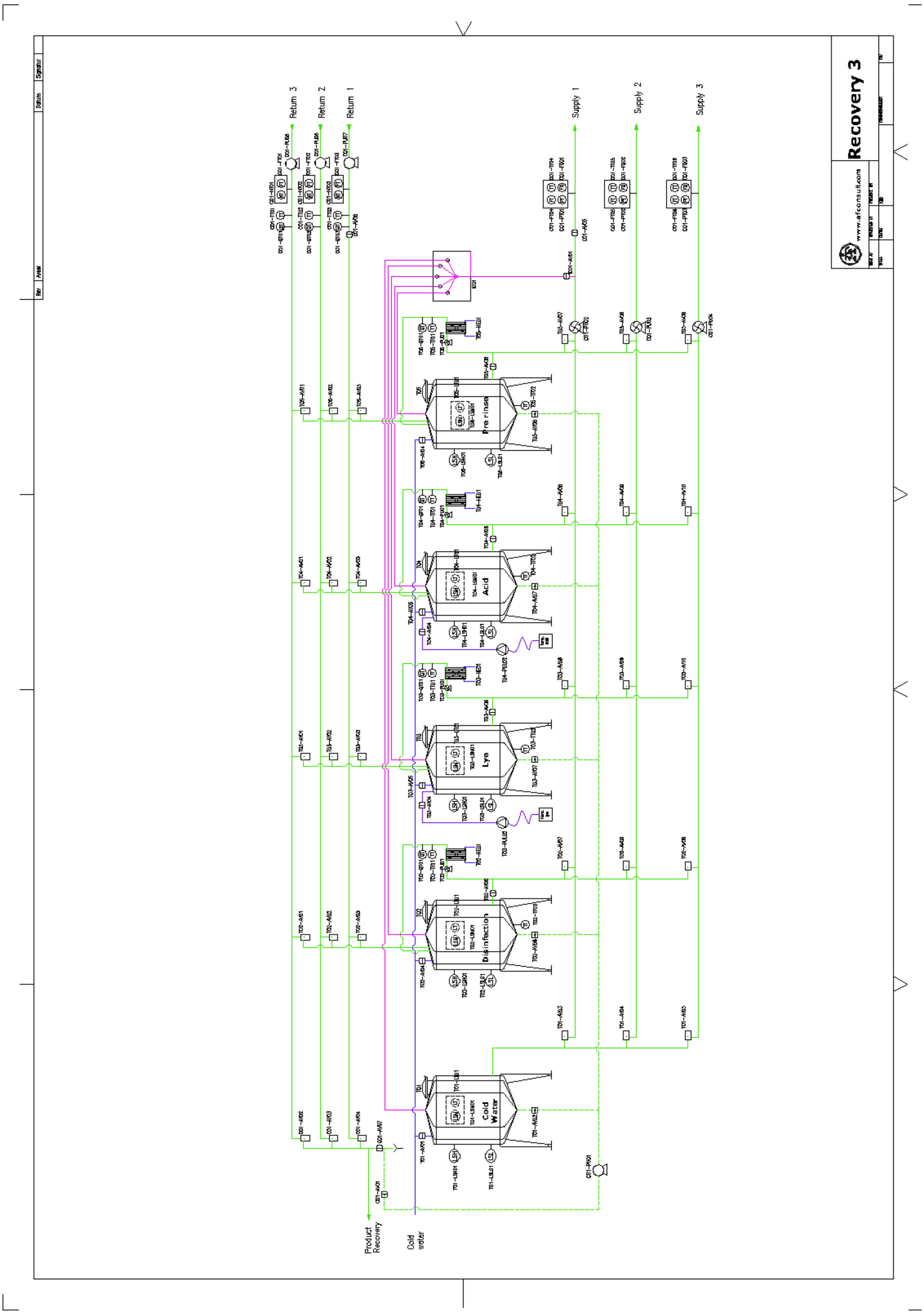


Figure 4.5. P&ID Recovery Food

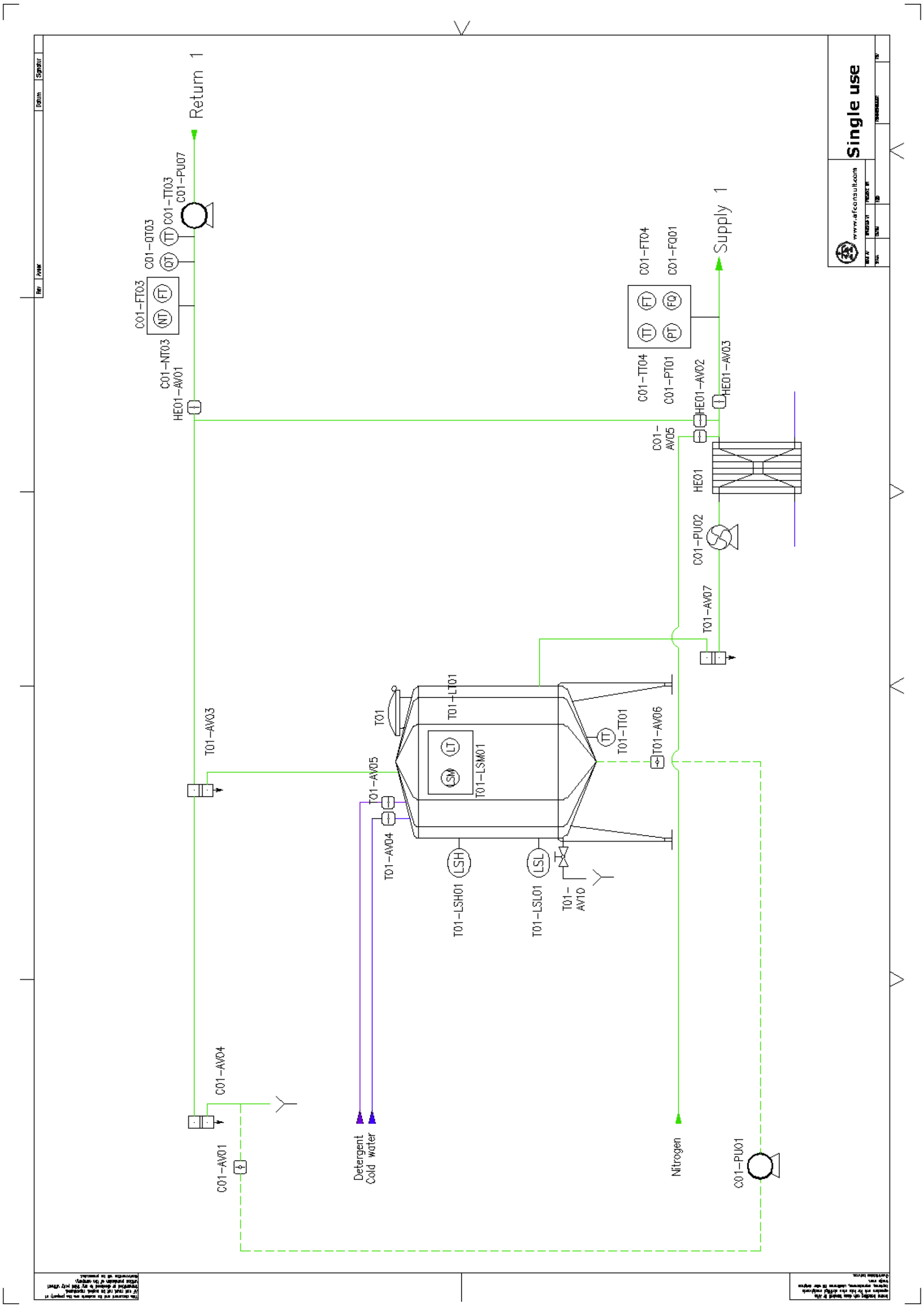


Figure 4.6. P&ID Single use Pharmaceutical

The differences and similarities between the systems are lucid through the P&IDs. Figure 4.4 describes a food system with one tank and one circuit. Heating the fluid in each cycle is performed by circulating the fluids over the tank through existing tubes. Figure 4.5 describes Recovery Food with three circuits, individual heating for each tank and an internal cleaning system. The product recovery tank is not displayed in Figure 4.5. Figure 4.6 describes a pharmaceutical system with one tank, one circuit, nitrogen and sample tap. Heating the fluid in each cycle is performed by circulating the fluids over the tank through existing tubes.

The large difference between the food systems are the number of tanks and ability to reuse water and detergents. The pharmaceutical system are very similar to Single use Food concerning P&IDs except for nitrogen and sample tap. Common for all systems is the variation of circuits in order to clean different cleaning objects.

Since the valve option have the largest impact when drawing the P&IDs in CAD, the valve option is serving as a base for the P&IDs. Three P&IDs were created for each of the three examined systems based on valve option. The P&IDs can be altered to attain the different options described in each individual process description. The valves predominantly used in CIP processes are butterfly, seat and mix proof valves. Even though there is really only one valve option for the pharmaceutical industry, the drainable mix proof valve, three P&IDs were created to emphasize how the process varies with different valves.

4.6 Component list

The three component lists are used alongside the P&IDs for each of the three examined systems and can be found in Appendix H. Each component in the P&IDs have defined and specified letters as well as numbers that result in an object number for each component.

The object number can be used as a cross-reference between the P&IDs and the components list. It relates to specific items and equipment on the P&IDs, for example tanks as Txx, heat exchangers as HExx, pumps as PUxx, etc. To avoid ambiguities the standard lettering system for ÅF is used.

As can be found in appendix H the component list contain the object number, function and type of component. Specific type, size, capacity, features and costs are not included due to preservation of independence concerning this reuse project. The component list facilitate documentation, design, purchasing and installation for the project as well as providing beneficial information for later stages.

4.7 Chemicals

This reuse concept are exemplifying chemicals which are divided into two sections centered around food and pharmaceutical applications. The substances are based on ÅF experience, they are well known, effective and are summarized in table 4.13. A full description of each presented chemical is found in Appendix I.

Table 4.13. Example of chemicals used in CIP applications.

	Food - Single use - Recovery	**Pharmaceutical** - Single use
Lye	P3-mip SP	COSA® CIP 96
Acid	P3-horolith CIP	COSA® CIP 72
Disinfection	P3-oxonia Active S	P3-cosa® DES

These chemicals are only covering a small fraction of all, there are especially a lot of variations within the pharmaceutical industry due to the quantity and complexity of pharmaceutical productions sites. Table 4.13 is included in the project as a first indication of applicable substances.

4.8 Sales and promotion

A vital aspect for a main fragment of projects is budget perspectives. Since the central concern in this thesis is reuse an illustration regarding differences when applying a reuse concept are illustrated in table 4.14 – 4.17 and figures 4.7 – 4.9. Quotation sheets are found in Appendix J.

4.8.1 Quotation

Table 4.14 is including examined assortments from ÅF quotation regarding a Single use Food system.

Table 4.14. Original and reuse costs of a Single use Food system

	Net sum	**Margin (%)**	**Gross sum 1**	**Reuse (%)**	**Gross sum 2**
Project and process	298,400	15	351,000	34	119,000
Installation	130,000	15	152,900	100	152,900
Automation	409,400	15	481,600	100	481,600
Components	236,700	20	295,800	100	295,800
Freight			4,733		4,700
Contingency			53,900		44,200
Warranty			32,400		26,500
Total			1,372,400		1,124,700

Table 4.15 is including examined assortments from ÅF quotation regarding a Recovery Food system.

Table 4.15. Original and reuse costs of a Recovery Food system

	Net sum	Margin (%)	Gross sum 1	Reuse (%)	Gross sum 2
Project and process	525,600	15	618,400	32	198,600
Installation	469,000	15	551,300	100	551,300
Automation	1,153,900	15	1,357,500	100	1,357,500
Components	1,090,000	20	1,362,900	100	1,362,900
Freight			21,800		21,800
Contingency			163,000		145,200
Warranty			97,800		87,100
Total			4,172,700		3,724,400

Table 4.16 is including examined assortments from ÅF quotation regarding a Single use Pharmaceutical system.

Table 4.16. Original and costs of a Single use Pharmaceutical system

	Net sum	Margin (%)	Gross sum 1	Reuse (%)	Gross sum 2
Project and process	436,800	15	513,900	40	205,600
Installation	185,300	15	218,000	100	218,000
Automation	548,900	15	645,800	100	645,800
Components	422,000	20	527,500	100	527,500
Freight			8,500		8,500
Contingency			80,000		66,900
Warranty			48,000		40,100
Total			2,041,600		1,712,400

The first three columns in table 4.14 and 4.15 are describing the cost for Single use Food and Recovery Food systems. The largest cost difference is found in the components section, the Recovery Food system is almost 4.5 times larger than the Single use Food system. This is reasonable due to the larger size of the Recovery system and the size also has a similar impact on installation and automation. Similar reasoning applies to the installation and automation sections being 3.5 and 3 times larger for the Recovery system. The least affected section when comparing Recovery Food and Single use Food is the project and process section. This is only 2 times larger for Recovery Food compared to Single use Food. The difference in project and process consist of an increase in regards to item list, construction, functional description, contact suppliers, purchase, project management, follow up, education and taking over.

The first three columns in table 4.16 are comparable to the same columns in 4.14 since the basic configuration of Single Use Pharmaceutical and Single use Food is the same. The largest cost difference is found in the component section where Single use Pharmaceutical is 2 times larger than Single use Food. This difference is explained by the use of mix proof valves in Single use Pharmaceutical, which are considerably more expansive than butterfly valves in Single use Food. The automation, installation as well as the project and process section are approximately 1.5 times larger than corresponding section in Single use Food. Differences in the automation section is comprising of increased costs in hardware and time. Installation costs are varying due to the material and components required to be installed. The project and process section consist of a large increase regarding qualification, factory acceptance test (FAT) and site acceptance test (SAT).

Freight, contingency and warranty are based on calculated costs in each of the three systems. Freight are consisting of a percentage of the component section and contingency as well as warranty ae consisting of a percentage of the net sum, this is also found in appendix J.

The last two columns in table 4.14, 4.15 and 4.16 are describing the reuse factor and the cost when using the reuse concept. Single use Pharmaceutical offer the largest reuse factor (40%) regarding project and processing compared to Single use Food (34%) and Recovery Food (32%). The reuse factor in the project and processing section are comprising and consistent topics not changing significantly between projects, e.g. purchase, project management, costumer meetings and assembly follow up on site. The reuse factor for installation and automation remains at 100% since much of the work are repeated for each new project. It is possible to reduce this factor, but only in regards to the amount of time spent by engineers working on the project. For example by programing a lot of similar PLCs or operator interfaces, the engineer will eventually get better and faster. The same applies for engineers working with installation, it is not likely that the installation time spent on a project will decrease more than 20%. All other fixed cost such as material and hardware will more or less remain the same between similar projects.

4.8.2 Cost reduction

By using a standard concept some parts in a project are reduced or excluded, e.g. project times and included costs. Relevant excluded topics are for example construction, functional description, documentation and tests in assembly line. These topics are reused in each project and will generate a more effective realization. In figure 4.7 – 4.9 these differences are illustrated in a circle chart based on table 4.14 – 4.16. The figures are describing the reuse share as a percentage of the original cost for each of the systems. As visualized the reuse concept is containing an equal percentage share of approximately 85% regardless of CIP system. The cost reduction is based on appendix J.

Figure 4.7 is visualizing an 18% cost reduction regarding Single use Food.

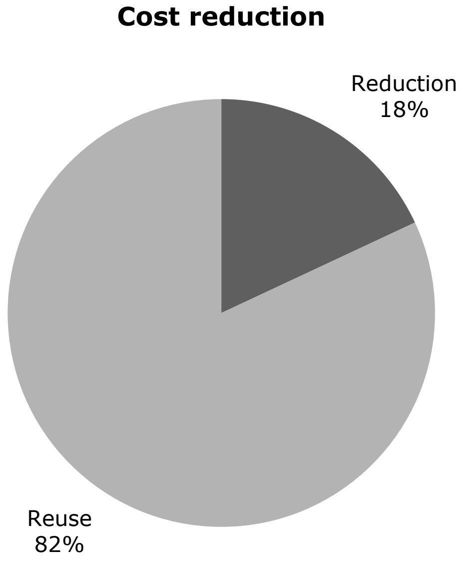


Figure 4.7. An illustration of the cost reduction regarding Single use Food

Figure 4.8 is visualizing an 11% reduction regarding Recovery Food due to larger consistent sections not changing significantly between projects (table 4.15). Since the only section assumed to be affected by reuse is "Project and Process", its share will have less impact on the reduction comparing with Single use Food.

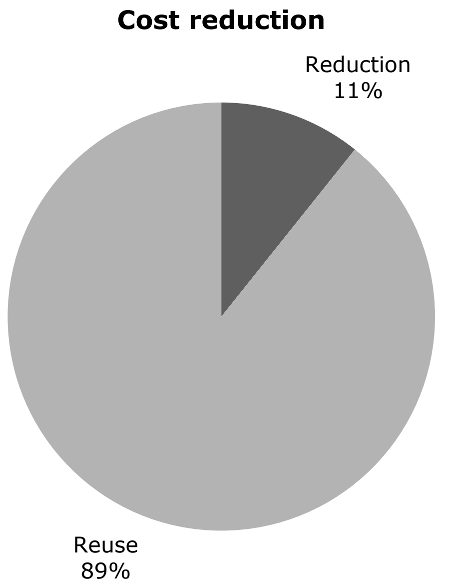


Figure 4.8. An illustration of the cost reduction regarding Recovery Food

The reduction is set to 16% concerning Single use Pharmaceutical. This percentage is approximately equal compared with Single use Food since the major costs are proportional.

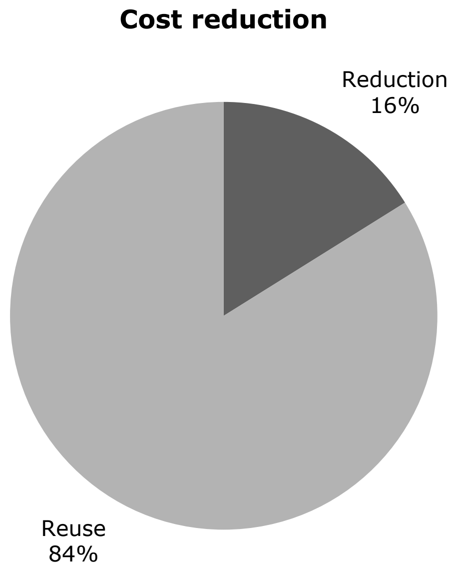


Figure 4.9. An illustration of the cost reduction regarding Single use Pharmaceutical

4.8.3 Promotion

In order to achieve higher results e.g. higher amount of costumers, sales brochures for each individual system are developed. This is done in order to promote the CIP reuse concept and facilitate sales meetings. All brochures are created with ÅFs sales representative and are based upon seven sections; selling points, application, description, basic configuration, technical data, demands and optional features. Each of the three brochures is mentioning vital process aspects and is viewed as a summary for each process. These brochures are found in appendix K.

4.9 Reuse concept

The eight different segments making up the reuse concept had different impact on the workload. The most time consuming parts in the project were for various reasons calculations, heat and mass balance, P&ID as well as sales documentation. The different calculations covered several areas and were performed on an ad-hoc basis. P&IDs were created in AutoCAD which included a learning curve before the program could be used as first intended. Sales documentation required more time since it included several employees as well as economic calculations.

There are several general benefits to be gained by implementing a reuse concept. By selling a reused concept the development cost is reduced. This is defined as all costs from initiation to implementation of a process. A reused concept is also eliminating the possibility of repeating past mistakes. This is due to the fact that observed mistakes will not have an impact on subsequent project and processes. It is easier for the manufacturer to promote an already built process and it is also easier for a customer to absorb information about the process. Another benefit is clear delivery limits, i.e. the division of work between customer and manufacturer which facilitate collaboration.

In order for a reuse concept to work, the CIP process must be sold in sufficient volume. The employees must be given time to adjust and familiarize with the concept which is only obtained by building several processes. This volume is unlikely to be obtained in Sweden alone due to competitiveness within the industry as well as lack of construction regarding new processes that are requiring CIP. Broadening the customer base from an international perspective is the best way to facilitate, maintain and sustain a recuse concept.

5 Conclusion

A lot of time and effort went into figuring out what different main segments each system should include. The project period (20 weeks) has been a limiting factor due to the versatile variation of systems included in the field of CIP. Process descriptions, P&IDs and quotations regarding any optional system were excluded in an early stage of the project. The sectioning concerning the three main systems has tough delivered a secure and fundamental base considering further work.

This project has been focusing on eight different segments concerning three CIP systems. One important segment, not included in the reuse concept is automation. Together with the “process” segment i.e. the eight project steps, this is the largest part in a CIP project. The lack of automation is leading up to a reuse concept not covering the entire spectra. A corrective action is to use an automation engineer in order to get as much as possible of the software ready for being handled in a reuse concept.

In today’s society competitiveness is essential i.e. efficiency regarding minimum time and risk are at all times prioritized. Marketing, delivery limits and development costs are factors known to be handled in a more efficient manner when using a reuse concept containing a distinct set of key topics. A general CIP project have an obvious extent when studying application and area of usage compared with several other technologies. This is the logical explanation for why CIP projects are a good area trying out a reuse concept. Transferring the reuse concept to other projects could include problems not covered by this concept. A larger area of application are making unexpected events more realistic and project frames more obscure. A future scope is to include all projects, or at least as many as possible, in an individual reuse concept. Depending on application creating a reuse concept is more or less plausible and will demand different amount of times. Studying former projects in each area over time combined with inspiration from this CIP reuse concept as a foundation will hopefully generate a more efficient future way of working.

As mentioned above this master thesis is representing a basis upon which future CIP projects are supposed to be built. Together with supervisors at ÅF a final conclusion, in resemblance with the empirical rule saying 80 % of the result is accomplished within 20 % of the time accessible (The Pareto principle), has been done. In this case the broad opinion is about the reuse concept making up 70 % of the results within 30 % of the time. This fact in pin pointing at the level of reliability, main segments in a CIP project are handled and included. Nevertheless this concept is not covering a big percentage of time required due to fact saying individual adaptions are craving much time.

6 References

Albrecht, K. and H. Joachim (2007). International Regulations. Clean-In-Place for Biopharmaceutical Processes, CRC Press: 361-377.

Banner, M. J. (1998). The Principles of Cleaning and Disinfection,. Plymouth,USA, Diversey Corporation.

Brolund, J. (2016). Project Engineer, Food & Pharmaceutical, ÅF. A. Werne.

Bylund, G. (2015). Dairy Processing Handbook. Lund, Tetra Pak.

C, S. M. a. D. (2000). Chilled Foods: A Comprehensive Guide, CRC Press.

CCFRA (1983). Hygenic design of food processing equipment. C. a. C. F. R. Association. Campden, Working Party on Hygenic Design of the Heat Preserved Foods Panel. Technical Manual No.7.

Chemex (2015). "Cip Cleaners & Additives."

Cocker, R. (2003). The regulation of hygiene in food processing: an introduction. Cambridge, Woodhead Publishing.

Ecolab (2003). Oxonia Active, Ecolab Food & Beverage Division.

H. L. M. Lelieveld, J. T. H. a. D. N. (2014). Hygiene in food processing Principles and practice, Woodhead Publishing Limited.

Hellborg, D. (2016). Chemical engineer ÅF.

Holah, J. T. (1998). "Hygienic design: international issues. Dairy, Food and Environmental Sanitation." 18: 212–220.

IDF (1979). Design and Use of CIP Systems in the Dairy Industry,. Document No. 117,. Brussels, International Dairy Federation.

Kylee R. Goode, K. A., Phillip T. Robbins, and Peter J. Fryer (2013). Fouling and Cleaning Studies in the Food and Beverage Industry Classified by Cleaning Type. Comprehensive Reviews in Food Scienceand Food Safety, Institute of Food Technologists®. 12: 123-126.

Linda, R. and C. A. Jay (2007). Waste Treatment for the CIP System. Clean-In-Place for Biopharmaceutical Processes, CRC Press: 315-326.

Nilsson, J.-Å. (2016). Technical manager ÅF.

Nilsson, K.-E. (2016). Chemical engineer ÅF.

Pak, T. (2015). Cleaning in place: A guide to cleaning technology in the food processing industry.

Romney, A. J. D. (1990). Cleaning in Place,. Huntingdon, UK, Society of Dairy Technology,.

Seiberling, D. A. (2007). Introduction and Historical Development. Clean-In-Place for Biopharmaceutical Processes, CRC Press: 1-19.

SPX (2014). Dairy Technology. Silkesborg, Danmark, SPX Corporation.

Stephan, D. (2011). "What is Cleaning in Place and How Does it Work?".

Tamime, A. Y. (2009). Cleaning-in-Place: Dairy, Food and Beverage Operations, Wiley.

Tuthill, R. A. C. a. A. H. (2000). "Stainless Steels - An Introduction to their Metallurgy and Corrosion Resistance." Dairy, Food and Enviromental Sanitation 20(7): 506-517.

Appendix A

Process description Single use Food

Single use food

This description is handling the Single use system meaning the fluids are supposed to be directed towards the drain once the cleaning is complete. The production equipment and its belonging demands has a great impact on how effectively the system will operate. To be able to demonstrate similarities and differences a general object has been used, specified to a 20 cubic meter cylinder tank together with 200 meters of tubes, Ø51 mm.

Process

The process is constructed by an individual tank including different sensors; level, temperature and conductivity. A centrifugal pump is applied to press fluids towards the object, and a liquid ring pump is helping by dragging fluids back towards the CIP station. Connections in to and out from the tank are available for water, lye, acid and return solution. The diverse fluids are utilized in different parts of the CIP-cycle, more information regarding the CIP-cycle is found below.

Initial flush

Cold water is filling the tank and later pumped the initial part of the object. A drainage if the object is done and remaining product is pushed towards the drain for a particular amount of time. The water flow is the capable of either continuing towards the drain or circulating for a particular amount of time. Circulation is completed when the flow is redirected towards the drain and the tank is drained.

Lye circulation

The tank is filled with water and lye and is heated to 75 degrees Celsius. The heating occurs by circulation through a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water is later pushed towards the drain by the lye mixture until the conductivity sensor is measuring a correct conductivity. This concentration of the lye mixture is circulated over both the CIP unit and the object for a particular amount of time and is then redirected towards the drain. The lye step is completed by a drainage of the storage tank.

Intermediate rinse

A complete emptying of lye in the system is done by a rinse of water. The storage tank is filled with cold water and is heated to 40 degrees Celsius when pumped to the object. This is pushing the remaining lye to the object and a drainage is done. A water rinse towards the drain is followed until the conductivity sensor is measuring a correct conductivity, this water is pumped through the CIP unit and the object to the drain for a particular amount of time.

Acid circulation

The storage tank is filled with water and acid and is heated to 65 degrees Celsius. The heating occurs by circulation through a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water is later pushed towards the drain by the acid mixture until the conductivity sensor is measuring a correct conductivity. This concentration of the acid mixture is circulated over both the CIP unit and the object for a particular amount of time and is then redirected towards the drain. The acid step is completed by a drainage of the storage tank.

Intermediate rinse

A complete emptying of acid in the system is done by a rinse of water. The storage tank is filled with cold water and is heated to 40 degrees Celsius when pumped to the object. This is pushing the remaining lye to the object and a drainage is done. A water rinse towards the drain is followed until the conductivity sensor is measuring a correct conductivity. This water is pumped through the CIP unit and the object to the drain for a particular amount of time.

Disinfection

The disinfection is done either thermally or chemically.

i. Water is heated to 90 degrees Celsius by circulation over a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water pushed towards the drain by the heated water. The water flow is circulated over both the CIP unit and the object for a particular amount of time and then redirected towards the drain. The disinfection step is completed by a drainage of the storage tank.
ii. A disinfection chemical is added to the storage tank and the mixture is heated to 75 degrees Celsius by circulation over a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water pushed towards the drain by the heated water. The water flow is circulated over both the CIP unit and the object until the conductivity sensor is measuring a correct conductivity. This concentration of the mixture is circulated over both the CIP unit and the object for a particular amount of time and is then redirected towards the drain. . The disinfection step is completed by a drainage of the storage tank.

Final rinse

To perform the final rinse the storage tank is filled with cold water and is sent to the initial part of the object. This is pushing the remaining residue to the object and a drainage is done. A water rinse towards the drain is followed until the conductivity sensor is measuring a correct conductivity. The water flow is then capable of either continuing towards the drain or circulating for a particular amount of time. Circulation is completed when the flow is redirected towards the drain and the storage tank is drained.

Demands on CIP unit

i. 3 bar
ii. 10 – 95 degrees Celsius
iii. 2 m/s (>1,5 m/s)

Demands on production

i. Batch production, traceability
ii. Plain production process

Time

The time required for a CIP cycle for a Single use system is approximately one hour (63 min) distributed upon the following stages:

i. Cold water rinse (3 min)
ii. Lye circulation (20 min)
iii. Intermediate rinse (5 min)
iv. Acid circulation (15 min)
v. Intermediate rinse (5 min)
vi. Disinfection (10 min)
vii. Final rinse (5 min)

Detergents

Commonly used detergents in the food industry regarding lye, acid and disinfection are:

i. P3-mip SP
ii. P3-horolith CIP
iii. P3-oxonia Active S

Demands on components

General demands

i. Leakage have to be easily discovered.
ii. Maintenance is required on a regular basis
iii. Passages have to be smooth (R_a < 1,6) and big cross-section changes should be avoided.
iv. Stainless steel (304/316) should be used and FDA certificate must be included.

Specific demands

Pumps

Utilized sorts of pumps are centrifugal pumps and liquid ring pumps and corresponding demands are:

i. Correct dimension and efficiency.
ii. Seals should be mechanical and convenient for maintenance.
iii. If possible the pump should be self-draining.

Valves

A large variation of valves are available due to different applications, for example flow-steering and flow-control. Demands on valves are as follows:

i. Mix proof valves must be design to prevent pressure build up and also be able to counteract forces.

Tanks

There are classified into two different categories, storage and process tanks. Demands concerning these are:

i. Connections must fulfill all hygienic requirements.
ii. Spray nozzles have to reach all surfaces efficiently.

Heat exchanger

Heating is done by water or steam and demands are as following:

i. Correct dimension and efficiency.

Sensors

Sensors controlling and monitoring parameters as level, temperature and conductivity are situated on supply pipes, return pipes and tanks. Demands are:

i. Wide interval for measurement
ii. High accuracy within interval
iii. Able to have tolerable contact undependable of surrounding parameters

Options

The CIP process could be varied in multiple ways to be able to satisfy as many applications as possible. The variations is selected freely to maintain a custom-made process. Different alternatives and descriptions are shown below.

Valves

i. Butterfly valves
ii. Seat valves
iii. Mix proof valves

Valves are able to respond the control system in three different ways:

i. Single feedback
ii. Double feedback
iii. ASI
iv. No feedback

Heat exchangers

i. Plate heat exchanger
ii. Tubular heat exchanger
iii. Welded stainless heat exchanger

Heating

i. Via a heat exchanger before going out to object.

Sensors

i. On each tank a level switch middle (LSM) and a level stick (LT) is additional.
ii. On supply pipes a temperature transmitter (TT), flow transmitter (FT), pressure transmitter (PT) or a mass flow meter (FQ) is additional.
iii. On return pipes a fluidity transmitter (Kylee R. Goode) or a flow transmitter (FT) is additional.

Internal cleaning

i. Meaning the flow is redirected from supply to return without going to object.

Circuits

i. One set of piping, with or without heating.
ii. Two sets of piping, with or without heating.
iii. Three sets of piping, with or without heating.

Drainage

i. An effluent in the bottom of each tank leading straight to the drain.

Control system

i. Manual
ii. Local PLC
iii. Superior control system

Magnet

i. Calcium magnet

Process description Recovery Food

This description is handling the Recovery system meaning the fluids are recycled once the cleaning is complete. The production equipment and its belonging demands has a great impact on how effectively the system will operate. To be able to demonstrate similarities and differences a general object has been used, specified to a 20 cubic meter cylinder tank together with 200 meters of tubes, Ø51 mm.

Process

The CIP unit is based upon three different versions: Recovery 1, Recovery 2 and Recovery 3. Each version is based on a specific number of tanks including different sensors; level, temperature and conductivity. A centrifugal pump is applied to press fluids towards the object, and a liquid ring pump is helping by dragging fluids back towards the CIP unit.

The cold water tank has connections for cold water and internal cleaning. The circulation and the pre-rinse tanks have connections for water, internal cleaning, heating and return. The disinfection and detergent tanks have connections for water, internal cleaning, heating, return and chemicals. The different fluids are used in various steps which are broken-down below.

Pre-rinse

The storage tank is initially containing water from the prior CIP-cycle. Cold water is sent to the object and led to a recovery tank due to high concentration of product. When the conductivity sensor is measuring a correct conductivity the water flow, containing no or a small amount of product, is redirected towards drain or circulation. Circulation is completed when the flow is redirected towards the drain and the storage tank is drained.

Lye circulation

The storage tank is initially containing water and lye, when necessary a heating occurs to 75 degrees Celsius. The heating occurs by circulation through a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water is later pushed towards the drain by the lye mixture until the conductivity sensor is measuring a correct conductivity. This concentration of the lye mixture is circulated over both the CIP unit and the object for a particular amount of time and is then redirected back to the lye storage tank.

Intermediate rinse

A complete emptying of lye in the system is done by a rinse of water. Water is used from the cold water tank and is heated to 40 degrees Celsius when pumped to the object. This is pushing the remaining lye to the object and a drainage is done. A water rinse towards the drain is followed until the conductivity sensor is measuring a correct conductivity, this water is pumped through the CIP unit and the object to the drain for a particular amount of time.

Acid circulation

The storage tank is initially containing water and acid, when necessary a heating occurs to 65 degrees Celsius. The heating occurs by circulation through a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water is later pushed towards the drain by the acid mixture until the conductivity sensor is measuring a correct conductivity. This concentration of the acid mixture is circulated over both the CIP unit and the object for a particular amount of time and is then redirected back to the acid storage tank.

Intermediate rinse

A complete emptying of lye in the system is done by a rinse of water. Water is used from the cold water tank and is heated to 40 degrees Celsius when pumped to the object. This is pushing the remaining lye to the object and a drainage is done. A water rinse towards the drain is followed until the conductivity sensor is measuring a correct conductivity, this water is pumped through the CIP unit and the object to the drain for a particular amount of time.

Disinfection

The disinfection is done either thermally or chemically.

i. Water is heated to 90 degrees Celsius by circulation over a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water pushed towards the drain by the heated water. The water flow is circulated over both the CIP unit and the object for a particular amount of time and then redirected back towards the disinfection storage tank.
ii. A disinfection chemical is added to the storage tank and the mixture is heated to 75 degrees Celsius by circulation over a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water pushed towards the drain by the heated water. The water flow is circulated over both the CIP unit and the object until the conductivity sensor is measuring a correct conductivity. This concentration of the mixture is circulated over both the CIP unit and the object for a particular amount of time and is then redirected back towards the disinfection storage tank.

Final rinse

To perform the final rinse water from the cold water storage tank is used and is sent to the initial part of the object. This is pushing the remaining residue to the object and a drainage is done. The remaining residue is pushed towards the drain by the cold water flow until the conductivity sensor is measuring a correct conductivity. The water flow is then circulating over both the CIP unit and the object for a particular amount of time. Circulation is completed when the flow is redirected towards the disinfection storage tank.

Demands on unit

i. 3 bar
ii. 10 – 95 ˚C
iii. 2 m/s (>1,5 m/s)
iv. 95 % of detergents are reused
v. 75 % of water from final rinse are reused

Demands on production

i. Large and advanced production process

Time

The time required for a CIP cycle for a Recovery system is approximately one hour (65 min) distributed upon the following stages:

i. Pre-rinse (5 min)
ii. Lye circulation (20 min)
iii. Intermediate rinse (5 min)
iv. Acid circulation (15 min)
v. Intermediate rinse (5 min)
vi. Disinfection (10 min)
vii. Final rinse (5 min)

Detergent

Commonly used detergents in the food industry regarding lye, acid and disinfection are:

i. P3-mip SP
ii. P3-horolith CIP
iii. P3-oxonia Active S

Demands on components

General demands

v. Leakage have to be easily discovered.
vi. Maintenance is required on a regular basis
vii. Passages have to be smooth (R_a < 1,6) and big cross-section changes should be avoided.
viii. Stainless steel (304/316) should be used and FDA certificate must be included.

Specific demands

Pumps

Utilized sorts of pumps are centrifugal pumps and liquid ring pumps and corresponding demands are:

iv. Correct dimension and efficiency.
v. Seals should be mechanical and convenient for maintenance.
vi. If possible the pump should be self-draining.

Valves

A large variation of valves are available due to different applications, for example flow-steering and flow-control. Demands on valves are as follows:

ii. Mix proof valves must be design to prevent pressure build up and also be able to counteract forces.

Tanks

There are classified into two different categories, storage and process tanks. Demands concerning these are:

iii. Connections must fulfill all hygienic requirements.
iv. Spray nozzles have to reach all surfaces efficiently.

Heat exchanger

Heating is done by water or steam and demands are as following:

ii. Correct dimension and efficiency.

Sensors

Sensors controlling and monitoring parameters as level, temperature and conductivity are situated on supply pipes, return pipes and tanks. Demands are:

iv. Wide interval for measurement
v. High accuracy within interval
vi. Able to have tolerable contact undependable of surrounding parameters

Options

The CIP process could be varied in multiple ways to be able to satisfy as many applications as possible. The variations is selected freely to maintain a custom-made process. Different alternatives and descriptions are shown below.

Valves

iv. Butterfly valves
v. Seat valves
vi. Mix proof valves

Valves are able to respond the control system in three different ways:

v. Single feedback
vi. Double feedback
vii. ASI
viii. No feedback

Tanks

i. One cold water storage tank and one lye storage tank (Recovery 1)
ii. One cold water storage tank, one lye storage tank, one acid storage tank and one disinfection storage tank (Recovery 2).
iii. One cold water storage tank, one lye storage tank, one acid storage tank, one disinfection storage tank, one pre-rinse storage tank and one product recovery storage tank (Recovery 3).

Heat exchangers

iv. Plate heat exchanger
v. Tubular heat exchanger
vi. Welded stainless heat exchanger

Heating

ii. By a for all storage tanks mutual heat exchanger.
iii. By a for each and every tank individual heat exchanger.

Sensors

iv. On each tank a level switch middle (LSM) and a level stick (LT) is additional.
v. On supply pipes a temperature transmitter (TT), flow transmitter (FT), pressure transmitter (PT) or a mass flow meter (FQ) is additional.
vi. On return pipes a fluidity transmitter (Kylee R. Goode) or a flow transmitter (FT) is additional.

Internal cleaning

ii. Meaning the flow is redirected from supply to return without going to object.
iii. Manual switch board, meaning separate pipes only used for internal cleaning. Exist for Recovery 2 and 3.

Circuits

iv. One set of piping, with or without heating.
v. Two sets of piping, with or without heating.
vi. Three sets of piping, with or without heating.

Drainage

i. An effluent in the bottom of each tank leading straight to the drain.

Control system

iv. Manual
v. Local PLC

Superior control system

Magnet

ii. Calcium magnet

Process description Single use Pharmaceutical

Process

The process is constructed by an individual tank including different sensors; level, temperature and conductivity. A centrifugal pump is applied to press fluids towards the object, and a liquid ring pump is helping by dragging fluids back towards the CIP station. Connections in to and out from the tank are available for water, lye, acid and return solution. The diverse fluids are utilized in different parts of the CIP-cycle, more information regarding the CIP-cycle is found below.

The production equipment and its belonging demands has a great impact on how effectively the CIP-versions will operate. To be able to demonstrate similarities and differences a general object has been used after each CIP-version. The object has been specified to a 20 cubic meter cylinder tank together with 200 meters of tube, Ø51 mm.

Initial flush

Cold water is filling the tank and later pumped the initial part of the object. A drainage if the object is done and remaining product is pushed towards the drain for a particular amount of time. The water flow is the capable of either continuing towards the drain or circulating for a particular amount of time. Circulation is completed when the flow is redirected towards the drain and the tank is drained.

Lye circulation

The tank is filled with water and lye and is heated to 75 degrees Celsius. The heating occurs by circulation through a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water is later pushed towards the drain by the lye mixture until the conductivity sensor is measuring a correct conductivity. This concentration of the lye mixture is circulated over both the CIP unit and the object for a particular amount of time and is then redirected towards the drain. The lye step is completed by a drainage of the storage tank.

Intermediate rinse

A complete emptying of lye in the system is done by a rinse of water. The storage tank is filled with cold water and is heated to 40 degrees Celsius when pumped to the object. This is pushing the remaining lye to the object and a drainage is done. A water rinse towards the drain is followed until the conductivity sensor is measuring a correct conductivity, this water is pumped through the CIP unit and the object to the drain for a particular amount of time.

Acid circulation

The storage tank is filled with water and acid and is heated to 65 degrees Celsius. The heating occurs by circulation through a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water is later pushed towards the drain by the acid mixture until the conductivity sensor is measuring a correct conductivity. This concentration of the acid mixture is circulated over both the CIP unit and the object for a particular amount of time and is then redirected towards the drain. The acid step is completed by a drainage of the storage tank.

Intermediate rinse

A complete emptying of acid in the system is done by a rinse of water. The storage tank is filled with cold water and is heated to 40 degrees Celsius when pumped to the object. This is pushing the remaining lye to the object and a drainage is done. A water rinse towards the drain is followed until the conductivity sensor is measuring a correct conductivity. This water is pumped through the CIP unit and the object to the drain for a particular amount of time.

Disinfection

The disinfection is done either thermally or chemically.

iii. Water is heated to 90 degrees Celsius by circulation over a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water pushed towards the drain by the heated water. The water flow is circulated over both the CIP unit and the object for a particular amount of time and then redirected towards the drain. The disinfection step is completed by a drainage of the storage tank.

iv. A disinfection chemical is added to the storage tank and the mixture is heated to 75 degrees Celsius by circulation over a heat exchanger ahead of being sent to the initial part of the object. A drainage of the object is done and remaining water pushed towards the drain by the heated water. The water flow is circulated over both the CIP unit and the object until the conductivity sensor is measuring a correct conductivity. This concentration of the mixture is circulated over both the CIP unit and the object for a particular amount of time and is then redirected towards the drain. . The disinfection step is completed by a drainage of the storage tank.

Final rinse

To perform the final rinse the storage tank is filled with cold water and is sent to the initial part of the object. This is pushing the remaining residue to the object and a drainage is done. A water rinse towards the drain is followed until the conductivity sensor is measuring a correct conductivity. The water flow is then capable of either continuing towards the drain or circulating for a particular amount of time. Circulation is completed when the flow is redirected towards the drain and the storage tank is drained.

Qualification and validation

There are two qualifications for operating a CIP system within the pharmaceutical industry, installation qualification (IQ) and performance qualification (PQ). IQ consist of documented verification that the equipment meet the terms regarding design, manufacturer and user. PQ comprises of verification documentation regarding performance and reproducibility for equipment and additional systems in a setting representative of commercial processing.

The purpose of cleaning validation is to have documented evidence that a cleaning procedure sufficiently cleans an equipment to a predetermined level. This is accomplished through a cleaning validation program that contains three levels of documentation. The first level comprises of a cleaning validation policy that forms by whom, how, when, where, what and why of the cleaning validation program. This is followed by a cleaning validation master plan that specify the same information but for a given project. The third level establish the cleaning validation protocols which forms the procedures, sample methods, acceptance criteria and other relevant information regarding cleaning validation for a specific project.

Certificates

In general, the design must comply with European Hygienic Engineering & Design Group (EHEDG) guidelines regarding manufacturing, welding, hygienic- and aseptic design of process equipment and piping. Pharmaceutical production calls for demands regarding Good Manufacturing Practice (GMP) and Food & Drug Administration (FDA) requirements.

Steel must be A316L or corresponding quality, materials of construction must be documented with a Declaration of Compliance, minimum 2.1 certificate according to EN10204. Surface roughness must facilitate easy and effective cleaning, minimize the risk of contamination and microbial growth. Suppliers must comply with GMP as well to Regulation EC 2023/2006 and FDA 21 CFR § 174.5. Food contact materials must be traceable according to Regulation EC 1935/2204 and FDA 21 CFR § 174-190 and accompanied by a Declaration of Compliance. Regarding welding, the contractor needs to assure the documentation of each welder, all welding procedures and a log. Each individual weld must comply with the required tempering degree. Pressure testing of tanks must comply with European Pressure Equipment Directive/EN 13445-5, or similar. Pumps and other components that are in contact with the product must be sanitary and self-draining according to Installation Requirement specification.

Demands on CIP unit

iv. 3 bar
v. 10 – 95 degrees Celsius
vi. 2 m/s (>1,5 m/s)
vii. Margin of error for chemical dosage within 1%

Demands on production

iii. Batch production, traceability
iv. Plain production process

Time

The time required for a CIP cycle for a Single use system is approximately one hour (63 min) distributed upon the following stages:

i. Cold water rinse (3 min)
ii. Lye circulation (20 min)
iii. Intermediate rinse (5 min)
iv. Acid circulation (15 min)
v. Intermediate rinse (5 min)
vi. Disinfection (10 min)
vii. Final rinse (5 min)

Detergents

Commonly used detergents in the pharmaceutical industry regarding lye, acid and disinfection are:

i. COSA® CIP 96
ii. COSA® CIP 72

iii. P3-cosa® DES

Demands on components

General demands

ix. Leakage have to be easily discovered.
x. Maintenance is required on a regular basis
xi. Passages have to be smooth (R_a between 0,8-30) and big cross-section changes should be avoided.
xii. Stainless steel (304/316) should be used and FDA certificate must be included.

Specific demands

Pumps

Utilized sorts of pumps are centrifugal pumps and liquid ring pumps and corresponding demands are:

vii. Correct dimension and efficiency.
viii. Seals should be mechanical and convenient for maintenance.
ix. If possible the pump should be self-draining.

Valves

A large variation of valves are available due to different applications, for example flow-steering and flow-control. Demands on valves are as follows:

iii. Mix proof valves must be design to prevent pressure build up and also be able to counteract forces.

Tanks

There are classified into two different categories, storage and process tanks. Demands concerning these are:

v. Connections must fulfill all hygienic requirements.
vi. Spray nozzles have to reach all surfaces efficiently.

Heat exchanger

Heating is done by water or steam and demands are as following:

iii. Correct dimension and efficiency.

Nitrogen

In order to clear a Ø51 mm CIP system, the gas volume must be equivalent to a liquid flow rate of 36-39 m^3/h at the beginning of the gas blow.

Sensors

Sensors controlling and monitoring parameters as level, temperature and conductivity are situated on supply pipes, return pipes and tanks. Demands are:

vii. Wide interval for measurement
viii. High accuracy within interval
ix. Able to have tolerable contact undependable of surrounding parameters

Options

The CIP process could be varied in multiple ways to be able to satisfy as many applications as possible. The variations is selected freely to maintain a custom-made process. Different alternatives and descriptions are shown below.

Valves

vii. Butterfly valves
viii. Seat valves
ix. Mix proof valves

Valves are able to respond the control system in three different ways:

ix. Single feedback
x. Double feedback
xi. ASI
xii. No feedback

Heat exchangers

vii. Plate heat exchanger
viii. Tubular heat exchanger
ix. Welded stainless heat exchanger

Heating

iv. Via a heat exchanger before going out to object.

Sensors

vii. On each tank a level switch middle (LSM) and a level stick (LT) is additional.
viii. On supply pipes a temperature transmitter (TT), flow transmitter (FT), pressure transmitter (PT) or a mass flow meter (FQ) is additional.
ix. On return pipes a fluidity transmitter (Kylee R. Goode) or a flow transmitter (FT) is additional.

Internal cleaning

iv. Meaning the flow is redirected from supply to return without going to object.

Circuits

vii. One set of piping, with or without heating.
viii. Two sets of piping, with or without heating.

ix. Three sets of piping, with or without heating.

Drainage

i. An effluent in the bottom of each tank leading straight to the drain.

Sample tap

i. A manually operated ball valve for sampling.

Nitrogen

i. Gas blow with nitrogen to facilitate the transition between cycles by clearing the CIP system of remaining liquids.

Control system

vi. Manual
vii. Local PLC
viii. Superior control system

Magnet

iii. Calcium magnet, water softening

Validation

i. GMP
ii. FDA
iii. EHEDG

Appendix B

Fouling											
Object variables											
	Tube length	m	200		Tank height		3,8		Rho $_{\text{water, 75 °C}}$ [1]	kg/dm^3	0,9748
	Tube diameter	m	0,051		Tank diameter		2,6		Rho $_{\text{water, 65 °C}}$ [1]	kg/dm^3	0,9805
	Tube thickness	m	0,0013		Tank thickness	m	0,002		Rho$_{\text{disinfection}}$ [1]	kg/dm^3	0,9653
	Tube volume	m^3	0,41		Tank volume	m^3	20,18		Rho$_{\text{pre rinse}}$ [1]	kg/dm3	0,9922
	Tube inner area	m^2	32,04		Tank inner area	m^2	41,66		Rho $_{\text{acid}}$ [2]	kg/dm^3	1,66
									Rho $_{\text{lye}}$ [3]	kg/dm^3	2,1
									Rho$_{\text{whole milk}}$ [4]	kg/dm^3	1,035
Fouling thickness											
	Residue thickness	m	0,001								
Fouling quantity											
	Tube	l	32,04								
	Tank	l	41,66								
			73,70								
	Tube	kg	33,16579364								
	Tank	kg	43,11553174								
			76,28								
Mass flow rates											
	Stages	Time (min)	Residue factor	Removed residue (kg)	Remaining residue (kg)	Rho (kg/dm^3)	Flow rate in (kg/s)	Flow rate residue (kg/s)	Flow rate out (kg/s)		
	Pre rinse	5	0,9	68,65	7,63	0,9922	4,054	0,2288	4,283		
	Lye	20	0,9	6,87	0,76	0,9917	4,052	0,0057	4,057		
	Acid	15	0,9	0,69	0,08	0,9873	4,034	0,0008	4,034		
	Disinfection	10	1	0,08	0,00	0,9653	3,944	0,0001	3,944		
References											
	[1]Handbook, Department of chemical engineering, Lund University, Mattias Alveteg, MediaTryck, 2013										
	[2]Wikipedia, Citric acid, https://en.wikipedia.org/wiki/Citric_acid, 2016-14-04										
	[3]Wikipedia Sodium hydroxide, https://en.wikipedia.org/wiki/Sodium_hydroxide, 2016-14-04										
	[4]http://hypertextbook.com/facts/2002/AliciaNoelleJones.shtml, 2016-14-04										

Figure 1. Calculation of residue amount

Appendix C

Object parameters

Tube length	m	200
Tube diameter	m	0,051
Tube thickness δ	m	0,0013
Tube volume	m^3	0,408564125
Tube inner area	m^2	32,04424507
Tank height		3,8
Tank diameter		2,6
Tank thickness δ	m	0,002
Tank volume	m^3	20,17530802
Tank inner area	m^2	41,65751859

Parameters

Electricity cost	kr/kwh	1
Water/steam cost	kr/kwh	0,13072
Cold water price	kr/l	0,01
Lye price	kr/l	7,35
Acid price	kr/l	5,25
Velocity	m/s	2
Object temperature initial	˚C	5
Temperaure interwall signal	˚C	3
Rho_{water}	kg/l	1
$C_{p,water}$	kJ/kg˚C	4,18
$C_{p, stainless\ steele}$	kJ/kg˚C	0,5
$rho_{stainless\ steele}$	kg/m^3	8000
Pump		
Impeller diameter	m	0,175
Output	kW	2,9
Scale factor		
Scale factor	tubes, pump	

Cycle parameters

	Flow (l/min)	Initial temperature (˚C)	Final temperatur (˚C)	Time heating fluid (min)	Time heating/cooling equipment (min)	Time stages (min)
Pre rinse	245,138	10	40	3	2	3
Initial rinse	245,138	10	10	0	0	0
Lye	245,138	10	75	4	2	20
Intermediate rinse	245,138	10	40	3	2	5
Acid	245,138	10	65	2	2	15
Intermediate rinse	245,138	10	40	3	2	5
Disinfection	245,138	10	90	5	2	10
Final rinse	245,138	10	10	0	2	5
						63

Figure 2. Consumptions calculations for Single use system.

Energy

	Energy demand-heating fluid (kW)	Energy demand-heating equipment (kW)	Energy demand-heating fluid (kWh)	Energy demand-heating equipment (kWh)	Heating demand per stage	Cost-heating
Pre rinse	512,339	0,000	25,617	0,000	25,617	3,349
Initial rinse	0,000	0,000	0,000	0,000	0,000	0,000
Lye	1110,069	219,540	74,005	7,318	81,323	10,630
Intermediate rinse	512,339	0,000	25,617	0,000	25,617	3,349
Acid	939,289	52,910	31,310	1,764	33,073	4,323
Intermediate rinse	512,339	0,000	25,617	0,000	25,617	3,349
Disinfection	1366,238	157,054	113,853	5,235	119,088	15,567
Final rinse	0,000	0,000	0,000	0,000	0,000	0,000
	4952,614	**429,503**	**296,018**	**14,317**	**310,335**	**40,57 kr**

	Energy demand-electricity fluid (kWh)	Energy demand-electricity equipment (kWh)	Energy demand-electricity steady (kWh)	Elecricity demand per stage (kWh)	Cost-elecricity
Pre rinse	0,145	0,096666667	0,145	0,386666667	0,386666667
Initial rinse	0	0	0	0	0
Lye	0,193333333	0,096666667	0,966666667	1,256666667	1,256666667
Intermediate rinse	0,145	0,096666667	0,241666667	0,483333333	0,483333333
Acid	0,096666667	0,096666667	0,725	0,918333333	0,918333333
Intermediate rinse	0,145	0,096666667	0,241666667	0,483333333	0,483333333
Disinfection	0,241666667	0,096666667	0,483333333	0,821666667	0,821666667
Final rinse	0	0,096666667	0,241666667	0,338333333	0,338333333
	0,967	**0,677**	**3,045**	**4,688**	**4,69 kr**

Total energy demand	Total cost
315,023	**45,26 kr**

Water

	Flow (l/min)	Time stages (min)	Reuse	Proportion	CIP-volume (l)	Cost
Pre rinse	245,138	3	0	1	0,000	0,000
Initial rinse	245,138	0	1	1	0,000	0,000
Lye	245,138	20	1	0,985	4829,228	48,292
Intermediate rinse	245,138	5	1	1	1225,692	12,257
Acid	245,138	15	1	0,99	3640,306	36,403
Intermediate rinse	245,138	5	1	1	1225,692	12,257
Disinfection	245,138	10	1	0,99	2426,871	24,269
Final rinse	245,138	5	1	1	1225,692	12,257
					14573,482	**145,73 kr**

Figure 3. Consumptions calculations for Single use system, sequel.

Chemicals					
		Proportion	Total volyme (l)	Chemical Volume (l)	Cost
	Lye	0,015	4902,769	73,542	540,530
	P3-mip SP				
	Acid	0,01	3677,077	36,771	193,047
	P3-horolith CIP				
	Disinfectant	0,01	2451,385	24,514	128,698
	P3-oxonia Active S				
					733,58 kr

Summary		
		Cost
	Energy	45,26
	Water	145,73
	Chemicals	733,58
		924,57 kr

Figure 4. Consumption calculations for Single use system, sequel.

Calculations						
Amout of object steele	m	=	rho*((Arör*δrör)+(Atank*δtank))		999,7804461	kg
Pre rinse						
Energy required to heat object steele	Q_1	=	m*Cp*ΔT		#DIV/0!	kJ/min
Time to heat object steele	t				0	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$		3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1			0	#DIV/0!	kW
Initial rinse						
Energy required to heat object steele	Q_1	=	m*Cp*ΔT		0	kJ/min
Time to heat object steele	t				2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$	0	3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1			0	-51,23394122	kW
Lye						
Energy required to heat object steele	Q_1	=	m*Cp*ΔT		16246,43225	kJ/min
Time to heat object steele	t				2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$		3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1				219,5399296	kW
Intermediate rinse						
Energy required to heat object steele	Q_1	=	m*Cp*ΔT		#REF!	kJ/min
Time to heat object steele	t				2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$	0	3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1			0	#REF!	kW

Figure 5. Consumptions calculations for Single use system, sequel.

Acid									
Energy required to heat object steele	Q_1	=	$m*Cp*\Delta T$					6248,627788	kJ/min
Time to heat object steele	t							2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$					3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1							52,90985524	kW
Intermediate rinse									
Energy required to heat object steele	Q_1	=	$m*Cp*\Delta T$					#REF!	kJ/min
Time to heat object steele	t							2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$				0	3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1						0	#REF!	kW
Disinfection									
Energy required to heat object steele	Q_1	=	$m*Cp*\Delta T$					12497,25558	kJ/min
Time to heat object steele	t							2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$					3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1							157,0536517	kW
Final rinse									
Energy required to heat object steele	Q_1	=	$m*Cp*\Delta T$					#REF!	kJ/min
Time to heat object steele	*t*							2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$				0	3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1						0	#REF!	kW

Figure 6. Consumptions calculations for Single use system, sequel.

Energy, chemical and water demand per CIP-cycle

Object parameters

Tube length	m	200	
Tube diameter	m	0,051	
Tube thickness δ	m	0,0013	
Tube volume	m^3	0,408564125	
Tube inner area	m^2	32,04424507	
Tank height		3,8	
Tank diameter		2,6	
Tank thickness δ	m	0,002	
Tank volume	m^3	20,17530802	
Tank inner area	m^2	41,65751859	

Parameters

Electricity cost	kr/kwh	1
Water/steam cost	kr/kwh	0,13072
Cold water price	kr/l	0,01
Lye price	kr/l	7,35
Acid price	kr/l	5,25
Velocity	m/s	2
Object temperature initial	˚C	5
Temperaure interwall signal	˚C	3
Rho_{water}	kg/l	1
$C_{p,water}$	kJ/kg˚C	4,18
$C_{p, stainless\ steele}$	kJ/kg˚C	0,5
$rho_{stainless\ steele}$	kg/m^3	8000
Pump		
Impeller diameter	m	0,175
Output	kW	6
Scale factor	heating recovery	0,5
Scale factor	tubes, pump	

Adjust if needed
Calculated
Linked from tab/sheet

Cycle parameters

	Flow (l/min)	Initial temperature (˚C)	Final temperatur (˚C)	Time heating fluid (min)	Time heating/cooling equipment (min)	Time stages (min)
Pre rinse	245,138	37	40	0	2	5
Cold water	245,138	10	10	0	0	0
Lye	245,138	72	75	4	2	20
Intermediate rinse	245,138	10	40	3	2	5
Acid	245,138	62	65	2	2	15
Intermediate rinse	245,138	10	40	3	2	5
Disinfection	245,138	87	90	5	2	10
Final rinse	245,138	10	10	0	2	5
						65

Figure 7. Consumptions calculations for Recovery system.

Energy

	Energy demand-heating fluid (kW)	Energy demand-heating equipment (kW)	Energy demand-heating fluid (kWh)	Energy demand-heating equipment (kWh)	Heating demand per stage	Cost-heating
Pre rinse	51,234	94,567	0,000	3,152	3,152	0,206
Cold water	0,000	0,000	0,000	0,000	0,000	0,000
Lye	51,234	219,540	3,416	7,318	10,734	0,702
Intermediate rinse	512,339	0,000	25,617	0,000	25,617	1,674
Acid	51,234	52,910	1,708	1,764	3,471	0,227
Intermediate rinse	512,339	0,000	25,617	0,000	25,617	1,674
Disinfection	51,234	157,054	4,269	5,235	9,505	0,621
Final rinse	0,000	0,000	0,000	0,000	0,000	0,000
	1229,615	**524,071**	**60,627**	**17,469**	**78,096**	**5,10 kr**

	Energy demand-electricity fluid (kWh)	Energy demand-electricity equipment (kWh)	Energy demand-electricity steady (kWh)	Elecricity demand per stage (kWh)	Cost-elecricity
Pre rinse	0	0,2	0,5	0,7	0,7
Cold water	0	0	0	0	0
Lye	0,4	0,2	2	2,6	2,6
Intermediate rinse	0,3	0,2	0,5	1	1
Acid	0,2	0,2	1,5	1,9	1,9
Intermediate rinse	0,3	0,2	0,5	1	1
Disinfection	0,5	0,2	1	1,7	1,7
Final rinse	0	0,2	0,5	0,7	0,7
	1,700	**1,400**	**6,500**	**9,600**	**9,60 kr**

Total energy demand	Total cost
87,696	**14,70 kr**

Water

	Flow (l/min)	Time stages (min)	Reuse	Proportion	CIP-volume (l)	Cost
Pre rinse	245,138	5	1	1	1225,692	12,257
Cold water	245,138	0	1	1	0,000	0,000
Lye	245,138	20	0,05	0,985	241,461	2,415
Intermediate rinse	245,138	5	1	1	1225,692	12,257
Acid	245,138	15	0,05	0,99	182,015	1,820
Intermediate rinse	245,138	5	1	1	1225,692	12,257
Disinfection	245,138	10	0,05	0,99	121,344	1,213
Final rinse	245,138	5	0,25	1	306,423	3,064
					4528,320	**45,28 kr**

Figure 8. Consumptions calculations for Recovery system, sequel.

Chemicals

	Proportion	Total volyme (l)	Chemical Volume (l)	Cost
Lye	0,015	245,138	3,677	27,027
P3-mip SP				
Acid	0,01	183,854	1,839	9,652
P3-horolith CIP				
Disinfectant	0,01	122,569	1,226	6,435
P3-oxonia Active S				
				36,68 kr

Summary

	Cost
Energy	14,70
Water	45,28
Chemicals	36,68
	96,67 kr

Figure 9. Consumptions calculations for Recovery system, sequel.

Calculations						
Amout of object steele	m	=	rho*((Arör*δrör)+(Atank*δtank))		999,7804461	kg
Pre rinse						
Energy required to heat object steele	Q_1	=	m*Cp*ΔT		8748,078903	kJ/min
Time to heat object steele	t				2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$		3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1				94,56737383	kW
Cold water						
Energy required to heat object steele	Q_1	=	m*Cp*ΔT		#DIV/0!	kJ/min
Time to heat object steele	t				0	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$	0	3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1			0	#DIV/0!	kW
Lye						
Energy required to heat object steele	Q_1	=	m*Cp*ΔT		16246,43225	kJ/min
Time to heat object steele	t				2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$		3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1				219,5399296	kW
Intermediate rinse						
Energy required to heat object steele	Q_1	=	m*Cp*ΔT		#REF!	kJ/min
Time to heat object steele	t				2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$	0	3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1			0	#REF!	kW

Figure 10. Consumptions calculations for Recovery system, sequel.

Acid									
Energy required to heat object steele	Q_1	=	$m*Cp*\Delta T$					6248,627788	kJ/min
Time to heat object steele	t							2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$					3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1							52,90985524	kW
Intermediate rinse									
Energy required to heat object steele	Q_1	=	$m*Cp*\Delta T$					#REF!	kJ/min
Time to heat object steele	t							2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$				0	3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1						0	#REF!	kW
Disinfection									
Energy required to heat object steele	Q_1	=	$m*Cp*\Delta T$					12497,25558	kJ/min
Time to heat object steele	t							2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$					3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1							157,0536517	kW
Final rinse									
Energy required to heat object steele	Q_1	=	$m*Cp*\Delta T$					#REF!	kJ/min
Time to heat object steele	*t*							2	
Energy loss from fluid to object steele	Q_2	=	$m_{water}*C_{p,water}*\Delta T_{interwall}$				0	3074,036473	kJ/min
Energy required from heat exchanger	Q_2-Q_1						0	#REF!	kW

Figure 11. Consumptions calculations for Recovery system, sequel.

Appendix D

Diameter and flow relation

ø (m)	Cross section (m)	Flow (m^3/s)	Flow l/h	Flow (m^3/h)	USGPM
0,025	0,0005	0,001	3534,292	3,534	15,561
0,051	0,002	0,004	14708,308	14,708	64,761
0,063	0,003	0,006	22444,166	22,444	98,822
0,076	0,005	0,009	32662,511	32,663	143,813
0,101	0,008	0,016	57685,296	57,685	253,988

Moody's friction factor

ø (m)	Re	λ=4f[1]
0,025	49751,244	0,021
0,051	101492,537	0,018
0,063	125373,134	0,017
0,088	175124,378	0,017
0,101	200995,025	0,016

Parameters[1]

Velocity	2	m/s
Rho	1000	kg/m3
Kinematic viscosi	0,001005	kg/(ms)
$L_{Supply/Return}$	100	m
$L_{Drainage}$	40	m

ξ, Pipe bends and Valves[1]

	ξ	Quantity	Supply 1-3	Return 4-6	Drainage 7
T-section	1,4	8,0	1,3	1,3	5,0
Narrow pipe ben	0,7	0,0	0,0	0,0	3,0
Rounded pipe be	0,5	20,0	3,3	3,3	2,0
		20,4	3,4	3,4	10,14

	Mix proof valv	Seat valve[7]	Butterfly valve
Quantity	3	3	0
ξ	3	3	3
	9	9	0

Figure 12. Pressure drop calculations.

Pressure drop Supply							
ø (m)	Pipe length (Pa)	Pipe bends (Pa)	Valves (Pa)	Tank (Pa)*	Heat exchanger (Pa)	Total (Pa)	Total (bar)
0,025	168000,000	6800	18000	200000	30000	422800,000	4,228
0,051	70588,235	6800	18000	200000	30000	325388,235	3,254
0,063	53968,254	6800	18000	200000	30000	308768,254	3,088
0,088	38636,364	6800	18000	200000	30000	293436,364	2,934
0,101	31683,168	6800	18000	200000	30000	286483,168	2,865

Pressure drop Return					
ø (m)	Pipe length (Pa)	Pipe bends (Pa)	Valves (Pa)	Total (Pa)	Total (bar)
0,025	168000,000	40800	18000	226800,000	2,268
0,051	70588,235	40800	18000	129388,235	1,294
0,063	53968,254	40800	18000	112768,254	1,128
0,088	38636,364	40800	18000	97436,364	0,974
0,101	31683,168	40800	18000	90483,168	0,905

Pressure drop Drainage				
ø (m)	Pipe length (Pa)	Pipe bends (Pa)	Total (Pa)	Total (bar)
0,025	67200,000	20280	87480,000	0,875
0,051	28235,294	20280	48515,294	0,485
0,063	21587,302	20280	41867,302	0,419
0,088	15454,545	20280	35734,545	0,357
0,101	12800,000	20280	33080,000	0,331

Figure 13. Pressure drop calculations, sequel.

Summary and Pump models

	Supply		Return		Drainage	
Flow interval	3,53	57,69	3,53	57,69	0	12
Pressure interval	2,86	4,23	0,90	2,27	0,33	0,87
Pump model	W+22/20		Ws+20/15		Ws+20/15	
	W+35/35		Ws+30/30		LKHSP -10	
	W+35/55		Ws+44/50			
	LKH Prime		MR Liquid-Ring Pump 300			
	LKH Prime UltraPure 20					

Model	Supplier	Flow interval (m3/h)	RPM	Frequency (Hz)	ø Impeller (mm)	ø Inlet (mm)	ø Outlet (mm)	Power (kW)
W+22/20[2]	APV	2-32	2900	50	140	51	51	2,6
W+35/35[2]	APV	3-55	2900	50	175	63,5	51	6
W+35/55[2]	APV	8-86	2900	50	180	76	63,5	8,6
LKH Prime[3]	Alfa Laval	0-75	3000	50	165	63,5	51	7
LKH Prime UltraPure 20[3]	Alfa Laval	0-80	3600	60	165	63,5	51	11
Ws+20/15[4]	APV	3-30	2900	50	142	63,5	51	3
Ws+30/30[4]	APV	4-50	2900	50	175	63,5	51	7
Ws+44/50[4]	APV	6-95	2900	50	220	76	51	18
MR Liquid-Ring Pump 300[5]	Alfa Laval	0-80	1500	50	240	76	76	8
LKHSP -10	Alfa Laval	0-20	3000	50	110	63,5	51	1,1

References

[1] Handbook, Department of chemical engineering, Lund University, 2016-03-31

[2] APV, Sanitary Centrifugal Pumps, 50 Hz Curve Book, 2016-03-31

[3] Alfa Laval, LKH Prime - Prime UltraPure - Performance Curves, 2016-03-31

[4] SPX, Sanitary Centrifugal Pumps, Ws+ Self-Priming Pumps, 2016-03-31

[5] Alfa Laval, Performance Curves, MR Liquid Pump - 50 HZ/60 HZ, 2016-03-31

[6] Alfa Laval, LKHSP -10 Self-priming Centrifugal Pumps 50 Hz/60Hz, 2016-03-31

[7] Alfa Laval, Simply Unique Single Seat, Alfa Laval Unique SSV Tangential, 2016-03-31

* Overpressure concerning the spray nozzle located in the top of the object tank.

A comparison between pressure diagram (DN50/51) and calculations in Excel sheet concerning pressure drop in a mix proof valve causing $\xi=3$

Figure 14. Pressure drop calculations, sequel.

Appendix E

Mass and energy balance, Start up

Mass balance

Pre-rinse

$$m_{3:1} = 0 \cdot m_{1:1} + 0 \cdot m_{f1} = 0 \cdot 4{,}0542 + 0 \cdot 0{,}2288 = 0 \text{ kg/s}$$

$$m_{4:1} = 1 \cdot m_{1:1} + 1 \cdot m_{f1} = 1 \cdot 4{,}0542 + 1 \cdot 0{,}2288 = 4{,}283 \text{ kg/s}$$

$$x_{1:1} = \frac{m_{1:1} \cdot x_1}{m_{1:1} + m_{f1}} = \frac{4{,}054 \cdot 1}{4{,}054 + 0{,}2288} = 0{,}947$$

$$x_{f1} = \frac{m_{1:1} + m_{f1} - m_{2:1} \cdot x_{1:1}}{m_{2:1}} = \frac{4{,}054 + 0{,}2288 - 4{,}283 \cdot 0{,}947}{4{,}283} = 0{,}0534$$

Lye circulation

$$m_{3:2} = 0{,}95 \cdot m_{1:2} + 0{,}95 \cdot m_{f2} = 0{,}95 \cdot 3{,}983 + 0{,}95 \cdot 0{,}0057 = 3{,}789 \text{ kg/s}$$

$$m_{4:2} = 0{,}05 \cdot m_{1:2} + 0{,}05 \cdot m_{f2} = 0{,}05 \cdot 3{,}983 + 0{,}05 \cdot 0{,}0057 = 0{,}199\ kg/s$$

$$x_{2:1} = \frac{m_{1:2} \cdot x_2}{m_{1:2} + m_{f2}} = \frac{3{,}983 \cdot 0{,}985}{0{,}983 + 0{,}0057} = 0{,}984$$

$$x_{2:2} = \frac{m_{1:2} \cdot x_3}{m_{1:2} + m_{f2}} = \frac{3{,}983 \cdot 0{,}015}{3{,}983 + 0{,}0057} = 0{,}015$$

$$x_{f2} = \frac{m_{1:2} + m_{f2} - m_{2:2} \cdot x_{2:1} - m_{2:2} \cdot x_{2:2}}{m_{2:2}} = \frac{3{,}983 + 0{,}0057 - 3{,}988 \cdot 0{,}984 - 3{,}988 \cdot 0{,}015}{3{,}988} = 0{,}00143$$

Acid circulation

$$m_{3:3} = 0{,}95 \cdot m_{1:3} + 0{,}95 \cdot m_{f3} = 0{,}95 \cdot 4{,}006 + 0{,}95 \cdot 0{,}0008 = 3{,}806\ kg/s$$

$$m_{4:3} = 0{,}05 \cdot m_{1:3} + 0{,}05 \cdot m_{f3} = 0{,}05 \cdot 4{,}006 + 0{,}05 \cdot 0008 = 0{,}200\ kg/s$$

$$x_{3:1} = \frac{m_{1:3} \cdot x_4}{m_{1:3} + m_{f3}} = \frac{4{,}006 \cdot 0{,}99}{4{,}006 + 0{,}0008} = 0{,}9898$$

$$x_{3:2} = \frac{m_{1:3} \cdot x_5}{m_{1:3} + m_{f3}} = \frac{4{,}006 \cdot 0{,}01}{4{,}006 + 0{,}0008} = 0{,}010$$

$$x_{f3} = \frac{m_{1:3} + m_{f3} - m_{2:3} \cdot x_{3:1} - m_{2:3} \cdot x_{3:2}}{m_{2:3}} = \frac{4{,}006 + 0{,}0008 - 4{,}007 \cdot 0{,}9898 - 4{,}007 \cdot 0{,}01}{4{,}007} = 0{,}0001996$$

Disinfection

$$m_{3:4} = 0{,}95 \cdot m_{1:4} + 0{,}95 \cdot m_{f4} = 0{,}95 \cdot 3{,}944 + 0{,}95 \cdot 0{,}0001 = 3{,}747\ kg/s$$

$$m_{4:4} = 0{,}05 \cdot m_{1:4} + 0{,}05 \cdot m_{f4} = 0{,}05 \cdot 3{,}944 + 0{,}05 \cdot 0{,}0001 = 0{,}197\ kg/s$$

$$x_{4:1} = \frac{m_{1:4} \cdot x_1}{m_{1:4} + m_{f4}} = \frac{3{,}944 \cdot 1}{3{,}944 + 0{,}001} = 0{,}999975$$

$$x_{f4} = \frac{m_{1:4} + m_{f4} - m_{2:4} \cdot x_{4:1}}{m_{2:4}} = \frac{3{,}944 + 0{,}0001 - 3{,}944 \cdot 0{,}999975}{3{,}944} = 2{,}54 \cdot 10^{-5}$$

Final rinse

$$m_{3:5} = 0{,}75 \cdot m_{1:5} = 0{,}75 \cdot 4{,}084 = 3{,}063\ kg/s$$

$$m_{4:5} = 0{,}25 \cdot m_{1:5} = 0{,}25 \cdot 4{,}084 = 1{,}021\ kg/s$$

Intermediate rinse

$$m_{1:1} = 4{,}054\ kg/s$$

Energy balance

CIP unit

Pre-rinse

$$W_{1:1} = (m_{1:1} \cdot Cp_4 \cdot T_2 + E - m_1 \cdot Cp_1 \cdot T_1) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 + 6 - 4{,}084 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 42{,}64\ kWh$$

Lye circulation

$$W_{1:2} = \left(m_{1:2} \cdot Cp_5 \cdot T_3 + E - \left(0{,}99 \cdot m_1 \cdot Cp_1 + m_2 \cdot C_{p2}\right) \cdot T_1\right) \cdot t = (3{,}983 \cdot 4{,}190 \cdot 75 + 6 - (0{,}99 \cdot 4{,}084 + 0{,}07 \cdot 1{,}492) \cdot 10) \cdot 0{,}33 = 358{,}68\ kWh$$

Intermediate rinse

$$W_{1:3} = (m_{1:1} \cdot Cp_4 \cdot T_2 + E - m_1 \cdot Cp_1 \cdot T_1) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 + 6 - 4{,}084 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 42{,}64\ kWh$$

Acid circulation

$$W_{1:4} = \left(m_{1:3} \cdot Cp_6 \cdot T_4 + E - \left(0{,}99 \cdot m_1 \cdot Cp_1 + m_3 \cdot C_{p3}\right) \cdot T_1\right) \cdot t = \left(4{,}006 \cdot 4{,}183 \cdot 65 + 6 - (0{,}99 \cdot 4{,}0846 \cdot 4{,}194 + 0{,}055 \cdot 1{,}18)\right) \cdot 0{,}25 = 231{,}24\ kWh$$

Intermediate rinse

$$W_{1:5} = (m_{1:1} \cdot Cp_4 \cdot T_2 + E - m_1 \cdot Cp_1 \cdot T_1) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 + 6 - 4{,}084 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 42{,}64\ kWh$$

Disinfection

$$W_{1:6} = (m_{1:4} \cdot Cp_7 \cdot T_5 + E - m_1 \cdot Cp_1 \cdot T_1) \cdot t = (3{,}944 \cdot 4{,}201 \cdot 90 + 6 - 4{,}086 \cdot 4{,}194 \cdot 10) \cdot 0{,}17 = 220{,}97\ kWh$$

Final rinse

$$W_{1:7} = (m_1 \cdot Cp_1 \cdot T_1 + E - m_1 \cdot Cp_1 \cdot T_1) \cdot t = (4{,}086 \cdot 4{,}194 \cdot 10 + 6 - 4{,}084 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 0{,}5\ kWh$$

Object

Pre-rinse

$$W_{2:1} = \left(m_{1:1} \cdot C_{p4} \cdot T_2 + m_{f1} \cdot C_{pf1} \cdot T_{f1} - m_{13:1} \cdot C_{p4} \cdot T_6\right) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 + 0{,}2288 \cdot 3{,}93 \cdot 3 - 4{,}283 \cdot 4{,}175 \cdot 37) \cdot 0{,}083 = 1{,}51\ kWh$$

Lye circulation

$$W_{2:2} = \left(m_{1:2} \cdot C_{p5} \cdot T_3 + m_{f2} \cdot C_{pf2} \cdot T_{f2} - m_{12:2} \cdot C_{p5} \cdot T_7 - m_{13:2} \cdot C_{p5} \cdot T_7\right) \cdot t = (3{,}983 \cdot 4{,}190 \cdot 75 + 0{,}0057 \cdot 3{,}93 \cdot 40 - 3{,}789 \cdot 4{,}190 \cdot 72 - 0{,}199 \cdot 4{,}190 \cdot 72) \cdot 0{,}33 = 16{,}42\ kWh$$

Intermediate rinse

$$W_{2:3} = \left(m_{1:1} \cdot C_{p4} \cdot T_2 - m_{13:6} \cdot C_{p4} \cdot T_6\right) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 - 4{,}054 \cdot 4{,}175 \cdot 37) \cdot 0{,}083 = 4{,}23\ kWh$$

Acid circulation

$$W_{2:4} = \left(m_{1:3} \cdot C_{p6} \cdot T_4 + m_{f3} \cdot C_{pf3} \cdot T_{f3} - m_{12:3} \cdot C_{p6} \cdot T_8 - m_{13:3} \cdot C_{p6} \cdot T_8\right) \cdot t = (4{,}006 \cdot 4{,}183 \cdot 65 + 0{,}0008 \cdot 3{,}93 \cdot 62 - 3{,}806 \cdot 4{,}183 \cdot 62 - 0{,}200 \cdot 4{,}183 \cdot 62) \cdot 0{,}25 = 12{,}58\ kWh$$

Intermediate rinse

$$W_{2:5} = \left(m_{1:1} \cdot C_{p4} \cdot T_2 - m_{13:6} \cdot C_{p4} \cdot T_6\right) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 - 4{,}054 \cdot 4{,}175 \cdot 37) \cdot 0{,}083 = 4{,}23\ kWh$$

Disinfection

$$W_{2:6} = \left(m_{1:4} \cdot C_{p7} \cdot T_5 + m_{f4} \cdot C_{pf4} \cdot T_{f4} - m_{12:4} \cdot C_{p7} \cdot T_9 - m_{13:4} \cdot C_{p7} \cdot T_9\right) \cdot t = (3{,}994 \cdot 4{,}201 \cdot 90 + 0{,}0001 \cdot 3{,}93 \cdot 65 - 3{,}747 \cdot 4{,}201 \cdot 87 - 0{,}197 \cdot 4{,}201 \cdot 87) \cdot 0{,}16 = 8{,}28\ kWh$$

Final rinse

$$W_{2:7} = \left(m_1 \cdot C_{p1} \cdot T_1 - m_{12:5} \cdot C_{p1} \cdot T_1 - m_{13:5} \cdot C_{p1} \cdot T_1\right) \cdot t = (4{,}086 \cdot 4{,}194 \cdot 10 - 3{,}063 \cdot 4{,}194 \cdot 10 - 1{,}201 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 0\ kWh$$

Mass and energy balance, Operation

Mass balance

Pre-rinse

$$m_{1:1} = m_{2:1} = m_{4:1} = 4{,}054\ kg/s$$

$$x_{H_2O:1} = x_{1:1} = 0{,}94657$$

$$x_{fouling1} = x_{f1} = 0{,}05343$$

Lye circulation

$$m_{1:2} = m_{2:2} = m_{3:2} = 3{,}983\ kg/s$$

$$x_{H_20:2} = x_{2:1} = 0{,}98359$$

$x_{lut:2} = x_{2:2} = 0{,}01498$

$x_{fouling2} = x_{f2} = 0{,}00143$

Acid circulation

$m_{1:3} = m_{2:3} = m_{3:3} = 4{,}006\ kg/s$

$x_{H_20:3} = x_{3:1} = 0{,}98980$

$x_{acid:3} = x_{3:2} = 0{,}009998$

$x_{fouling3} = x_{f3} = 0{,}000199$

Disinfection

$m_{1:4} = m_{2:4} = m_{3:4} = 3{,}944$

$x_{H_20:4} = x_{4:1} = 0{,}999975$

$x_{fouling4} = x_{f4} = 0{,}000025$

Final rinse

$0{,}25 \cdot m_{1:5} = 0{,}25 \cdot m_{2:5} = m_{4:5} = 1{,}021\ kg/s$

$0{,}75 \cdot m_{1:5} = 0{,}75 \cdot m_{2:5} = m_{3:5} = 3{,}063\ kg/s$

Intermediate rinse

$m_{1:1} = m_{2:1} = m_{4:1} = 4{,}054$

Energy balance

CIP unit

Pre-rinse

$$W_{1:1} = (m_{1:1} \cdot Cp_4 \cdot T_2 + E - m_1 \cdot Cp_1 \cdot T_1) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 + 6 - 4{,}084 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 42{,}64\ kWh$$

Lye circulation

$$W_{1:2} = (m_{1:2} \cdot Cp_5 \cdot T_3 + E - m_{3:2} \cdot Cp_5 \cdot T_7) \cdot t = (3{,}983 \cdot 4{,}190 \cdot 75 + 6 - 3{,}789 \cdot 4{,}190 \cdot 72) \cdot 0{,}33 = 38{,}16\ kWh$$

Intermediate rinse

$$W_{1:3} = (m_{1:1} \cdot Cp_4 \cdot T_2 + E - m_1 \cdot Cp_1 \cdot T_1) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 + 6 - 4{,}084 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 42{,}64\ kWh$$

Acid circulation

$$W_{1:4} = (m_{1:3} \cdot Cp_6 \cdot T_4 + E - m_{3:3} \cdot Cp_6 \cdot T_8) \cdot t = (4{,}006 \cdot 4{,}183 \cdot 65 + 6 - 3{,}806 \cdot 4{,}183 \cdot 62) \cdot 0{,}25 = 27{,}03\ kWh$$

Intermediate rinse

$$W_{1:5} = (m_{1:1} \cdot Cp_4 \cdot T_2 + E - m_1 \cdot Cp_1 \cdot T_1) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 + 6 - 4{,}084 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 42{,}64\ kWh$$

Disinfection

$$W_{1:6} = (m_{1:4} \cdot Cp_7 \cdot T_5 + E - m_{3:4} \cdot Cp_7 \cdot T_9) \cdot t = (3{,}944 \cdot 4{,}201 \cdot 90 + 6 - 3{,}747 \cdot 4{,}201 \cdot 87) \cdot 0{,}17 = 21{,}28\ kWh$$

Final rinse

$$W_{1:7} = (m_1 \cdot Cp_1 \cdot T_1 + E - m_1 \cdot Cp_1 \cdot T_1) \cdot t = (4{,}086 \cdot 4{,}194 \cdot 10 + 6 - 4{,}084 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 0{,}5\ kWh$$

Object

Pre-rinse

$$W_{2:1} = \left(m_{1:1} \cdot C_{p4} \cdot T_2 - m_{4:1} \cdot C_{p4} \cdot T_6\right) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 - 4{,}054 \cdot 4{,}175 \cdot 37) \cdot 0{,}083 = 4{,}23\ kWh$$

Lye circulation

$$W_{2:2} = \left(m_{1:2} \cdot C_{p5} \cdot T_3 - m_{1:2} \cdot C_{p5} \cdot T_7\right) \cdot t = (3{,}983 \cdot 4{,}190 \cdot 75 - 3{,}983 \cdot 4{,}190 \cdot 72) \cdot 0{,}33 = 16{,}69\ kWh$$

Intermediate rinse

$$W_{2:3} = \left(m_{1:1} \cdot C_{p4} \cdot T_2 - m_{4:1} \cdot C_{p4} \cdot T_6\right) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 - 4{,}054 \cdot 4{,}175 \cdot 37) \cdot 0{,}083 = 4{,}23\ kWh$$

Acid circulation

$$W_{2:4} = \left(m_{1:3} \cdot C_{p6} \cdot T_4 - m_{1:3} \cdot C_{p6} \cdot T_8\right) \cdot t = (4{,}006 \cdot 4{,}183 \cdot 65 - 4{,}006 \cdot 4{,}183 \cdot 62) \cdot 0{,}25 = 12{,}57\ kWh$$

Intermediate rinse

$$W_{2:5} = \left(m_{1:1} \cdot C_{p4} \cdot T_2 - m_{4:1} \cdot C_{p4} \cdot T_6\right) \cdot t = (4{,}054 \cdot 4{,}175 \cdot 40 - 4{,}054 \cdot 4{,}175 \cdot 37) \cdot 0{,}083 = 4{,}23\ kWh$$

Disinfection

$$W_{2:6} = \left(m_{1:4} \cdot C_{p7} \cdot T_5 - m_{1:4} \cdot C_{p7} \cdot T_9\right) \cdot t = (3{,}944 \cdot 4{,}201 \cdot 90 - 3{,}944 \cdot 4{,}201 \cdot 87) \cdot 0{,}17 = 8{,}28\ kWh$$

Final rinse

$$W_{2:7} = \left(m_1 \cdot C_{p1} \cdot T_1 - m_1 \cdot C_{p1} \cdot T_1\right) \cdot t = (4{,}086 \cdot 4{,}194 \cdot 10 - 4{,}086 \cdot 4{,}194 \cdot 10) \cdot 0{,}083 = 0\ kW$$

Appendix F

Flow spec

		Stage	Flow (kg/s)	Temperature (˚C)	Pressure minimum	Fraction 1*	Fraction 2**	Fraction 3***
m1		Cold water	4,086	10	3	1	-	-
m2		Lye (50%)	0,07	10	3	1	-	-
m3		Acid (50%)	0,055	10	3	1	-	-
m1:1		Pre rinse	4,054	40	3	1	-	-
m1:2		Lye circulation	3,983	75	3	0,985	0,015	-
m1:3		Acid circulation	4,006	65	3	0,99	0,01	-
m1:4		Disinfection	3,944	90	3	1	-	-
m1:5		Final rinse	4,084	10	3	1	-	-
mf1		Pre rinse	0,2288	3	3	-	-	1
mf2		Lye circulation	0,0057	40	3	-	-	1
mf3		Acid circulation	0,0008	75	3	-	-	1
mf4		Disinfection	0,0001	65	3	-	-	1
m2:1		Pre rinse	4,2828	37	3	0,94657	-	0,05343
m2:2		Lye circulation	3,9887	72	3	0,9836	0,01498	0,00143
m2:3		Acid circulation	4,0068	62	3	0,9898	0,01	0,0002
m2:4		Disinfection	3,9441	87	3	0,999975	-	0,000025
m2:5		Final rinse	4,084	10	3	1	-	-
m3:1		Pre rinse	0	37	3	0,94657	-	0,05343
m3:2		Lye circulation	3,789265	72	3	0,9836	0,01498	0,00143
m3:3		Acid circulation	3,80646	62	3	0,9898	0,01	0,0002
m3:4		Disinfection	3,746895	87	3	0,999975	-	0,000025
m3:5		Final rinse	3,063	10	3	1	-	-
m4:1		Pre rinse	4,2828	37	3	0,94657	-	0,05343
m4:2		Lye circulation	0,199435	72	3	0,9836	0,01498	0,00143
m4:3		Acid circulation	0,20034	62	3	0,9898	0,01	0,0002
m4:4		Disinfection	0,197205	87	3	0,999975	-	0,000025
m4:5		Final rinse	1,021	10	3	1	-	-
m4:6		Intermediate rinse	4,054	37	3	1	-	-
b11		Disinfection	3,944	87	3	1	-	-
b12		Disinfection	3,944	90	3	1	-	-
b21		Lye circulation	3,983	72	3	0,985	0,015	-
b22		Lye circulation	3,983	75	3	0,985	0,015	-
b31		Acid circulation	4,006	62	3	0,99	0,01	-
b32		Acid circulation	4,006	65	3	0,99	0,01	-
b41		Pre rinse	4,054	37	3	1	-	-
b42		Pre rinse	4,054	40	3	1	-	-
a11		Disinfection		160	6	1	-	-
a12		Disinfection		155	6	1	-	-
a21		Lye circulation		160	6	1	-	-
a22		Lye circulation		155	6	1	-	-
a31		Acid circulation		160	6	1	-	-
a32		Acid circulation		155	6	1	-	-
a41		Pre rinse		160	6	1	-	-
a42		Pre rinse		155	6	1	-	-
Fraction 1*		Water						
Fraction 2**		Chemical						
Fraction 3***		Fouling/Dirt						

Figure 15. Flow specification, start up

		Stage	Flow (kg/s)	Temperature (˚C)	Pressure min	Fraction 1*	Fraction 2**	Fraction 3***
m1:1		Pre rinse	4,054	40	3	0,94657	-	0,05343
m1:2		Lye circulation	3,983	75	3	0,9836	0,01498	0,00143
m1:3		Acid circulation	4,006	65	3	0,9898	0,01	0,0002
m1:4		Disinfection	3,944	90	3	0,999975	-	0,000025
m1:5		Final rinse	4,084	10	3	1	-	-
mf1		Pre rinse	0,2288	3	3	0,94657	-	0,05343
mf2		Lye circulation	0,0057	40	3	0,9836	0,01498	0,00143
mf3		Acid circulation	0,0008	75	3	0,9898	0,01	0,0002
mf4		Disinfection	0,0001	65	3	0,999975	-	0,000025
m2:1		Pre rinse	4,2828	37	3	0,94657	-	0,05343
m2:2		Lye circulation	3,9887	72	3	0,9836	0,01498	0,00143
m2:3		Acid circulation	4,0068	62	3	0,9898	0,01	0,0002
m2:4		Disinfection	3,9441	87	3	0,999975	-	0,000025
m2:5		Final rinse	4,084	10	3	1	-	-
m3:1		Pre rinse	0	37	3	0,94657	-	0,05343
m3:2		Lye circulation	3,789265	72	3	0,9836	0,01498	0,00143
m3:3		Acid circulation	3,80646	62	3	0,9898	0,01	0,0002
m3:4		Disinfection	3,746895	87	3	0,999975	-	0,000025
m3:5		Final rinse	3,063	10	3	1	-	-
m4:1		Pre rinse	4,2828	37	3	0,94657	-	0,05343
m4:2		Lye circulation	0,199435	72	3	0,9836	0,01498	0,00143
m4:3		Acid circulation	0,20034	62	3	0,9898	0,01	0,0002
m4:4		Disinfection	0,197205	87	3	0,999975	-	0,000025
m4:5		Final rinse	1,021	10	3	1	-	-
m4:6		Intermediate rinse	4,054	37	3	1	-	-
b11		Disinfection	3,944	87	3	1	-	-
b12		Disinfection	3,944	90	3	1	-	-
b21		Lye circulation	3,983	72	3	0,985	0,015	-
b22		Lye circulation	3,983	75	3	0,985	0,015	-
b31		Acid circulation	4,006	62	3	0,99	0,01	-
b32		Acid circulation	4,006	65	3	0,99	0,01	-
b41		Pre rinse	4,054	37	3	1	-	-
b42		Pre rinse	4,054	40	3	1	-	-
a11		Final rinse		160	6	1	-	-
a12		Final rinse		160	6	1	-	-
a21		Lye circulation		160	6	1	-	-
a22		Lye circulation		160	6	1	-	-
a31		Acid circulation		160	6	1	-	-
a32		Acid circulation		160	6	1	-	-
a41		Disinfection		160	6	1	-	-
a42		Disinfection		160	6	1	-	-
Fraction 1*		water						
Fraction 2**		Chemical						
Fraction 3***		Fouling						

Figure 16. Flow specification, operation

Appendix G

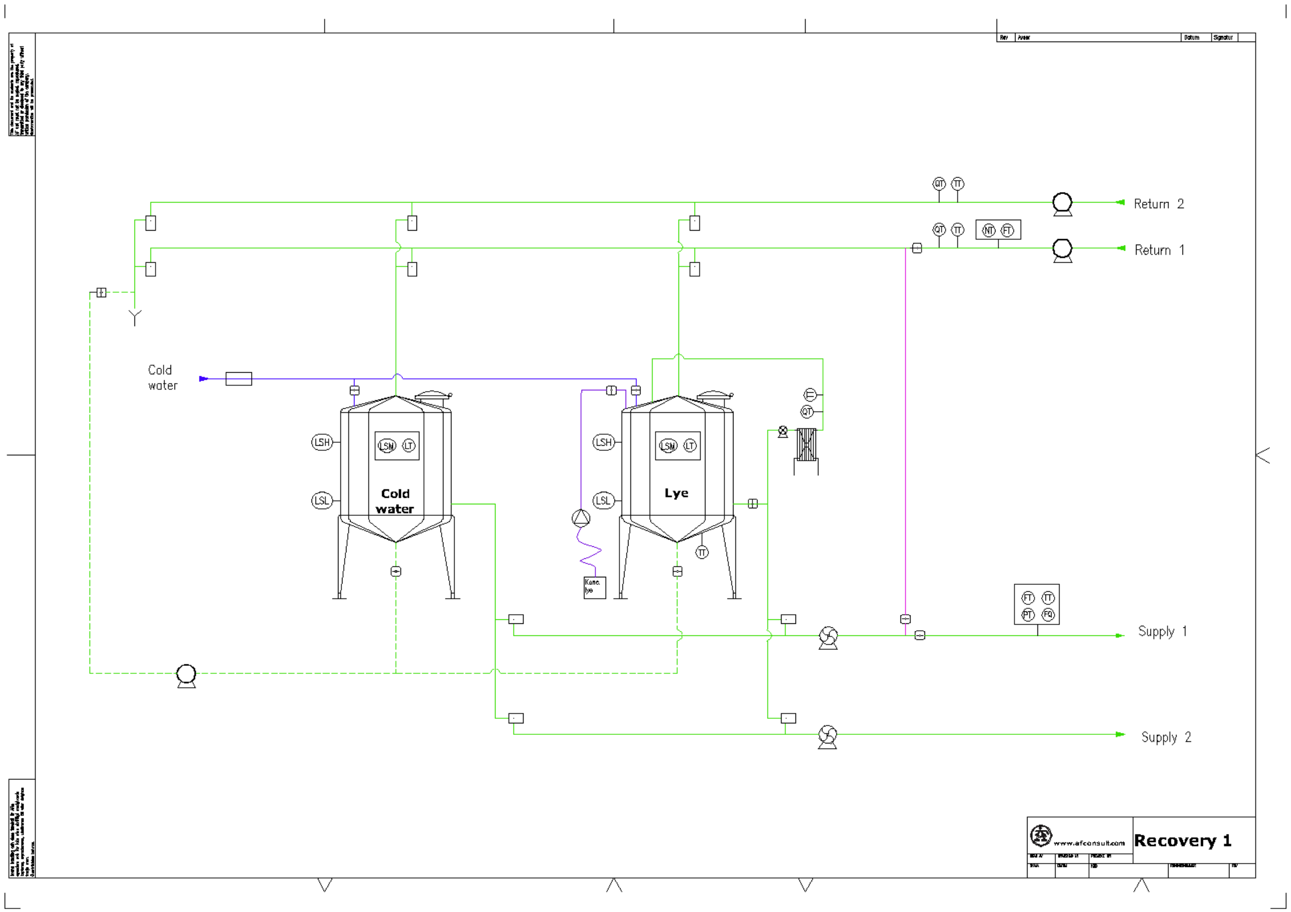


Figure 17. P&ID of the smallest recovery system, recovery 1

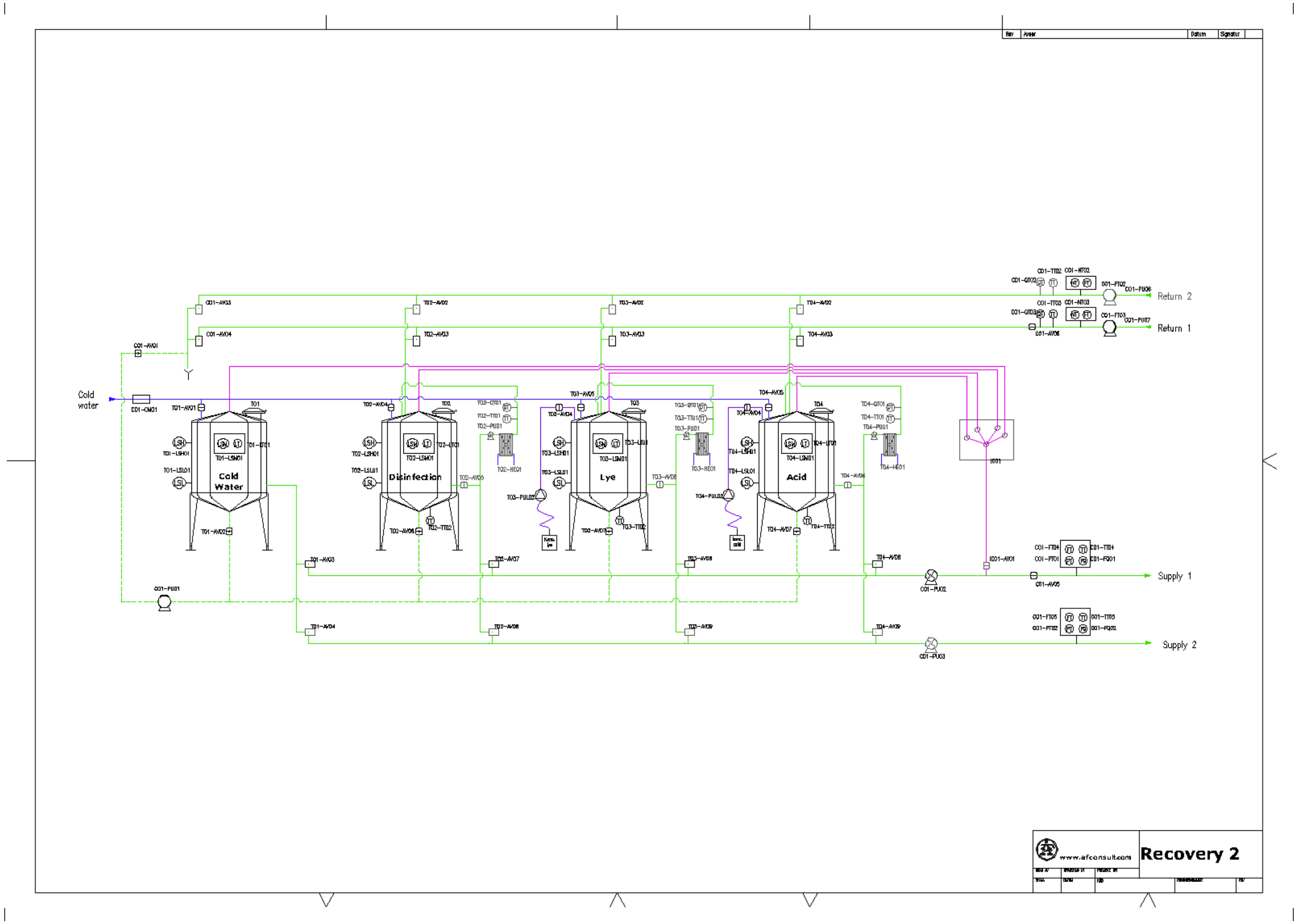


Figure 18. P&ID of Recovery system 2

Appendix H

		Labe				INDEX	Object number	Function	Type
S1	-	C	01	-	AV	01	S1-C01-AV01	Cut-off drainage	Butterfly valve
S1	-	C	01	-	CM	01	S1-C01-CM01	Descaling cold water	Calcium magnet
S1	-	C	01	-	PU	01	S1-C01-PU01	Pump drainage	Liquid ring pump
S1	-	C	01	-	AV	02	S1-C01-AV02	Cut-off drainage, circuit three	Butterfly valve
S1	-	C	01	-	AV	03	S1-C01-AV03	Cut-off drainage, circuit two	Butterfly valve
S1	-	C	01	-	AV	04	S1-C01-AV04	Cut-off drainage, circuit one	Butterfly valve
S1	-	C	01	-	PU	02	S1-C01-PU02	Supply pump, circuit one	Centrifugal pump
S1	-	C	01	-	PU	03	S1-C01-PU03	Supply pump, circuit two	Centrifugal pump
S1	-	C	01	-	PU	04	S1-C01-PU04	Supply pump, circuit three	Centrifugal pump
S1	-	C	01	-	QT	01	S1-C01-QT01	Sensor return, circuit three	Conductivity transmitter
S1	-	C	01	-	TT	01	S1-C01-TT01	Sensor return, circuit three	Temperature transmitter
S1	-	C	01	-	NT	01	S1-C01-NT01	Sensor return, circuit three	Fluidity transmitter
S1	-	C	01	-	FT	01	S1-C01-FT01	Sensor return, circuit three	Flow transmitter
S1	-	C	01	-	PU	05	S1-C01-PU05	Return Pump, circuit three	Liquid ring pump
S1	-	C	01	-	QT	02	S1-C01-QT02	Sensor return, circuit two	Conductivity transmitter
S1	-	C	01	-	TT	02	S1-C01-TT02	Sensor return, circuit two	Temperature transmitter
S1	-	C	01	-	NT	02	S1-C01-NT02	Sensor return, circuit two	Fluidity transmitter
S1	-	C	01	-	FT	02	S1-C01-FT02	Sensor return, circuit two	Flow transmitter
S1	-	C	01	-	PU	06	S1-C01-PU06	Return Pump, circuit two	Liquid ring pump
S1	-	C	01	-	QT	03	S1-C01-QT03	Sensor return, circuit one	Conductivity transmitter
S1	-	C	01	-	TT	03	S1-C01-TT03	Sensor return, circuit one	Temperature transmitter
S1	-	C	01	-	NT	03	S1-C01-NT03	Sensor return, circuit one	Fluidity transmitter
S1	-	C	01	-	FT	03	S1-C01-FT03	Sensor return, circuit one	Flow transmitter
S1	-	C	01	-	PU	07	S1-C01-PU07	Return Pump, circuit one	Liquid ring pump
S1	-	C	01	-	FT	04	S1-C01-FT04	Sensor supply, circuit one	Flow transmitter
S1	-	C	01	-	TT	04	S1-C01-TT04	Sensor supply, circuit one	Temperature transmitter
S1	-	C	01	-	PT	01	S1-C01-PT01	Sensor supply, circuit one	Pressure transmitter
S1	-	C	01	-	FQ	01	S1-C01-FQ01	Sensor supply, circuit one	Flow transmitter
S1	-	C	01	-	FT	05	S1-C01-FT05	Sensor supply, circuit two	Flow transmitter
S1	-	C	01	-	TT	05	S1-C01-TT05	Sensor supply, circuit two	Temperature transmitter
S1	-	C	01	-	PT	02	S1-C01-PT02	Sensor supply, circuit two	Pressure transmitter
S1	-	C	01	-	FQ	02	S1-C01-FQ02	Sensor supply, circuit two	Flow transmitter
S1	-	C	01	-	FT	06	S1-C01-FT06	Sensor supply, circuit three	Flow transmitter
S1	-	C	01	-	TT	06	S1-C01-TT06	Sensor supply, circuit three	Temperature transmitter
S1	-	C	01	-	PT	03	S1-C01-PT03	Sensor supply, circuit three	Pressure transmitter
S1	-	C	01	-	FQ	03	S1-C01-FQ03	Sensor supply, circuit three	Flow transmitter
S1	-	T	01				S1-T01	CIP storage tank	Tank
S1	-	T	01	-	AV	01	S1-T01-AV01	Cut-off return, circiut three	Butterfly valve
S1	-	T	01	-	AV	02	S1-T01-AV02	Cut-off return, circiut two	Butterfly valve
S1	-	T	01	-	AV	03	S1-T01-AV03	Cut-off return, circiut one	Butterfly valve
S1	-	T	02	-	AV	04	S1-T02-AV04	Cut-off detergent	Butterfly valve
S1	-	T	01	-	AV	05	S1-T01-AV05	Cut-off cold water	Butterfly valve
S1	-	T	01	-	AV	06	S1-T01-AV06	Cut-off drainage storage tank	Butterfly valve
S1	-	T	01	-	AV	07	S1-T01-AV07	Cut-off supply, circuit one	Butterfly valve
S1	-	T	01	-	AV	08	S1-T01-AV08	Cut-off supply, circuit two	Butterfly valve
S1	-	T	01	-	AV	09	S1-T01-AV09	Cut-off supply, circuit three	Butterfly valve
S1	-	T	01	-	LSH	01	S1-T01-LSH01	Sensor tank	Level switch high
S1	-	T	01	-	LSL	01	S1-T01-LSL01	Sensor tank	Level switch low
S1	-	T	01	-	LSM	01	S1-T01-LSM01	Sensor tank	Level switch middle
S1	-	T	01	-	LT	01	S1-T01-LT01	Sensor tank	Level stick
S1	-	T	01	-	TT	01	S1-T01-TT01	Sensor tank	Temperature transmitter
S1	-	HE	01				S1-HE01	Heating supply, circuit one	Heat exchanger
S1	-	HE	01	-	AV	01	S1-HE01-AV01	Cut-off return, heating circulation	Butterfly valve
S1	-	HE	01	-	AV	02	S1-HE01-AV02	Cut-off, heating circulation	Butterfly valve
S1	-	HE	02	-	AV	03	S1-HE02-AV03	Cut-off supply, heating circulation	Butterfly valve
S1	-	HE	02				S1-HE02	Heating supply, circuit two	Värmeväxlare
S1	-	HE	03				S1-HE03	Heating supply, circuit three	Värmeväxlare

Figure 19. Component list, Single use Food

		Labe				INDEX	Object number	Function	Type
R2	-	C	01	-	AV	01	R2-C01-AV01	Cut-off drainage	Butterfly valve
R2	-	C	01	-	CM	01	R2-C01-CM01	Descaling cold water	Calcium magnet
R2	-	C	01	-	PU	01	R2-C01-PU01	Pump drainage	Liquid ring pump
R2	-	C	01	-	AV	02	R2-C01-AV02	Cut-off drainage, circuit three	Seat valve
R2	-	C	01	-	AV	03	R2-C01-AV03	Cut-off drainage, circuit two	Seat valve
R2	-	C	01	-	AV	04	R2-C01-AV04	Cut-off drainage, circuit one	Seat valve
R2	-	C	01	-	PU	02	R2-C01-PU02	Supply pump, circuit one	Centrifugal pump
R2	-	C	01	-	PU	03	R2-C01-PU03	Supply pump, circuit two	Centrifugal pump
R2	-	C	01	-	PU	04	R2-C01-PU04	Supply pump, circuit three	Centrifugal pump
R2	-	C	01	-	QT	01	R2-C01-QT01	Sensor return, circuit three	Conductivity transmitter
R2	-	C	01	-	TT	01	R2-C01-TT01	Sensor return, circuit three	Temperature transmitter
R2	-	C	01	-	NT	01	R2-C01-NT01	Sensor return, circuit three	Fluidity transmitter
R2	-	C	01	-	FT	01	R2-C01-FT01	Sensor return, circuit three	Flow transmitter
R2	-	C	01	-	PU	05	R2-C01-PU05	Return Pump, circuit three	Liquid ring pump
R2	-	C	01	-	QT	02	R2-C01-QT02	Sensor return, circuit two	Conductivity transmitter
R2	-	C	01	-	TT	02	R2-C01-TT02	Sensor return, circuit two	Temperature transmitter
R2	-	C	01	-	NT	02	R2-C01-NT02	Sensor return, circuit two	Fluidity transmitter
R2	-	C	01	-	FT	02	R2-C01-FT02	Sensor return, circuit two	Flow transmitter
R2	-	C	01	-	PU	06	R2-C01-PU06	Return Pump, circuit two	Liquid ring pump
R2	-	C	01	-	QT	03	R2-C01-QT03	Sensor return, circuit one	Conductivity transmitter
R2	-	C	01	-	TT	03	R2-C01-TT03	Sensor return, circuit one	Temperature transmitter
R2	-	C	01	-	NT	03	R2-C01-NT03	Sensor return, circuit one	Fluidity transmitter
R2	-	C	01	-	FT	03	R2-C01-FT03	Sensor return, circuit one	Flow transmitter
R2	-	C	01	-	PU	07	R2-C01-PU07	Return Pump, circuit one	Liquid ring pump
R2	-	C	01	-	AV	05	R2-C01-AV05	Cut-off supply, circiut one	Butterfly valve
R2	-	C	01	-	AV	06	R2-C01-AV06	Cut-off supply, circiut one	Butterfly valve
R2	-	C	01	-	AV	07	R2-C01-AV07	Cut-off drain	Butterfly valve
R2	-	C	01	-	FT	04	R2-C01-FT04	Sensor supply, circuit one	Flow transmitter
R2	-	C	01	-	TT	04	R2-C01-TT04	Sensor supply, circuit one	Temperature transmitter
R2	-	C	01	-	PT	01	R2-C01-PT01	Sensor supply, circuit one	Pressure transmitter
R2	-	C	01	-	FQ	01	R2-C01-FQ01	Sensor supply, circuit one	Mass flow meter
R2	-	C	01	-	FT	05	R2-C01-FT05	Sensor supply, circuit two	Flow transmitter
R2	-	C	01	-	TT	05	R2-C01-TT05	Sensor supply, circuit two	Temperature transmitter
R2	-	C	01	-	PT	02	R2-C01-PT02	Sensor supply, circuit two	Pressure transmitter
R2	-	C	01	-	FQ	02	R2-C01-FQ02	Sensor supply, circuit two	Mass flow meter
R2	-	C	01	-	FT	06	R2-C01-FT06	Sensor supply, circuit three	Flow transmitter
R2	-	C	01	-	TT	06	R2-C01-TT06	Sensor supply, circuit three	Temperature transmitter
R2	-	C	01	-	PT	03	R2-C01-PT03	Sensor supply, circuit three	Pressure transmitter
R2	-	C	01	-	FQ	03	R2-C01-FQ03	Sensor supply, circuit three	Mass flow meter
R2	-	T	01				R2-T01	Cold water storage tank	Tank
R2	-	T	01	-	AV	01	R2-T01-AV01	Cut-off cold water	Butterfly valve
R2	-	T	01	-	AV	02	R2-T01-AV02	Cut-off tank, drainage	Butterfly valve
R2	-	T	01	-	AV	03	R2-T01-AV03	Cut-off supply, circuit one	Seat valve
R2	-	T	01	-	AV	04	R2-T01-AV04	Cut-off supply, circuit two	Seat valve
R2	-	T	01	-	AV	05	R2-T01-AV05	Cut-off supply, circuit three	Seat valve
R2	-	T	01	-	LSH	01	R2-T01-LSH01	Sensor tank	Level switch high
R2	-	T	01	-	LSL	01	R2-T01-LSL01	Sensor tank	Level switch low
R2	-	T	01	-	LSM	01	R2-T01-LSM01	Sensor tank	Level switch middle
R2	-	T	01	-	LT	01	R2-T01-LT01	Sensor tank	Level stick
R2	-	T	02				R2-T02	Disinfection storage tank	Tank
R2	-	T	02	-	AV	01	R2-T02-AV01	Cut-off return, circiut three	Seat valve
R2	-	T	02	-	AV	02	R2-T02-AV02	Cut-off return, circiut two	Seat valve
R2	-	T	02	-	AV	03	R2-T02-AV03	Cut-off return, circiut one	Seat valve
R2	-	T	02	-	AV	04	R2-T02-AV04	Cut-off cold water	Butterfly valve
R2	-	T	02	-	AV	05	R2-T02-AV05	Cut-off heating circulation	Butterfly valve
R2	-	T	02	-	AV	06	R2-T02-AV06	Cut-off tank, drainage	Butterfly valve
R2	-	T	02	-	AV	07	R2-T02-AV07	Cut-off supply, circuit one	Seat valve
R2	-	T	02	-	AV	08	R2-T02-AV08	Cut-off supply, circuit two	Seat valve
R2	-	T	02	-	AV	09	R2-T02-AV09	Cut-off supply, circuit three	Seat valve
R2	-	T	02	-	HE	01	R2-T02-HE01	Heating circulation	Plate heat exchanger, tubular heat exchanger, welded stainless heat exchanger
R2	-	T	02	-	PU	01	R2-T02-PU01	Pump heating circulation	Centrifugal pump
R2	-	T	02	-	QT	01	R2-T02-QT01	Sensor heating circulation	Conductivity transmitter
R2	-	T	02	-	TT	01	R2-T02-TT01	Sensor heating circulation	Temperature transmitter
R2	-	T	02	-	LSH	01	R2-T02-LSH01	Sensor tank	Level switch high
R2	-	T	02	-	LSL	01	R2-T02-LSL01	Sensor tank	Level switch low
R2	-	T	02	-	LSM	01	R2-T02-LSM01	Sensor tank	Level switch middle
R2	-	T	02	-	LT	01	R2-T02-LT01	Sensor tank	Level stick
R2	-	T	02	-	TT	02	R2-T02-TT02	Sensor storage tank	Temperature transmitter

Figure 20. Component list, Recovery Food

R2	-	T	03				R2-T03	Lye storage tank	Tank
R2	-	T	03	-	AV	01	R2-T03-AV01	Cut-off return, circiut three	Seat valve
R2	-	T	03	-	AV	02	R2-T03-AV02	Cut-off return, circiut two	Seat valve
R2	-	T	03	-	AV	03	R2-T03-AV03	Cut-off return, circiut one	Seat valve
R2	-	T	03	-	AV	04	R2-T03-AV04	Cut-off lye	Butterfly valve
R2	-	T	03	-	AV	05	R2-T03-AV05	Cut-off cold water	Butterfly valve
R2	-	T	03	-	AV	06	R2-T03-AV06	Cut-off heating circulation	Butterfly valve
R2	-	T	03	-	AV	07	R2-T03-AV07	Cut-off tank, drainage	Butterfly valve
R2	-	T	03	-	AV	08	R2-T03-AV08	Cut-off supply, circuit one	Seat valve
R2	-	T	03	-	AV	09	R2-T03-AV09	Cut-off supply, circuit two	Seat valve
R2	-	T	03	-	AV	10	R2-T03-AV10	Cut-off supply, circuit three	Seat valve
R2	-	T	03	-	HE	01	R2-T03-HE01	Heating circulation	Plate heat exchanger, tubular heat exchanger, welded stainless heat exchanger
R2	-	T	03	-	PU	01	R2-T03-PU01	Pump heating circulation	Centrifugal pump
R2	-	T	03	-	QT	01	R2-T03-QT01	Sensor heating circulation	Conductivity transmitter
R2	-	T	03	-	TT	01	R2-T03-TT01	Sensor heating circulation	Temperature transmitter
R2	-	T	03	-	LSH	01	R2-T03-LSH01	Sensor tank	Level switch high
R2	-	T	03	-	LSL	01	R2-T03-LSL01	Sensor tank	Level switch low
R2	-	T	03	-	LSM	01	R2-T03-LSM01	Sensor tank	Level switch middle
R2	-	T	03	-	PU	02	R2-T03-PU02	Pump lye	Level stick
R2	-	T	03	-	LT	01	R2-T03-LT01	Sensor tank	Temperature transmitter
R2	-	T	03	-	TT	02	R2-T03-TT02	Sensor storage tank	Temperature transmitter
R2	-	T	04				R2-T04	Acid storage tank	Tank
R2	-	T	04	-	AV	01	R2-T04-AV01	Cut-off return, circiut three	Seat valve
R2	-	T	04	-	AV	02	R2-T04-AV02	Cut-off return, circiut two	Seat valve
R2	-	T	04	-	AV	03	R2-T04-AV03	Cut-off return, circiut one	Seat valve
R2	-	T	04	-	AV	04	R2-T04-AV04	Cut-off acid	Butterfly valve
R2	-	T	04	-	AV	05	R2-T04-AV05	Cut-off cold water	Butterfly valve
R2	-	T	04	-	AV	06	R2-T04-AV06	Cut-off heating circulation	Butterfly valve
R2	-	T	04	-	AV	07	R2-T04-AV07	Cut-off tank, drainage	Butterfly valve
R2	-	T	04	-	AV	08	R2-T04-AV08	Cut-off supply, circuit one	Seat valve
R2	-	T	04	-	AV	09	R2-T04-AV09	Cut-off supply, circuit two	Seat valve
R2	-	T	04	-	AV	10	R2-T04-AV10	Cut-off supply, circuit three	Seat valve
R2	-	T	04	-	HE	01	R2-T04-HE01	Heating circulation	Plate heat exchanger, tubular heat exchanger, welded stainless heat exchanger
R2	-	T	04	-	PU	01	R2-T04-PU01	Pump heating circulation	Centrifugal pump
R2	-	T	04	-	QT	01	R2-T04-QT01	Sensor heating circulation	Conductivity transmitter
R2	-	T	04	-	TT	01	R2-T04-TT01	Sensor heating circulation	Temperature transmitter
R2	-	T	04	-	LSH	01	R2-T04-LSH01	Sensor tank	Level switch high
R2	-	T	04	-	LSL	01	R2-T04-LSL01	Sensor tank	Level switch low
R2	-	T	04	-	LSM	01	R2-T04-LSM01	Sensor tank	Level switch middle
R2	-	T	04	-	PU	02	R2-T04-PU02	Pump acid	Level stick
R2	-	T	04	-	LT	01	R2-T04-LT01	Sensor tank	Temperature transmitter
R2	-	T	04	-	TT	02	R2-T04-TT02	Sensor storage tank	Temperature transmitter
R2	-	T	05				R2-T05	Pre rinse storage tank	Tank
R2	-	T	05	-	AV	01	R2-T05-AV01	Cut-off return, circiut three	Seat valve
R2	-	T	05	-	AV	02	R2-T05-AV02	Cut-off return, circiut two	Seat valve
R2	-	T	05	-	AV	03	R2-T05-AV03	Cut-off return, circiut one	Seat valve
R2	-	T	05	-	AV	04	R2-T05-AV04	Cut-off cold water	Butterfly valve
R2	-	T	05	-	AV	05	R2-T05-AV05	Cut-off heating circulation	Butterfly valve
R2	-	T	05	-	AV	06	R2-T05-AV06	Cut-off tank, drainage	Butterfly valve
R2	-	T	05	-	AV	07	R2-T05-AV07	Cut-off supply, circuit one	Seat valve
R2	-	T	05	-	AV	08	R2-T05-AV08	Cut-off supply, circuit two	Seat valve
R2	-	T	05	-	AV	09	R2-T05-AV09	Cut-off supply, circuit three	Seat valve
R2	-	T	05	-	HE	01	R2-T05-HE01	Heating circulation	Plate heat exchanger, tubular heat exchanger, welded stainless heat exchanger
R2	-	T	05	-	PU	01	R2-T05-PU01	Pump heating circulation	Centrifugal pump
R2	-	T	05	-	QT	01	R2-T05-QT01	Sensor heating circulation	Conductivity transmitter
R2	-	T	05	-	TT	01	R2-T05-TT01	Sensor heating circulation	Temperature transmitter
R2	-	T	05	-	LSH	01	R2-T05-LSH01	Sensor tank	Level switch high
R2	-	T	05	-	LSL	01	R2-T05-LSL01	Sensor tank	Level switch low
R2	-	T	05	-	LSM	01	R2-T05-LSM01	Sensor tank	Level switch middle
R2	-	T	05	-	LT	01	R2-T05-LT01	Sensor tank	Level switch middle
R2	-	T	05	-	TT	02	R2-T05-TT02	Sensor tank	Temperature transmitter
R2	-	HE	01				R2-HE01	Heating supply, circuit one	Plate heat exchanger, tubular heat exchanger, welded stainless heat exchanger
R2	-	HE	01	-	AV	01	R2-HE01-AV01	Cut-off return, circiut one	Butterfly valve
R2	-	HE	02				R2-HE02	Heating supply, circuit two	Plate heat exchanger, tubular heat exchanger, welded stainless heat exchanger
R2	-	HE	03				R2-HE03	Heating supply, circuit three	Heat exchanger
R2	-	IC	01				R2-IC01	Internal cleaning	Manual switch board
R2	-	IC	01	-	AV	01	R2-IC01-AV01	Cut-off internal cleaning	Butterfly valve

Figure 21. Component list, Recovery Food, sequel

		Labe				INDEX	Object number	Function	Type
S3	-	C	01	-	AV	01	S3-C01-AV01	Cut-off drainage	Butterfly valve
S3	-	C	01	-	CM	01	S3-C01-CM01	Descaling cold water	Calcium magnet
S3	-	C	01	-	PU	01	S3-C01-PU01	Pump drainage	Liquid ring pump
S3	-	C	01	-	AV	02	S3-C01-AV02	Cut-off drainage, circuit three	Mix proof valve
S3	-	C	01	-	AV	03	S3-C01-AV03	Cut-off drainage, circuit two	Mix proof valve
S3	-	C	01	-	AV	04	S3-C01-AV04	Cut-off drainage, circuit one	Mix proof valve
S3	-	C	01	-	AV	05	S3-C01-AV05	Cut-off Nitrogen	Butterfly valve
S3	-	C	01	-	PU	02	S3-C01-PU02	Supply pump, circuit one	Centrifugal pump
S3	-	C	01	-	PU	03	S3-C01-PU03	Supply pump, circuit two	Centrifugal pump
S3	-	C	01	-	PU	04	S3-C01-PU04	Supply pump, circuit three	Centrifugal pump
S3	-	C	01	-	QT	01	S3-C01-QT01	Sensor return, circuit three	Conductivity transmitter
S3	-	C	01	-	TT	01	S3-C01-TT01	Sensor return, circuit three	Temperature transmitter
S3	-	C	01	-	NT	01	S3-C01-NT01	Sensor return, circuit three	Fluidity transmitter
S3	-	C	01	-	FT	01	S3-C01-FT01	Sensor return, circuit three	Flow transmitter
S3	-	C	01	-	PU	05	S3-C01-PU05	Return Pump, circuit three	Liquid ring pump
S3	-	C	01	-	QT	02	S3-C01-QT02	Sensor return, circuit two	Conductivity transmitter
S3	-	C	01	-	TT	02	S3-C01-TT02	Sensor return, circuit two	Temperature transmitter
S3	-	C	01	-	NT	02	S3-C01-NT02	Sensor return, circuit two	Fluidity transmitter
S3	-	C	01	-	FT	02	S3-C01-FT02	Sensor return, circuit two	Flow transmitter
S3	-	C	01	-	PU	06	S3-C01-PU06	Return Pump, circuit two	Liquid ring pump
S3	-	C	01	-	QT	03	S3-C01-QT03	Sensor return, circuit one	Conductivity transmitter
S3	-	C	01	-	TT	03	S3-C01-TT03	Sensor return, circuit one	Temperature transmitter
S3	-	C	01	-	NT	03	S3-C01-NT03	Sensor return, circuit one	Fluidity transmitter
S3	-	C	01	-	FT	03	S3-C01-FT03	Sensor return, circuit one	Flow transmitter
S3	-	C	01	-	PU	07	S3-C01-PU07	Return Pump, circuit one	Liquid ring pump
S3	-	C	01	-	FT	04	S3-C01-FT04	Sensor supply, circuit one	Flow transmitter
S3	-	C	01	-	TT	04	S3-C01-TT04	Sensor supply, circuit one	Temperature transmitter
S3	-	C	01	-	PT	01	S3-C01-PT01	Sensor supply, circuit one	Pressure transmitter
S3	-	C	01	-	FQ	01	S3-C01-FQ01	Sensor supply, circuit one	Mass flow meter
S3	-	C	01	-	FT	05	S3-C01-FT05	Sensor supply, circuit two	Flow transmitter
S3	-	C	01	-	TT	05	S3-C01-TT05	Sensor supply, circuit two	Temperature transmitter
S3	-	C	01	-	PT	02	S3-C01-PT02	Sensor supply, circuit two	Pressure transmitter
S3	-	C	01	-	FQ	02	S3-C01-FQ02	Sensor supply, circuit two	Mass flow meter
S3	-	C	01	-	FT	06	S3-C01-FT06	Sensor supply, circuit three	Flow transmitter
S3	-	C	01	-	TT	06	S3-C01-TT06	Sensor supply, circuit three	Temperature transmitter
S3	-	C	01	-	PT	03	S3-C01-PT03	Sensor supply, circuit three	Pressure transmitter
S3	-	C	01	-	FQ	03	S3-C01-FQ03	Sensor supply, circuit three	Mass flow meter
S3	-	T	01				S3-T01	CIP storage tank	Tank
S3	-	T	01	-	AV	01	S3-T01-AV01	Cut-off return, circiut three	Mix proof valve
S3	-	T	01	-	AV	02	S3-T01-AV02	Cut-off return, circiut two	Mix proof valve
S3	-	T	01	-	AV	03	S3-T01-AV03	Cut-off return, circiut one	Mix proof valve
S3	-	T	02	-	AV	04	S3-T02-AV04	Cut-off detergent	Butterfly valve
S3	-	T	01	-	AV	05	S3-T01-AV05	Cut-off cold water	Butterfly valve
S3	-	T	01	-	AV	06	S3-T01-AV06	Cut-off drainage storage tank	Butterfly valve
S3	-	T	01	-	AV	07	S3-T01-AV07	Cut-off supply, circuit one	Mix proof valve
S3	-	T	01	-	AV	08	S3-T01-AV08	Cut-off supply, circuit two	Mix proof valve
S3	-	T	01	-	AV	09	S3-T01-AV09	Cut-off supply, circuit three	Mix proof valve
S3	-	T	01	-	AV	10	S3-T01-AV10	Manual sample tap	Manual ball valve
S3	-	T	01	-	LSH	01	S3-T01-LSH01	Sensor tank	Level switch high
S3	-	T	01	-	LSL	01	S3-T01-LSL01	Sensor tank	Level switch low
S3	-	T	01	-	LSM	01	S3-T01-LSM01	Sensor tank	Level switch middle
S3	-	T	01	-	LT	01	S3-T01-LT01	Sensor tank	Level stick
S3	-	T	01	-	TT	01	S3-T01-TT01	Sensor tank	Temperature transmitter
S3	-	HE	01				S3-HE01	Heating supply, circuit one	Heat exchanger
S3	-	HE	01	-	AV	01	S3-HE01-AV01	Cut-off return, heating circulation	Butterfly valve
S3	-	HE	01	-	AV	02	S3-HE01-AV02	Cut-off, heating circulation	Butterfly valve
S3	-	HE	02	-	AV	03	S3-HE02-AV03	Cut-off supply, heating circulation	Butterfly valve
S3	-	HE	02				S3-HE02	Heating supply, circuit two	Värmeväxlare
S3	-	HE	03				S3-HE03	Heating supply, circuit three	Värmeväxlare

Figure 22. Component list, Single use Pharmaceutical

Appendix I

P3-mip SP
Beskrivning Flytande, starkt alkaliskt, rengöringsmedel för användning inom livsmedelsindustrin
Produktfördelar • Lämplig till enfas rengöring
• Utomordentlig skumdämpning > 45°C
• Bra rengöringseffekt vid hög smutsbelastning
Egenskaper
Koncentrat Utseende: klar till opak, brun vätska *
Förvaring: −15°C til +50°C
Hållbarhet: min. 2 år
Löslighet: blandbar med vatten i alla förhållanden
Densitet/20°C: 1,33 − 1,37 g/cm³ *
P-innehåll: 0,24%
N-innehåll: 0,28%
COD: 95 − 115 mg O2/g
Flampunkt: > 100°C
Brukslösning pH: 12.5 – 13,1*
(1%, 20°C, demineraliserat vatten)

P3-horolith CIP
Beskrivning Flytande, starkt surt rengöringsmedel till CIP-rengöring inom livsmedelsindustrin.
Produktfördelar • Lämplig till enfasrengöring
• Skumdämpande > 45°C
• Effektiv vid låga koncentrationer
Egenskaper
Koncentrat Utseende: klar, färglös vätska *
Förvaring: −20°C til +40°C
Hållbarhet: min. 2 år
Löslighet: Fullständigt löslig i vatten
Densitet/20°C: 1,270 − 1,310 g/cm³ *
P-innehåll: 14,6%
N-innehåll: 0,00%
COD: 108 − 128 mg O2/g
Flampunkt: > 100°C
Brukslösning pH: 1,6 − 2,2*
(1%, 20°C, demineraliserat vatten)
Skumkarakteristik: ej skummande > 45°C

P3-oxonia Active S
Beskrivning Flytande, starkt surt desinfektionsmedel för användning inom livsmedelsindustrin
Produktfördelar • Utomordentlig avdödningseffekt på jäst och bakterier
• Dosering via konduktivitet
• God stabilitet i brukslösning
Egenskaper

Koncentrat Utseende: klar, färglös vätska *
Förvaring: −20°C till 35°C
Hållbarhet: Min. 9 månader
Löslighet: Fullständigt löslig i vatten
Densitet/20°C: 1,13 − 1,17 g/cm³ *
P-innehåll: 0,18%
N-innehåll: 0,00%
COD: Produkten avger syre. En bestämmelse är därför inte möjlig.
Flampunkt: 77°C
Brukslösning pH: 1,3 − 1,9 *
(1%, 20°C, demineraliserat vatten)
Skumkaraktäristik: Ej skummande

COSA® CIP 96
Description **Liquid, alkaline cleaning agent for CIP applications and membrane filtration plants in the pharmaceutical industry, produced under GMP guidelines**
Characteristics □ high cleaning efficacy
□ suitable for any water hardness
Subject to incoming goods control
Appearance: clear, slightly yellowish liquid
Density (20 °C): 1.34 - 1.38 g/cm³
Titration:
Use solution: 50 ml (1 % solution)
Titrant: 0.5 mol/l Hydrochloric Acid (HCl)
Endpoint: pH-value = 8.3
Consumption: 7.5 – 7.9 ml
% Total Alkalinity (expressed as Na_2O):
% Alkalinity as Na_2O =
(ml HCl to pH 8.3)*(0.5 mol/l)*(31)*(100)
Sample weight [g]*(1000)
% Total Alkalinity (expressed as Na_2O): 23.25 - 24.49 %

COSA® CIP 72
Description **Liquid, acid detergent for the removal of inorganic soil in the pharmaceutical, Biotech and cosmetic industry**
Characteristics □ phosphorous-free
□ based on organic acids
□ suitable for CIP-systems
□ surfactant-free
Subject to incoming goods control
Appearance: clear, colourless liquid
Titration:
Use solution: 50 ml (1 % solution)
Titrant: 1.0 mol/l Sodiumhydroxide (NaOH)
Endpoint: pH-value = 8.3
Consumption: 4.0 – 4.4 ml
% Acidity (expressed as Formic Acid):

% Acidity as HCOOH =
(ml NaOH to pH 8.3)*(1 mol/l)*(46)*(100)
Sample weight [g] (1000)
Acidity (expressed as HCOOH): 36.80 - 40.48%

P3-cosa® DES
Beskrivning Flytande, surt desinfektionsmedel till användning i den farmaceutiska/kosmetiska industrin
Produktfördelar • effektivt mot alla typer mikroorganismer (bakterier, jäst, mögelsvampar, sporer, virus)
• ekologisk kompatibell
• godkänt av USDA
Egenskaper
Koncentrat Utseende: Klar, färglös vätska *
Förvaring: −20°C till + 40°C
Hållbarhet Min. 1 år
Löslighet: Blandbart med vatten i alla förhållanden
Densitet/20°C: 1,07 − 1,11 g/cm3 *
P-innehåll: 0,18%
N-innehåll: 0,00%
COD: Produkten avger syre. En bestämmelse är därför inte möjlig.
Flammpunkt: Inte brännbar
Brukslösning pH: 2,9 − 3,5 *
(1%, 20°C, demineraliserat vatten)
Skumkaraktäristik: Inte skummande

Appendix J

Customer:	0	**CURRENCY/RATE Compared to 1 EUR:**			
Project:	0	**DKK**	**7,45**	**EUR**	**1,00**
Project no.:	0	**NOK**	**7,39**	**GBP**	**0,80**
Date:	1900-01-00	**SEK**	**9,26**	**USD**	**1,28**
Sales:	0	**CURRENCY:**	SEK		
With EXTERNAL automation		**RATE:**	**9,26**		

Code		Qty	SEK	Net sum	Margine (%)	Gross sum	Time price	Part of gross sum (%)	% of TOTAL
	Process Components	1	236 661	236 661	20,0%	295 826		23,4%	0,739565
	Standard Components	1	0	0	20,0%	0		0,0%	0
111	Time Process (Std)	373	800	298 400	15,0%	351 059	941	27,3%	0,877647
111	Time Proces (Pharma1)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma2)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma3)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma4)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma5)	0	0	0	15,0%	0	0	0,0%	0
112	Traveling cost	1	0	0	15,0%	0		0,0%	0
550	Automation	1	403 024	403 024	15,0%	474 146		36,9%	1,185365
550	Electrical installation	1	6 341	6 341	15,0%	7 460		0,6%	0,01865
330	Installation, mechanical	1	129 926	129 926	15,0%	152 854		11,9%	0,382135
700	Freight (2%)		2,0%	4 733		4 733			0,011833
	Sum			1 079 085	16,1%	1 286 078			
	Project costs without fright			1 079 085					
	Calculated sales price					1 372 405			
	Sales price (Internal F&P)					**400 000 kr**		**SEK**	
	Contributions			-679 085 kr	TB2	-169,8%			
	Alternative pricing	TB	Sales price						
		18%	1 421 234		24%	1 533 436			
		20%	1 456 765		26%	1 574 881			
		22%	1 494 118		28%	1 618 627			
	Contingency (2-5%)		5,0%	53 954		53 954			0,134886
	Warranty (2-3%)		3,0%	32 373		32 373			0,080931
	Calculation cost (0,5-1")	0	25 000	0		0			0
	Calculation cost (1-3")	0	50 000	0		0			0
	Calculation cost (3"-)	0	75 000	0		0			0
	TB (with contingency, warranty)			-765 412		-191,4%			
With INTERNAL ÅF automation (samfakturering)									
550	Price automation	1	0	0	0,0%	0			0 kr
	Total project cost			1 165 412					
	Price Total, External					**400 000 kr**		**SEK**	
	Total Contributions			-765 412 kr	TB3	-191,4%			343,1%

Figure 23. Original cost Single use Food

Customer:			0		**CURRENCY/RATE Compared to 1 EUR:**				
Project:			0		**DKK**	**7,45**	**EUR**	**1,00**	
Project no.:			0		**NOK**	**7,39**	**GBP**	**0,80**	
Date:			1900-01-00		**SEK**	**9,26**	**USD**	**1,28**	
Sales:			0		**CURRENCY:**	**SEK**			
With EXTERNAL automation					**RATE:**	**9,26**			
Code		Qty	**SEK**	Net sum	Margine (%)	Gross sum	Time price	Part of gross sum (%)	% of TOTAL
	Process Components	1	236 661	236 661	20,0%	295 826		28,5%	0,739565
	Standard Components	1	0	0	20,0%	0		0,0%	0
111	Time Process (Std)	128	800	102 400	15,0%	120 471	941	11,4%	0,301176
111	Time Proces (Pharma1)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma2)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma3)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma4)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma5)	0	0	0	15,0%	0	0	0,0%	0
112	Traveling cost	1	0	0	15,0%	0		0,0%	0
550	Automation	1	403 024	403 024	15,0%	474 146		44,9%	1,185365
550	Electrical installation	1	6 341	6 341	15,0%	7 460		0,7%	0,01865
330	Installation, mechanical	1	129 926	129 926	15,0%	152 854		14,5%	0,382135
700	Freight (2%)		2,0%	4 733		4 733			0,011833
	Sum			883 085	16,3%	1 055 490			
	Project costs without fright			883 085					
	Calculated sales price					1 126 136			
	Sales price (Internal F&P)					**400 000 kr**		**SEK**	
	Contributions			-483 085 kr	TB2	-120,8%			
	Alternative pricing	TB	Sales price						
		18%	1 163 087		24%	1 254 910			
		20%	1 192 165		26%	1 288 827			
		22%	1 222 733		28%	1 324 627			
	Contingency (2-5%)		5,0%	44 154		44 154			0,110386
	Warranty (2-3%)		3,0%	26 493		26 493			0,066231
	Calculation cost (0,5-1")	0	25 000	0		0			0
	Calculation cost (1-3")	0	50 000	0		0			0
	Calculation cost (3"-)	0	75 000	0		0			0
	TB (with contingency, warranty)			-553 732		-138,4%			
With INTERNAL ÅF automation (samfakturering)									
550	Price automation	1	0	0	0,0%	0			0 kr
	Total project cost			953 732					
	Price Total, External					**400 000 kr**		**SEK**	
	Total Contributions			-553 732 kr	TB3	-138,4%			281,5%

Figure 24. Reuse cost Single use Food

Customer:	0	**CURRENCY/RATE Compared to 1 EUR:**			
Project:	0	**DKK**	**7,45**	**EUR**	**1,00**
Project no.:	0	**NOK**	**7,39**	**GBP**	**0,80**
Date:	1900-01-00	**SEK**	**9,26**	**USD**	**1,28**
Sales:	0	**CURRENCY:**	SEK		
With EXTERNAL automation		**RATE:**	**9,26**		

Code		Qty	SEK	Net sum	Margine (%)	Gross sum	Time price	Part of gross sum (%)	% of TOTAL
	Process Components	1	1 090 287	1 090 287	20,0%	1 362 858		35,4%	3,407146
	Standard Components	1	0	0	20,0%	0		0,0%	0
111	Time Process (Std)	657	800	525 600	15,0%	618 353	941	15,8%	1,545882
111	Time Proces (Pharma1)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma2)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma3)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma4)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma5)	0	0	0	15,0%	0	0	0,0%	0
112	Traveling cost	1	0	0	15,0%	0		0,0%	0
550	Automation	1	1 122 875	1 122 875	15,0%	1 321 029		33,8%	3,302574
550	Electrical installation	1	31 002	31 002	15,0%	36 473		0,9%	0,091182
330	Installation, mechanical	1	468 559	468 559	15,0%	551 246		14,1%	1 kr
700	Freight (2%)		2,0%	21 806		21 806			0,054514
	Sum			3 260 128	16,7%	3 911 765			
	Project costs without fright			3 260 128					
	Calculated sales price					4 172 575			
	Sales price (Internal F&P)					**400 000 kr**		**SEK**	
	Contributions			-2 860 128 kr	TB2	-715,0%			
	Alternative pricing	TB	Sales price						
		18%	4 293 828		24%	4 632 814			
		20%	4 401 173		26%	4 758 025			
		22%	4 514 024		28%	4 890 192			
	Contingency (2-5%)		5,0%	163 006		163 006			0 kr
	Warranty (2-3%)		3,0%	97 804		97 804			0,24451
	Calculation cost (0,5-1")	0	25 000	0		0			0
	Calculation cost (1-3")	0	50 000	0		0			0
	Calculation cost (3"-)	0	75 000	0		0			0
	TB (with contingency, warranty)			-3 120 939		-780,2%			
With INTERNAL ÅF automation (samfakturering)									
550	Price automation	1	0	0	0,0%	0			0 kr
	Total project cost			3 520 939					
	Price Total, External					**400 000 kr**		**SEK**	
	Total Contributions			-3 120 939 kr	TB3	-780,2%			1043,1%

Figure 25. Original cost Recovery Food

Customer:			0		**CURRENCY/RATE Compared to 1 EUR:**				
Project:			0		**DKK**	**7,45**	**EUR**	**1,00**	
Project no.:			0		**NOK**	**7,39**	**GBP**	**0,80**	
Date:			1900-01-00		**SEK**	**9,26**	**USD**	**1,28**	
Sales:			0		**CURRENCY:**	**SEK**			
With EXTERNAL automation					**RATE:**	**9,26**			
Code		Qty	**SEK**	Net sum	Margine (%)	Gross sum	Time price	Part of gross sum (%)	% of TOTAL
	Process Components	1	1 090 287	1 090 287	20,0%	1 362 858		39,7%	3,407146
	Standard Components	1	0	0	20,0%	0		0,0%	0
111	Time Process (Std)	211	800	168 800	15,0%	198 588	941	5,7%	0,496471
111	Time Proces (Pharma1)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma2)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma3)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma4)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma5)	0	0	0	15,0%	0	0	0,0%	0
112	Traveling cost	1	0	0	15,0%	0		0,0%	0
550	Automation	1	1 122 875	1 122 875	15,0%	1 321 029		37,8%	3,302574
550	Electrical installation	1	31 002	31 002	15,0%	36 473		1,0%	0,091182
330	Installation, mechanical	1	468 559	468 559	15,0%	551 246		15,8%	1 kr
700	Freight (2%)		2,0%	21 806		21 806			0,054514
	Sum			2 903 328	16,9%	3 492 000			
	Project costs without fright			2 903 328					
	Calculated sales price					3 724 267			
	Sales price (Internal F&P)					**400 000 kr**		**SEK**	
	Contributions			-2 503 328 kr	TB2	-625,8%			
	Alternative pricing	TB	Sales price						
		18%	3 823 896		24%	4 125 782			
		20%	3 919 493		26%	4 237 290			
		22%	4 019 993		28%	4 354 992			
	Contingency (2-5%)		5,0%	145 166		145 166			0 kr
	Warranty (2-3%)		3,0%	87 100		87 100			0,21775
	Calculation cost (0,5-1")	0	25 000	0		0			0
	Calculation cost (1-3")	0	50 000	0		0			0
	Calculation cost (3"-)	0	75 000	0		0			0
	TB (with contingency, warranty)			-2 735 595		-683,9%			
With INTERNAL ÅF automation (samfakturering)									
550	Price automation	1	0	0	0,0%	0			0 kr
	Total project cost			3 135 595					
	Price Total, External					**400 000 kr**		**SEK**	
	Total Contributions			-2 735 595 kr	TB3	-683,9%			931,1%

Figure 26. Reuse cost Recovery Food

Customer:	0	**CURRENCY/RATE Compared to 1 EUR:**			
Project:	0	**DKK**	**7,45**	**EUR**	**1,00**
Project no.:	0	**NOK**	**7,39**	**GBP**	**0,80**
Date:	1900-01-00	**SEK**	**9,26**	**USD**	**1,28**
Sales:	0	**CURRENCY:**	**SEK**		
With EXTERNAL automation		**RATE:**	**9,26**		

Code		Qty	SEK	Net sum	Margine (%)	Gross sum	Time price	Part of gross sum (%)	% of TOTAL
	Process Components	1	421 958	421 958	20,0%	527 447		28,0%	1,318618
	Standard Components	1	0	0	20,0%	0		0,0%	0
111	Time Process (Std)	546	800	436 800	15,0%	513 882	941	26,9%	1,284706
111	Time Proces (Pharma1)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma2)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma3)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma4)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma5)	0	0	0	15,0%	0	0	0,0%	0
112	Traveling cost	1	0	0	15,0%	0		0,0%	0
550	Automation	1	542 562	542 562	15,0%	638 308		33,4%	1,595771
550	Electrical installation	1	6 341	6 341	15,0%	7 460		0,4%	0,01865
330	Installation, mechanical	1	185 265	185 265	15,0%	217 959		11,4%	0,544897
700	Freight (2%)		2,0%	8 439		8 439			0,021098
	Sum			1 601 365	16,3%	1 913 496			
	Project costs without fright			1 601 365					
	Calculated sales price					2 041 605			
	Sales price (Internal F&P)					**400 000 kr**		**SEK**	
	Contributions			-1 201 365 kr	TB2	-300,3%			
	Alternative pricing	TB	Sales price						
		18%	2 109 115		24%	2 275 624			
		20%	2 161 843		26%	2 337 127			
		22%	2 217 275		28%	2 402 047			
	Contingency (2-5%)		5,0%	80 068		80 068			0,200171
	Warranty (2-3%)		3,0%	48 041		48 041			0,120102
	Calculation cost (0,5-1")	0	25 000	0		0			0
	Calculation cost (1-3")	0	50 000	0		0			0
	Calculation cost (3"-)	0	75 000	0		0			0
	TB (with contingency, warranty)			-1 329 474		-332,4%			
	With INTERNAL ÅF automation (samfakturering)								
550	Price automation	1	0	0	0,0%	0			0 kr
	Total project cost			1 729 474					
	Price Total, External					**400 000 kr**		**SEK**	
	Total Contributions			-1 329 474 kr	TB3	-332,4%			510,4%

Figure 27. Original cost Single use Pharmaceutical

Customer:			0		**CURRENCY/RATE Compared to 1 EUR:**				
Project:			0		DKK	7,45	EUR	1,00	
Project no.:			0		NOK	7,39	GBP	0,80	
Date:			1900-01-00		SEK	9,26	USD	1,28	
Sales:			0		CURRENCY:	SEK			
With EXTERNAL automation					RATE:	9,26			
Code		Qty	SEK	Net sum	Margine (%)	Gross sum	Time price	Part of gross sum (%)	% of TOTAL
	Process Components	1	421 958	421 958	20,0%	527 447		33,4%	1,318618
	Standard Components	1	0	0	20,0%	0		0,0%	0
111	Time Process (Std)	217	800	173 600	15,0%	204 235	941	12,7%	0,510588
111	Time Proces (Pharma1)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma2)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma3)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma4)	0	0	0	15,0%	0	0	0,0%	0
111	Time Proces (Pharma5)	0	0	0	15,0%	0	0	0,0%	0
112	Traveling cost	1	0	0	15,0%	0		0,0%	0
550	Automation	1	542 562	542 562	15,0%	638 308		39,8%	1,595771
550	Electrical installation	1	6 341	6 341	15,0%	7 460		0,5%	0,01865
330	Installation, mechanical	1	185 265	185 265	15,0%	217 959		13,6%	0,544897
700	Freight (2%)		2,0%	8 439		8 439			0,021098
	Sum			1 338 165	16,6%	1 603 849			
	Project costs without fright			1 338 165					
	Calculated sales price					1 710 902			
	Sales price (Internal F&P)					**400 000 kr**		**SEK**	
	Contributions			-938 165 kr	TB2	-234,5%			
	Alternative pricing	TB	Sales price						
		18%	1 762 461		24%	1 901 603			
		20%	1 806 523		26%	1 952 998			
		22%	1 852 844		28%	2 007 247			
	Contingency (2-5%)		5,0%	66 908		66 908			0,167271
	Warranty (2-3%)		3,0%	40 145		40 145			0,100362
	Calculation cost (0,5-1")	0	25 000	0		0			0
	Calculation cost (1-3")	0	50 000	0		0			0
	Calculation cost (3"-)	0	75 000	0		0			0
	TB (with contingency, warranty)			-1 045 218		-261,3%			
With INTERNAL ÅF automation (samfakturering)									
550	Price automation	1	0	0	0,0%	0			0 kr
	Total project cost			1 445 218					
	Price Total, External					**400 000 kr**		**SEK**	
	Total Contributions			-1 045 218 kr	TB3	-261,3%			427,7%

Figure 28. Reuse cost Single use Pharmaceutical

Appendix K

CIP
SINGLE USE SYSTEM

- **Low investment cost**
- **Complete traceability**
- **Stationary or portable design**

Application
The CIP Single use system is an automated cleaning process for traceable production and small capacity applications within the food industry including tanks, piping, heat exchangers and filling machines.

The cleaning sequence regarding time, flow, concentration and temperature can be varied depending on the cleaning object.

The versatile Single use system allows traceability throughout the cleaning process and is well suited for batch production. By adding circuits the system is able to clean several objects simultaneously.

Siemens S7-400 is providing an optimized automation program for optimal cleaning results.

Description
The cleaning solution is heated to required temperature before it's routed to the object. Before the solution is circled back to the CIP, it's pumped to the drain until the right purity is obtained.

A full cleaning cycle includes a cold water rinse, lye circulation, intermediate rinse, acid circulation, intermediate rinse, disinfection and a final rinse. The cleaning solutions are discarded at the end of each cleaning step ensuring no cross-contamination.

A Single use system is automatically controlled and monitored by a PLC with cleaning programs and an informative interactive screen.

Base configuration
The basic configuration for the Single use system is one tank with associated transmitters. Transmitters is also found on the return pipe. Either a stationary or a portable design is disposable depending on application.

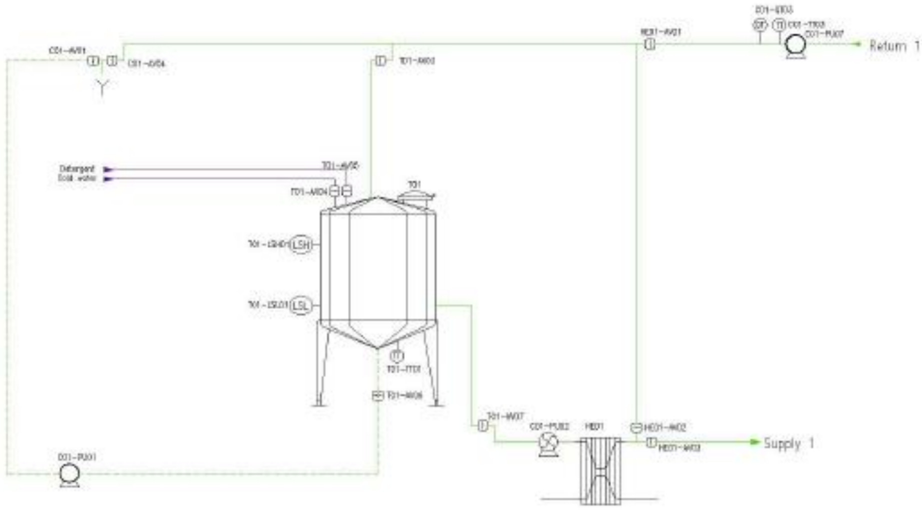
Technical data
Capacity: 3,5 – 58 m³/h
Temperature: 10-95˚C
Pressure: 3 bar
Cycle time: 63 min
Chemicals: P3-mip SP
P3-horolith CIP
P3-oxonia Active S

Demands
Fluid velocity: 1,5-2,1 m/s

Figure 29. Brochure, front page, Single use Food

CIP

SINGLE USE SYSTEM



Single use scheme

Optional features

The Single use system can be varied in multiple ways to be able to satisfy as many applications as possible. The different features is selected without restrictions to maintain a custom-made process.

Valves
- Butterfly valves
- Seat valves
- Mix proof valves

Circuits
- One circuit, with or without heating.
- Two circuit, with or without heating.
- Three or multiple circuits, with or without heating.

Control system
- Manual
- Local PLC
- Superior control system

Additional features
- Internal cleaning
- Calcium magnet

Figure 30. Brochure, back page, Single use Food

CIP
RECOVERY SYSTEM

- **Up to 86% cost saving per cleaning cycle**
- **Save up to 95% of detergents**
- **Reduced water, chemical and energy consumption**
- **Adjustable to different requirements**

Application
The CIP Recovery system is an automated cleaning process for complex and large capacity applications within the food industry including tanks, piping, heat exchangers and filling machines.

The cleaning sequence regarding time, flow, concentration and temperature can be varied depending on the cleaning object.

The versatile Recovery system varies from two to five tanks. By adding circuits the system is able to clean several objects simultaneously.

Siemens S7-400 is providing an optimized automation program for optimal cleaning results.

Description
The cleaning solution is heated to required temperature before it's routed to the object. Before the solution is circled back to the CIP, it's pumped to the drain until the right purity is obtained.

A full cleaning cycle includes a pre rinse, lye circulation, intermediate rinse, acid circulation, intermediate rinse, disinfection and a final rinse. Cleaning solutions are reused in order to reduce cost, energy and chemicals.

A Recovery system is automatically controlled and monitored by a PLC with cleaning programs and an informative interactive screen.

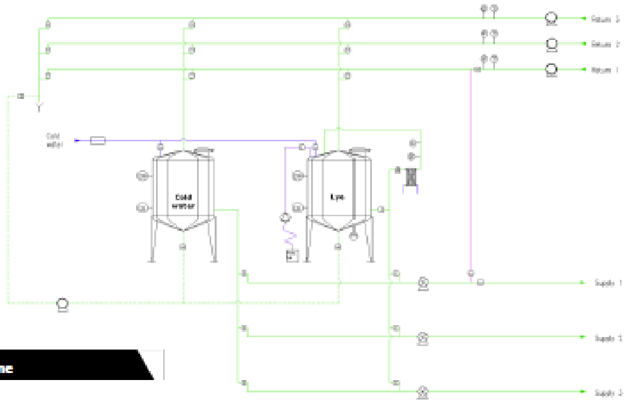
Base configuration
The three base configurations of the Recovery system are accompanied by transmitters on the storage tanks and return pipe.

- Recovery 1, one cold water and one lye storage tank.
- Recovery 2, one cold water, one lye, one acid and one disinfection storage tank.
- Recovery 3, one cold water, one lye, one acid, one disinfection, one pre rinse and one product recovery storage tank.

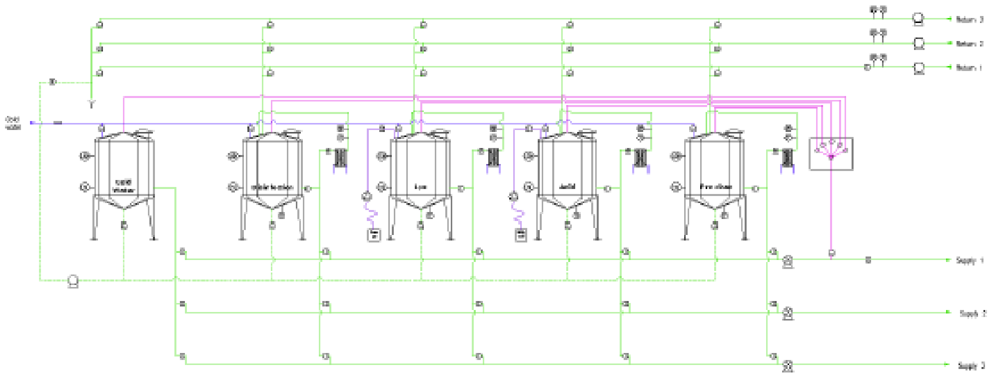
Technical data
Capacity: 3,5 – 58 m³/h
Temperature: 10-95˚C
Pressure: 3 bar
Cycle time: 68 min
Chemicals: P3-mip SP
P3-horolith CIP
P3-oxonia Active S

Demands
Fluid velocity: 1,5-2,1 m/s

Figure 31. Brochure, front page, Recovery Food



Recovery system 1 scheme



Recovery system 3 scheme

Optional features

The three recovery systems can be expanded and varied in multiple ways to be able to satisfy as many applications as possible. The different features is selected without restrictions to maintain a custom-made process.

Valves
- Butterfly valves
- Seat valves
- Mix proof valves

Heating
- Via a mutual heat exchanger
- Via individual heat exchangers

Internal cleaning
- Redirecting the flow from supply to return pipe
- Dedicated internal cleaning pipes via a manual switch board. Exists for Recovery 2 and 3.

Control system
- Manual
- Local PLC
- Superior control system

Circuits
- One circuit, with or without heating.
- Two circuit, with or without heating.
- Three or multiple circuits, with or without heating.

Figure 32. Brochure, back page, Recovery Food

CIP

SINGLE USE SYSTEM

- **Following EHEDG, GMP and FDA guidelines**
- **Complete traceability**
- **Stationary or portable design**

Application

The CIP Single use system is an automated cleaning process for traceable production and applications within the pharmaceutical industry including tanks, piping, heat exchangers and filling machines.

The cleaning sequence regarding time, flow, concentration and temperature can be varied depending on cleaning object.

The versatile Single use system allows traceability throughout the cleaning process and is well suited for batch production. By adding circuits the system is able to clean several objects simultaneously. Guidelines concerning EHEDG, GMP and FDA shapes the overall process design.

Siemens S7-400 is providing an optimized automation program for optimal cleaning results.

Description

The cleaning solution is heated to required temperature before it's routed to the object. Before the solution is circled back to the CIP, it's pumped to the drain until the right purity is obtained.

A full cleaning cycle includes a cold water rinse, lye circulation, intermediate rinse, acid circulation, intermediate rinse, disinfection and a final rinse. The cleaning solutions are discarded at the end of each cleaning step ensuring no cross-contamination.

A Single use system is automatically controlled and monitored by a PLC with cleaning programs and an informative interactive screen.

Base configuration

The basic configuration for the Single use system is one tank with associated transmitters. Transmitters is also found on the return pipe. Either a stationary or a portable design is disposable depending on application.

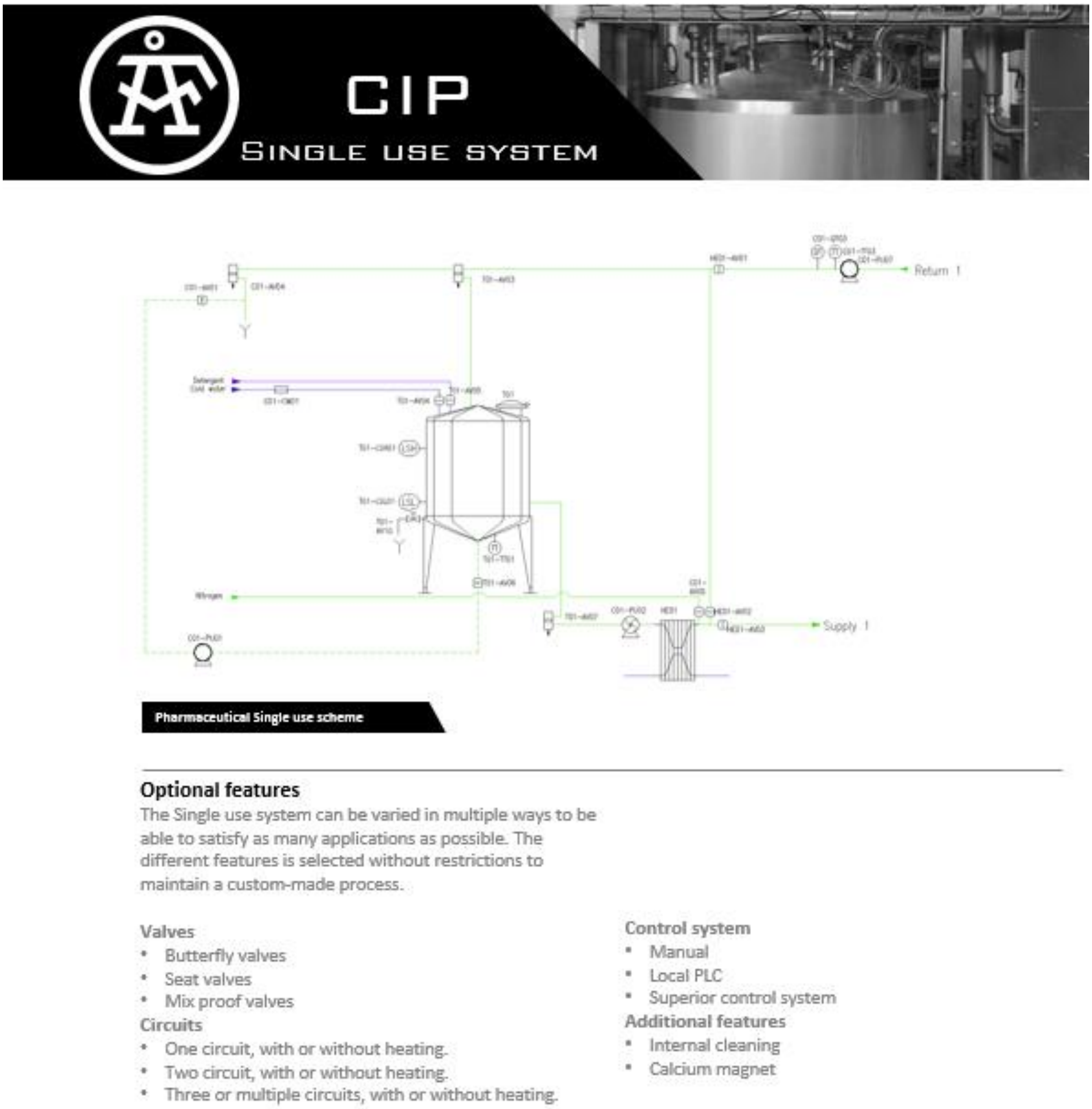
Technical data

Capacity: 3,5 – 58 m^3/h
Temperature: 10-95°C
Pressure: 3 bar
Cycle time: 63 min
Chemicals: Cosa® CIP 96
Cosa® CIP 72
P3-cosa® DES

Demands

Fluid velocity: 1,5-2,1 m/s

Figure 33. Brochure, front page, Single use Pharmaceutical



CIP
SINGLE USE SYSTEM

Return 1
Supply 1

Pharmaceutical Single use scheme

Optional features

The Single use system can be varied in multiple ways to be able to satisfy as many applications as possible. The different features is selected without restrictions to maintain a custom-made process.

Valves
- Butterfly valves
- Seat valves
- Mix proof valves

Circuits
- One circuit, with or without heating.
- Two circuit, with or without heating.
- Three or multiple circuits, with or without heating.

Control system
- Manual
- Local PLC
- Superior control system

Additional features
- Internal cleaning
- Calcium magnet

Figure 34. Brochure, back page, Single use Pharmaceutical