< Chemical process improvement>

Clean-in-Place (CIP)

IAMC Toolkit

Innovative approaches for the Sound Management of Chemicals and Chemical Waste

Introduction

Cleaning processing equipment (e.g. mixing vessels, pipelines) can cost personnel resources, cleaning chemicals, water and energy. Additionally, contamination from one chemical product to another is a concern.

This presentation introduces the reader to state-of-the-art Clean-in-Place (CIP) technology which results in improved cleaning performance, reduced resource use, reduced cleaning time and more time for equipment to produce valuable products.

The presentation also provides the reader with guidelines for designing and optimizing CIP facilities.

Contents

1. Overview of CIP
   - Definition of CIP
   - Fields of application
   - Benefits of CIP
   - Challenges when implementing CIP in SMEs
   - Limitations of CIP systems

Contents

Contents

4. CIP Optimization
   - Improve productivity
   - Improve resource consumption
   - Improve energy efficiency
   - Improve automation
   - Further possible process improvements

Overview of Clean-in-Place

- **Definition of CIP**
- **Fields of application**
- **Benefits of CIP**
- **Challenges when implementing CIP in SMEs**
- **Limitations of CIP systems**

Cleaning Technique: CIP vs COP

Techniques classified according to place:

CIP	COP
Clean-in-Place	Clean-out-of-Place
For interior surfaces of tanks and pipelines of liquid process equipment	For parts of equipment which require disassembly for proper cleaning
A chemical solution is circulated from a central reservoir through tanks and/or lines, then reused.	Parts are placed in a circulation tank and cleaned using a heated chemical solution and agitation.

Definition of CIP

General definition of CIP:

- Cleaning of complete items of plant or pipeline circuits without dismantling or opening of the equipment, and with little or no manual involvement on the part of the operator

Rotary sprayhead

Source: Industrial Trading Solutions Ltd

⇨ This term includes dedicated cleaning devices as well as portable systems which can be transferred from one vessel to another.

Fields of Application (1)

CIP is commonly used in manufacturing processes in the biotech, pharmaceuticals, food, dairy and beverage industries for the cleaning of:

- Vessels (bioreactors, fermenters, mix vessels)
- Other vessels (storage tanks, road tankers)
- Machinery
- Pipework
- Other equipment (heat exchangers, evaporators, membrane processing equipment)

All equipment to be cleaned has to be closed.

Fields of Application (2)

Examples of application in the food, beverage and pharmaceuticals industries:

- Liquid filling, e.g. breweries and wineries
- Dairy products
- Conveyor systems for unpacked products
- Meat slicers
- Pasteurization
- Pastry production
- Dust control units and silos (infestation risk)
- Pharmaceuticals in solid dosage forms

Fixed spray balls and rotary sprayhead

Source: Industrial Trading Solutions Ltd

Benefits of CIP (1)

Improved cleaning results

- Areas that are difficult to access can be cleaned.
- Automated CIP systems contribute to guaranteed and repeatable quality assurance.
- Automated CIP systems can provide full data logging for quality assurance requirements.

Improved occupational safety

- Safety operators are not required to enter the plant to clean it.
- Safety operators do not need to handle hazardous cleaning materials, more aggressive chemicals can be used.
- A fully automated cleaning system reduces labour requirements.

Benefits of CIP (2)

Material and energy savings

- Recycling of cleaning solutions reduces cleaning costs.
- Use of cleaning materials is more effectively controlled.
- Water consumption is reduced as cleaning cycles are designed to use the optimum quantity of water.

Improved productivity

- Production downtime between product runs is minimized.

⇨ CIP technology allows plant operators to cut costs in an eco-friendly manner while conforming to regulatory safety standards.

Case Study: Introduction of an Automatic CIP System

Initial situation	In a UK pharmaceutical manufacturing plant, the reaction tanks were each cleaned for six hours, constantly flushed to drain with hot water at 70°C. This was a purely manual process based upon operator experience, rather than positive signals from the process that the cleaning procedure was complete.
Approach	Conversion of the manual CIP process to automatic across 80 reaction vessels, using pressure transmitters, condition sensors and flow meters
Benefits	▪ Savings of £150,000 per year (reduction by 40%) ▪ Effective and reliable cleaning process ▪ Substantial savings in wastewater costs ▪ Recovery of valuable products ▪ Increased plant efficiency

Learning Objectives ?

Try to list some benefits of CIP

- Improved cleaning results
  - Areas that are difficult to access can be cleaned. Automated CIP systems contribute to guaranteed and repeatable quality assurance.
- Improved occupational safety
  - Safety operators are not required to enter the plant to clean it and do not need to handle hazardous cleaning materials.
- Material and energy savings
  - Recycling of cleaning solutions reduces cleaning costs. Use of cleaning materials is more effectively controlled.
- Improved productivity
  - Production downtime between product runs is minimized.

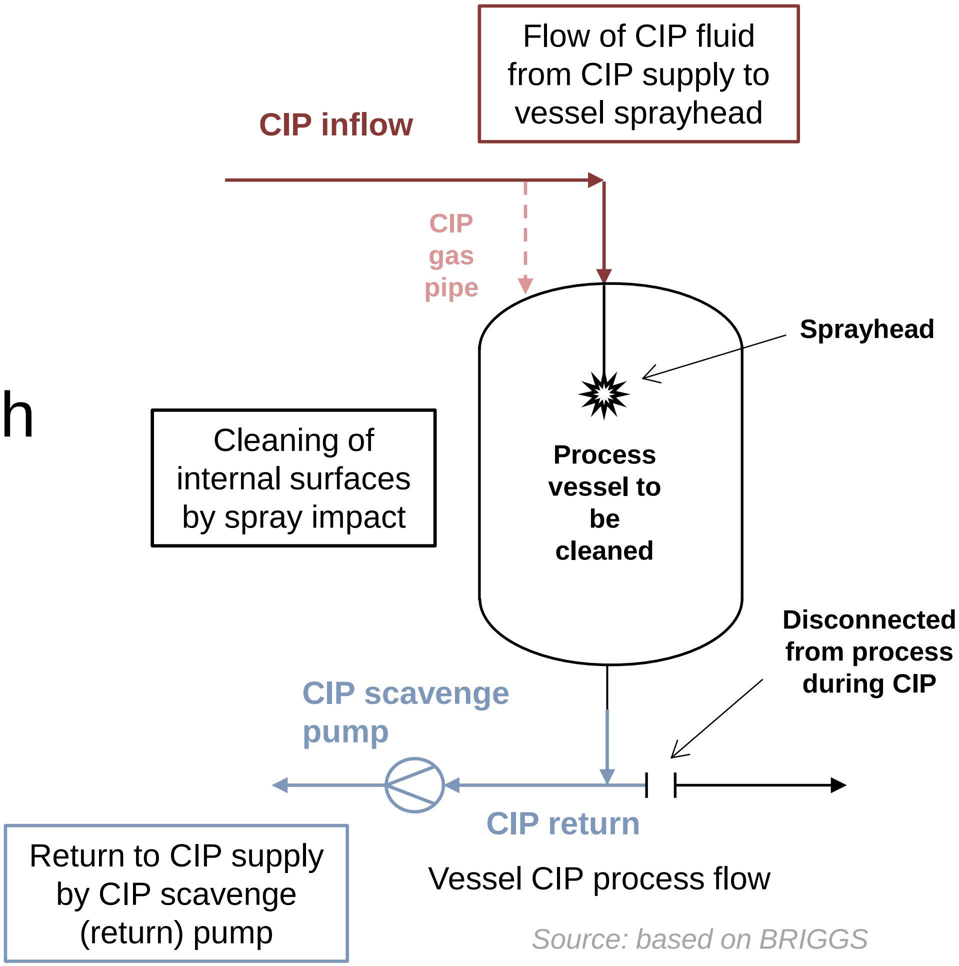
Technology Description

- CIP process description
- Types of CIP systems

CIP Process Description (1)

The process involves

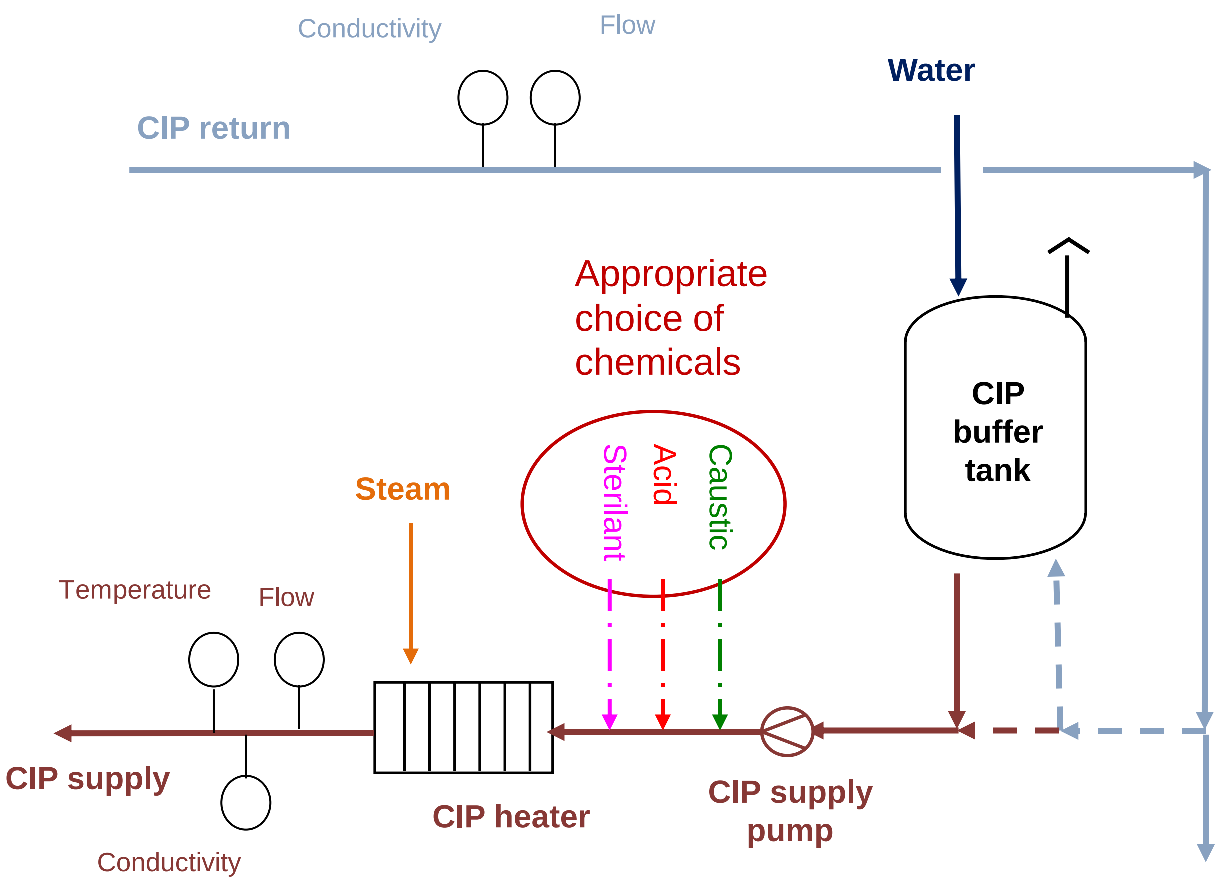
- Jetting or spraying of surfaces or circulation of cleaning solutions through the plant
- Conditions of increased turbulence and flow velocity



Vessel CIP process flow

Source: based on BRIGGS

CIP Process Description (2)



CIP chemicals can be returned into a central reservoir to be reused

Monitoring and adjustment of process parameters to ensure maximum cleaning

Source: based on BRIGGS

CIP Process Description (3)

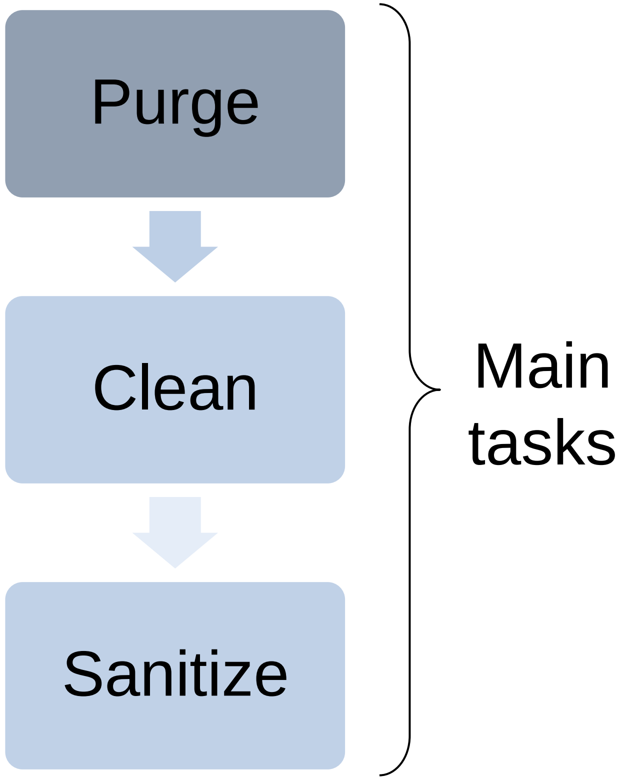
CIP cycles generally consist of a combination of the following steps:

Purge/Pre-rinse
- Product recovery
- Mechanical removal of soil

Detergent
- Removal of remaining soil
- Either caustic, acid or both

Final rinse
- Flush out residual detergent/soil

Sterilant/Sanitizer
- Destruction of residual organisms
- Either cold or hot



Product Recovery

The product (e.g. cosmetics, paints, polymers, etc.) remaining in the pipelines and process equipment has economic value and can be recovered using the following techniques:

- Pigging systems
- Whirlwind systems

Both technologies have options to combine product recovery and cleaning of process equipment and pipeline circuits.

C24_4_Product recovery

CIP Process Description (5)

Example of a CIP cycle from the dairy industry:

1. Product recovery using fresh purge water
2. Initial rinse (3-5 min) using recovered water to drain
3. Caustic wash at 75ºC (10-20 min) with recovery
4. Final rinse (3-5 min), fresh water to recovery tank
5. Cold sanitation (3-5 min)
6. Flush with fresh water and drain or leave full and drain the following day (depending on sanitizer used)
7. Additional procedures once a week to remove deposits from rinsing water (intermediate rinse, acid wash)

Types of CIP Systems (1)

Two types of CIP systems depending on area of application:

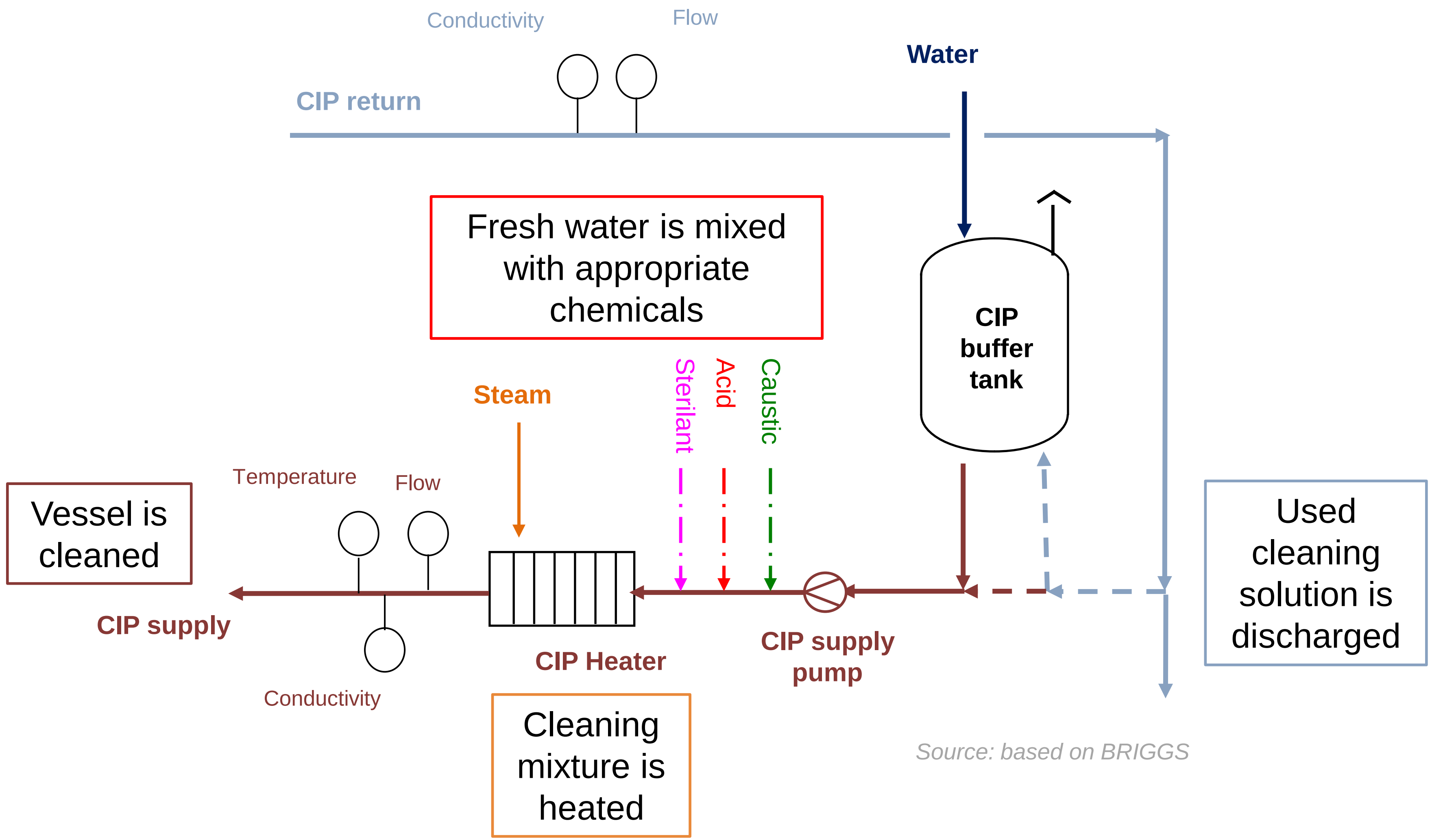
Distributed system	Central system
⇨ Individual sections of the plant can be cleaned with a local dedicated unit ⇨ Necessary for some operations requiring specific chemicals, e.g. membrane processing systems	⇨ The complete process facility is supplied by a single centralized system ⇨ Best choice for production areas with limited danger of damage through contamination ⇨ Usually highly automated to avoid downtime

Types of CIP Systems (2)

Two types of systems with different numbers of circuits:

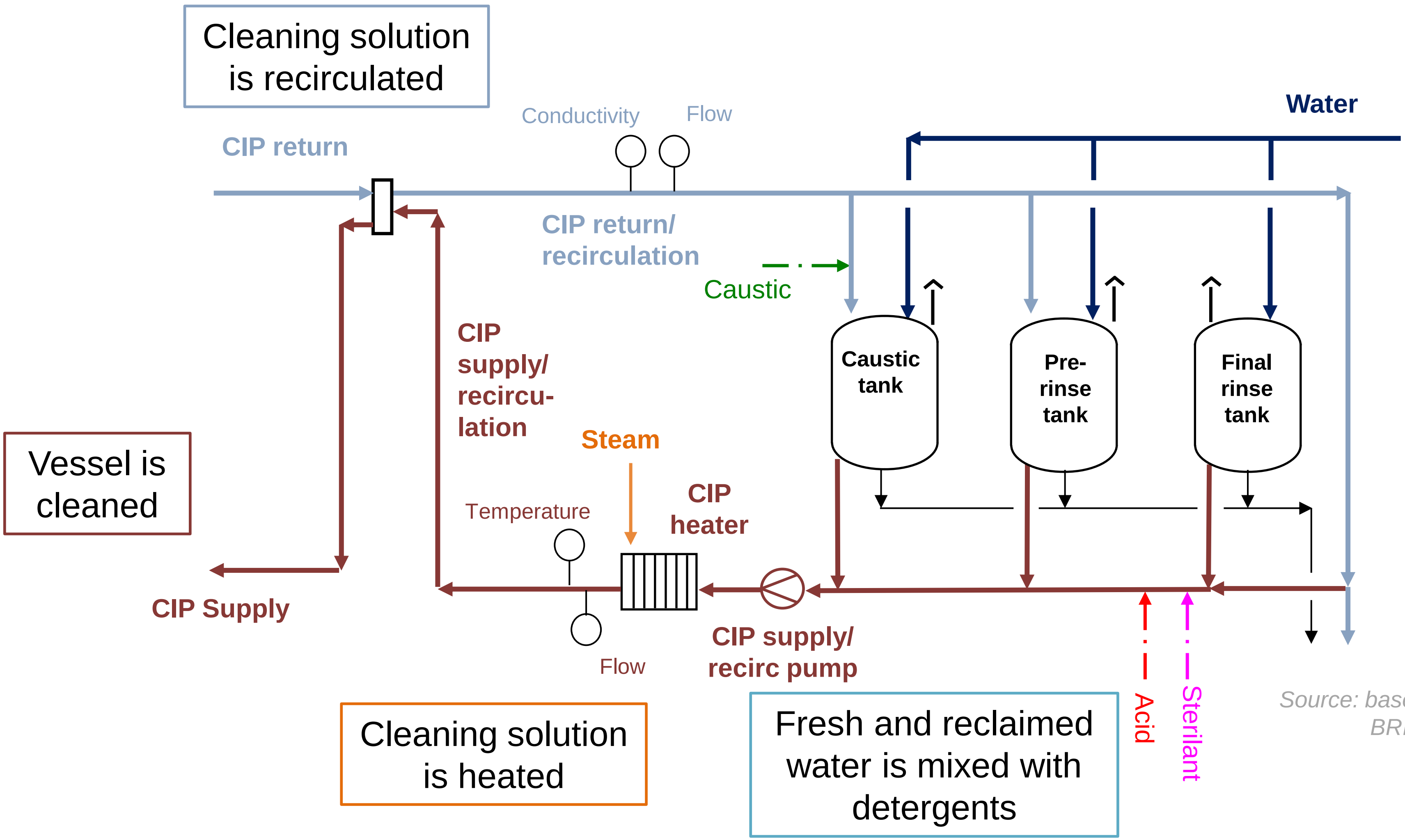
Single-use system	Multiple-use system
➪ CIP solution is used once and then discarded to drain ➪ Used to prevent microbiological cross-contamination ➪ High costs for cleaning chemicals, water and wastewater disposal	➪ CIP solution is recovered, restored and re-used ➪ More eco-friendly ➪ Monitoring for the build-up of residual soils is necessary and the cleaning chemicals have to be replenished

Example 1: Basic Single-Use System



Source: based on BRIGGS

Example 2: Multiple-Use System



Source: based on BRIGGS

Learning Objectives ?

What are the three main tasks of a CIP cycle?

- Purging, e.g. product recovery
- Cleaning, e.g. removal of fouling deposits
- Sanitizing, e.g. disinfection of equipment and lines

What types of CIP systems are there?

- Central vs. distributed system
- Single-use vs. multiple-use system

Learning Objectives

?

Can you describe the difference between single-use and multiple-use CIP systems?

- Single use:
  - CIP solution is used once and then discarded to drain
  - Used to prevent microbiological cross-contamination
  - High costs for cleaning chemicals, water and wastewater disposal

- Multiple use:
  - CIP solution is recovered, restored and re-used
  - More eco-friendly
  - Monitoring for the build-up of residual soils is necessary and the cleaning chemicals have to be replenished

CIP Design Considerations

- Factors to be considered
- Purging of product
- Choice of chemicals
- Process parameters
- Choice of equipment
- CIP cycle description

Factors to be Considered When Selecting Cleaning Techniques (1)

Plant and substance properties

- What is the physical nature of the plant or equipment to be cleaned?
- What is the nature of the deposit?
- What detergent, disinfectant shall be used?
- Are there any existing plant design constraints?
- Is there sufficient electrical power available?
- Is there a convenient supply of the right grade of water?

Health and environmental aspects

- Are there any particular hazards to be considered?
- Are the effluent disposal facilities adequate?

Factors to be Considered When Selecting Cleaning Techniques (2)

Cleaning requirements

- What is the frequency of cleaning?
- What is the required standard of cleanliness?
- Why is cleaning considered necessary?

Further factors

- Which system is the most cost-effective, all factors considered?
- Are the operators trained for handling the cleaning equipment?

Purging of Product from the Plant (1)

Product recovery (removal of large debris) can be carried out by using various media, such as

- Water
- Mechanical pigging devices
- Compressed air (whirlwind technology)
- Inert gas

Product recovery in the cleaning process:

- Part of a process sequence
- First stage of a CIP sequence

Purging of Product from the Plant (2)

Example:

In a dairy plant with a daily output of 1 million litres, a 0.5% loss of milk is equivalent to a loss of raw material worth £1,300 per day or £475,000 per year!

⇨ Product recovery from process lines provides considerable potential for savings.

Choice of Chemicals (1)

Choose from different types of chemicals for different purposes:

- Caustic detergents
- Acid detergents
- Detergent additives:
  - Sequestrants (chelating agents)
  - Surfactants (wetting agents)

Clean

- Sterilant/Sanitizer

Sanitize

Choice of Chemicals (2)

The choice of chemicals depends on:

- Fouling that has to be removed. In the dairy industry, for instance, the following procedures are applied:
  - Proteins are removed with hot alkali (caustic soda)
  - Calcium and other deposits are removed with a dilute mineral acid (mostly nitric acid or phosphoric acid)
  - Additionally, special formulations containing added components (e.g. sequestrants) are available

- The material of the equipment used, such as
  - Austenitic stainless steel - very resistant
  - Aluminium, copper or bronze surfaces - have to be handled with great care

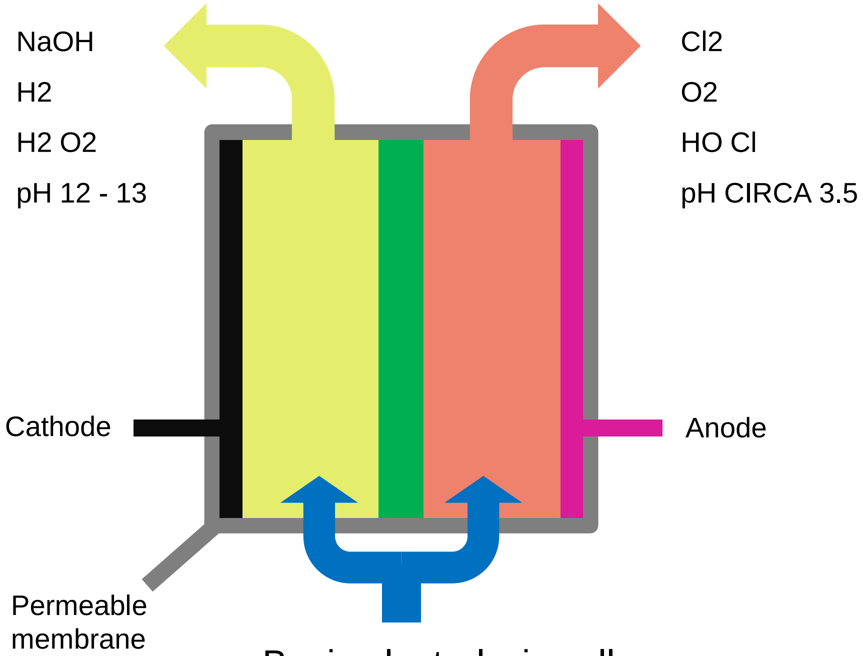
Choice of Chemicals (3)

Innovative CIP technology:

- Use of electro-chemically activated (ECA) water for both cleaning and sanitization

Procedure:

- Electrolysis of a solution of sodium chloride generates sodium hydroxide and hypochlorous acid
- Hypochlorous acid is a very potent sanitizer



Basic electrolysis cell
Source: based on SPX

Choice of Chemicals (4)

The use of ECA water offers a range of benefits, especially for food processing:

- Substitution of chemical detergents and sanitizers
- Improved microbial efficiency
- Destruction of all forms of pathogens
- Reduced CIP time
- Reduced water consumption
- Improved effluent management
- Non-toxic, truly “clean” technology
- On-site, on-demand generators

⇨ Application of CIP in the carbonated soft drinks industry typically has a payback of less than four months!

Process Parameters (1)

Circulation time depending on:

- Degree of fouling
- Type of equipment to be cleaned

- Typical cleaning times in the dairy industry:
  - 20 minutes of caustic circulation for pipework and vessels
  - Up to 40 minutes of caustic circulation for pasteurizers and UHT plants with higher levels of fouling
  - Normally 10 minutes for acid circulation

Process Parameters (2)

Operating temperatures:

- Typical CIP temperatures of different applications:

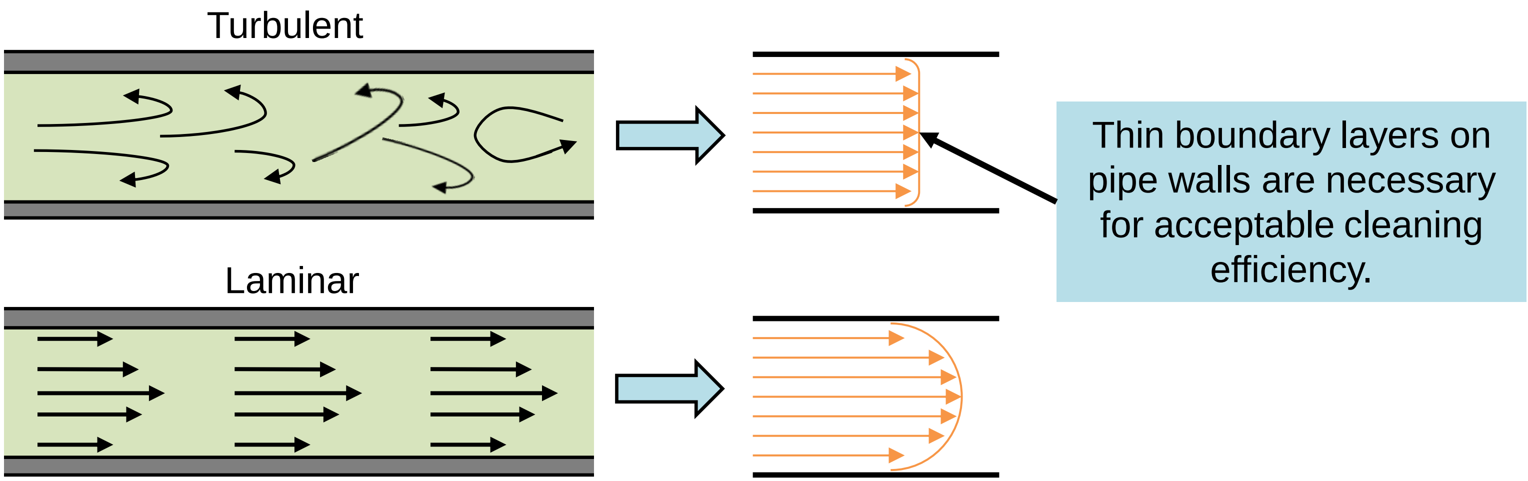
Vessel type	Flow rate
Brewery vessels	Hot 85°C
Brewery mains	Hot 85°C
Process vessels	Cold < 40°C
Process mains	Hot 75°C
Yeast vessels	Hot 75°C
Yeast mains	Hot 75°C

- Dairy industry: the higher the temperature the poorer the removal (optimum at 50°C)

Process Parameters (3)

Flow velocity:

- Turbulent flow with flow velocities of 1.5 to 2.1 m/s is usually applied, as cleaning under laminar conditions is not sufficient.



Turbulent vs. laminar flow

Source: based on Briggs

Choice of Equipment (1)

Selection of spray devices:

Application	Device
Simple applications	Spray balls run at relatively low pressures (1-2 bar)
High degree of fouling or large diameters (> 3 m)	Rotating jet devices run at higher pressures (5 bar)
Vessels with top mounted agitators	Two spray balls to overcome shadows cast by the agitator shaft and blades

Fixed spray balls and rotary sprayhead

Source: Industrial Trading Solutions Ltd

Choice of Equipment (2)

Calculation of flow rates for spray balls:

Vessel type	Flow rate
Vertical vessels (incl. silos)	Flow rate (l/h) = diameter (m) x 3.14 x 1,490
Horizontal tanks	Flow rate (l/h) = diameter (m) + length (m) x 2 x 1,490
Other tanks	Flow rate (l/h) = side (m) + end (m) x 2 x 1,490

⇨ Depending on the flow rate, the spray ball size is calculated.

Case Study: Introduction of Improved Spray Heads

Initial situation	A brewery cleaned its fermentation tanks with static spray heads.
Objective	Improvement of the cleaning process
Approach	Application of surge cleaners (TANKO® S50) in all 76 fermentation tanks (total capacity of 700 m^3; dimensions of up to 25 metres in height and 6 metres in width)
Outcome	Better cleaning results, significant savings and improved product safety
Benefits	▪ Reduction in CIP time by 34% ▪ Reduction in water/wastewater by 58% ▪ Reduction in acid consumption by 11% and in lye by 39% ▪ Reduction in costs for cleaning process by 61%

Choice of Equipment (3)

Selection of CIP pumps:

- Requirements for CIP supply pumps:
  - Centrifugal type (due to variations in flow and pressure)
  - Individually sized to match the highest rate and pressure circuit it supplies
- Requirements for CIP return pumps:
  - Self-priming liquid ring type (due to scavenging duty required)
  - Sized to return fluids at a rate 10% higher than that of the supply pump
- Requirements for CIP booster pumps:
  - Centrifugal type
  - Carefully sized so as not to introduce cavitation into the circuit

Choice of Equipment (4)

Selection of CIP pumps:

- Chemical dosing pumps for adding concentrates should be sized to transfer liquids at the highest possible rate depending on the concentrate storage method.

- Chemical dosing pumps for adding concentrates in-line should be sized to provide an even addition to the flow.

Learning Objectives ?

Which types of chemicals are used in CIP processes?

- Caustic detergents
- Acid detergents
- Detergent additives:
  - Sequestrants (chelating agents)
  - Surfactants (wetting agents)
- Sterilants/Sanitizers

What has to be considered when choosing the chemicals?

- Fouling to be removed
- Equipment materials

Can you think of examples in your own company?

Clean-in-Place Optimization

- Improve productivity
- Improve resource consumption
- Improve energy efficiency
- Improve automation
- Further possible process improvements

Improving Productivity

Cleaning processes in general do not add value:

- Production uptime is stopped
- Profitability decreases

However, new CIP technologies provide significant improvements in efficiency:

- Automated CIP facilitates and accelerates trouble-shooting
- Optimized CIP can reduce cleaning times by up to 20%
  - With a CIP time of around five hours per day, approximately one hour of extra production time can be gained!

Improving Resource Consumption

Cleaning is energy intensive: Almost half of a milk processing plant's energy is used to clean the equipment.

Reduction in energy consumption:

- Calculate and use the precise temperature needed for sufficient cleaning
  - Rule of thumb: For every 1°C reduction in CIP temperature, energy consumption for fluid heating will decrease by 1/60th.

Reduction in water/chemicals consumption

- Introduce recovery tanks to re-use the liquids

Improving Energy Efficiency

Energy efficiency can be improved by

- Replacing inefficient, outdated equipment components that waste electricity
  - Example: variable speed drives instead of fixed speed drives
- Modifying wasteful processes
  - Example: improved control of heating and chemical sorting processes through software monitoring which prevents fresh water from infiltrating the chemicals tank and avoids unnecessary heating

Improving Automation (1)

Automation

- Improves the quality of information available
- Allows tighter control of the cleaning process

Automation improvement:

- Installing a data sensor system
- Installing sensors in vessels and pipes
- Introducing an information system (software) to record and analyze sensor data
- Installing control panels
- Setting Key Performance Indicators (KPIs)

Improving Automation (2)

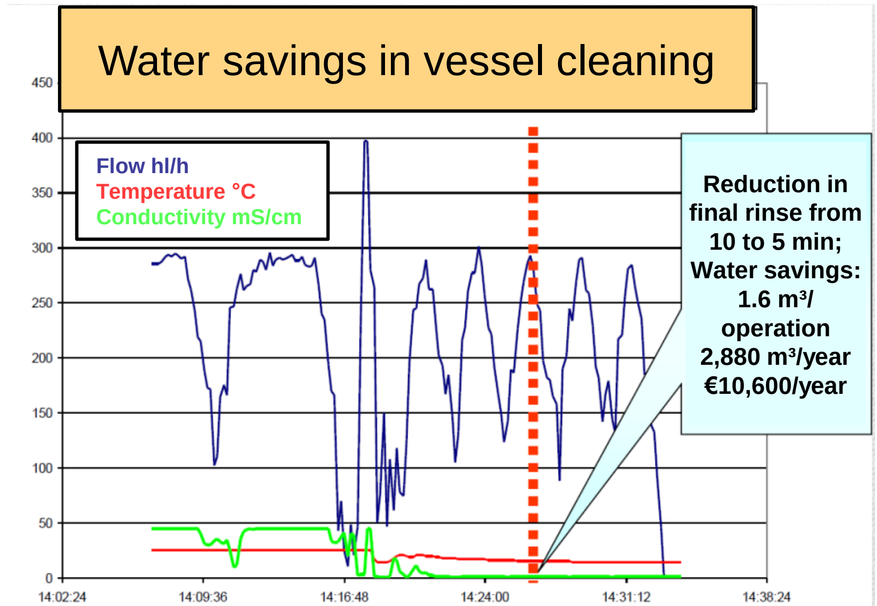
Four key automation parameters for efficient cleaning (4Ts):

- Time: duration of cleaning cycles
- Temperature: temperature of cleaning substances
- Titer: concentration of cleaning substances
- Turbulence: speed and impact of cleaning liquids

⇨ By using software to calculate the optimum combination of each parameter, considerable cost reductions can be achieved!

Case Study: Analysis and Optimization of a Cleaning Process

Objective	A beverage manufacturer wanted to analyze and optimize the CIP process.
Approach	Incorporation of a sensor system to calculate, visualize and document all the essential parameters in a data information system
Outcome	Rinsing time could be reduced from 10 to 5 minutes.
Benefits	▪ Annual savings of €10,600 ▪ Reduction in fresh water consumption by 2,880 m³ per year ▪ Amortization after one year



Data recording

Source: ©Steinhaus Informationssysteme GmbH

Additional Process Improvements

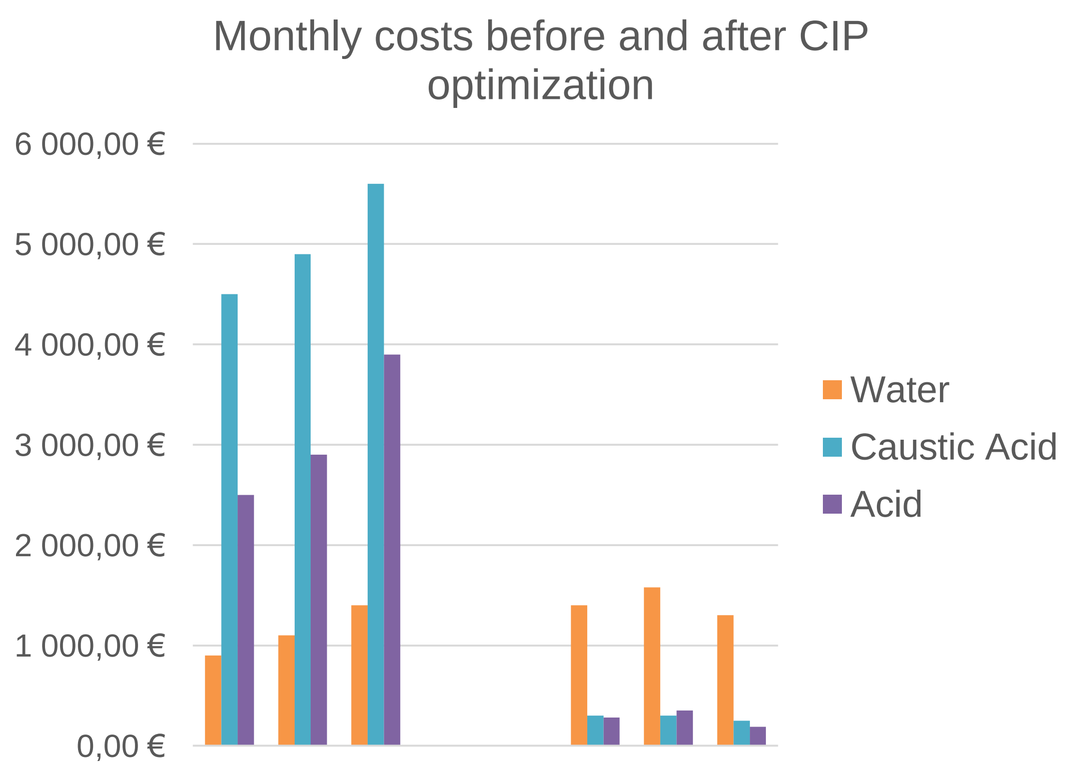
In order to improve your CIP system, you might want to

- Modify chemicals
- Alter cleaning times
- Adjust water temperature
- Reconfigure settings
- Maximize chemical effectiveness
- Implement eco-friendly solutions
- Use ozonated water
- Develop a conservation mind-set

⇨ A holistic approach which automates performance through software is generally more helpful than manually changing individual parameters.

Case Study: CIP Redesign and Optimization

Objective	CIP redesign and optimization
Outcome	Water usage increased by up to 50%, whereas chemicals consumption decreased dramatically by 80-95%.
Benefits	▪ Annual savings of approx. €90,000 ▪ Increase in production uptime ▪ Reduction in energy consumption



Adapted from "How to Optimize CIP Processes in Food and Beverage Operations"

Source: based on Schneider Electric

Learning Objectives

?

Do you remember the four automation parameters?

- Time: duration of cleaning cycles
- Temperature: temperature of cleaning substances
- Titer: concentration of cleaning substances
- Turbulence: speed and impact of cleaning liquids

How can they benefit your cleaning process?

By using software to calculate the optimum combination of these parameters, considerable cost reductions can be achieved!

Key messages

Reasons for using Clean-in-place processes:

- Repeatable, reliable and effective cleaning
- Cost increases for raw materials, equipment and cleaning solutions
- Customers demanding higher product quality
- High standards required to comply with environmental, safety and health regulations
- Process improvement increases plant efficiency and customer satisfaction

Key messages

Clean-in-place processes provide several advantages for industrial plants:

- Improving plant efficiency
- Improving product quality
- Guaranteed and repeatable processes that can be validated (high standards of hygiene)
- Cleaning of areas that are difficult to access
- Achieving savings on regular operating costs due to reduced wear-and-tear on equipment and lower labour requirements
- Reducing operator hazards associated with handling and inhaling cleaning chemicals

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