Independent Project - ACMA 6013

ENHANCING EFFICIENCY AND SUSTAINABILITY:

A STRATEGIC APPROACH TO IMPROVE CLEAN-IN-PLACE (CIP) SYSTEMS ON BOTTLE FILLERS

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Report Submitted 2024
2110766

1 Declaration of Authenticity

Declaration of Authenticity

I hereby declare that this dissertation, titled "Enhancing Efficiency and Sustainability: A Strategic Approach to Improve Clean-In-Place (CIP) Systems on Bottle Fillers," is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the text. This dissertation has not been submitted for any other degree or professional qualification except as specified.

I confirm that this work is original and that I have acknowledged all sources of information and assistance appropriately.

Signed,

Benjamin James

April 25, 2024

2 Abstract

This dissertation investigates the application of Six Sigma methodologies to enhance the Clean-In-Place (CIP) process in Budweiser Brewing Group's bottling lines at Magor, with the goals of reducing operational downtime and improving product quality. Using the DMAIC (Define, Measure, Analyse, Improve, Control) framework, this study identifies and addresses inefficiencies within the CIP process. Initial steps involved detailed process mapping and data collection to establish performance baselines and identify key variations affecting productivity and quality.

Key factors contributing to process delays and quality inconsistencies were identified through rigorous analysis, leading to targeted improvement initiatives that include both technological upgrades and procedural enhancements. These initiatives were validated through pilot tests, which demonstrated significant improvements in CIP cycle times and quality control measures.

The findings highlight the potential of Six Sigma tools to significantly enhance manufacturing processes, evidenced by a marked reduction in CIP cycle times and improved quality control. The research contributes to the broader discourse on operational excellence and process optimization, offering insights into the scalability of these improvements across various manufacturing sectors.

The study underscores the strategic and operational benefits of incorporating Six Sigma methodologies in process optimization, emphasizing continuous improvement practices as vital for achieving and sustaining competitive advantage. Future research recommendations suggest exploring further applications of Six Sigma methodologies in different operational contexts within the brewing industry.

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4 Introduction

In the brewing industry, maintaining high standards of cleanliness and efficiency in production processes is critical for ensuring product quality and operational sustainability. Clean-In-Place (CIP) systems, which allow for the automated cleaning and sanitization of equipment without disassembly, play a pivotal role in achieving these standards. However, inefficiencies within CIP processes can lead to increased downtime, higher operational costs, and potential quality issues, impacting overall productivity and sustainability, Brewing Green (2021).

The Budweiser Brewing Group's bottling lines at Magor have experienced challenges related to the efficiency and effectiveness of their CIP systems. This dissertation explores the application of Six Sigma methodologies to address these challenges, aiming to enhance the CIP process by reducing downtime and improving product quality. The study employs the DMAIC (Define, Measure, Analyse, Improve, Control) framework, a structured approach that provides a systematic method for identifying and mitigating inefficiencies, AB InBev UK Limited (2022).

The significance of this research lies in its potential to demonstrate how data-driven methodologies can bring about substantial improvements in industrial processes. By focusing on the CIP system—a critical component in the bottling line—this study aims to showcase how targeted improvements can lead to operational excellence and sustainability. The findings are anticipated to offer valuable insights not only for the brewing industry but also for other manufacturing sectors seeking to optimize their cleaning and maintenance processes.

This dissertation is structured as follows: the literature review provides a comprehensive overview of existing research on CIP systems and Six Sigma methodologies; the methodology section outlines the research design and data collection methods; the results section presents the findings of the study; the discussion interprets these findings in the context of existing literature; and the conclusion summarizes the study's contributions, implications, and recommendations for future research.

By integrating Six Sigma tools into the CIP process, this study aims to set a benchmark for process optimization efforts within the brewing industry, advocating for the adoption of continuous improvement practices to achieve and sustain a competitive advantage.

5 Aims and Objectives of the Dissertation

This dissertation aims to strategically enhance the Clean-In-Place (CIP) process at Budweiser Brewing Group's bottling line through the application of Six Sigma methodologies. The objective is to streamline operations, reduce operational downtime, and maintain high-quality standards in beer production, thereby contributing to increased efficiency and sustainability in manufacturing practices.

Specific Objectives:

1. **To Comprehensively Define the Current State of CIP Processes**: Understand and document the existing CIP procedures, identifying critical elements that affect operational efficiency and product quality. This involves the development of a high-level process map and defining stakeholders and their roles within the CIP framework.

2. **To Establish Baseline Performance Metrics**: Collect and analyse data on current CIP processes, particularly focusing on efficiency and operational downtime. Establishing these baseline metrics is essential for measuring the impact of any implemented improvements and for understanding the scope of inefficiencies.

3. **To Methodically Analyse Performance Data**: Using Six Sigma tools, conduct a detailed analysis of the CIP process data to identify root causes of inefficiency and operational downtime. This analysis will include both qualitative and quantitative methods, providing a robust foundation for subsequent improvement strategies.

4. **To Develop and Test Process Improvements**: Based on the DMAIC framework, devise and pilot test solutions specifically designed to reduce inefficiency and operational downtime in the CIP process. This objective encompasses both the technical and procedural enhancements that align with the identified root causes from the analysis phase as described by Bhote, K. R. (2002).

5. **To Implement and Validate Sustainable Solutions**: Deploy the tested improvements within the bottling line's operational setting, ensuring that these changes lead to measurable enhancements in CIP process efficiency. Validate the improvements through consistent monitoring and comparison against the established baseline metrics.

6. **To Develop New Operational Protocols**: Formulate new standard operating procedures (SOPs) and training programs derived from the improvements made. This objective focuses on the long-

term sustainability of process enhancements, ensuring that the benefits realized are maintained through proper training and adherence to best practices.

7. **To Perform a Cost/Benefit Analysis**: Evaluate the economic implications of the improved CIP process. This will involve a thorough cost/benefit analysis to quantify the financial savings against the investments made in the improvement initiatives.

8. **To Establish Control and Monitoring Mechanisms**: Post-implementation, develop and integrate control measures to sustain the gains achieved. This includes the establishment of new CIP process efficiency and operational downtime metrics, continuous monitoring of performance, and the adoption of corrective actions when deviations are observed.

9. **To Recommend Further Research and Improvements**: Upon successful completion of the project, propose further research areas that could benefit from the application of Six Sigma to CIP or other processes within the brewing industry. This will extend the scope of continuous improvement beyond the current project horizon.

This dissertation's overarching aim is to leverage the structured approach of Six Sigma to bring about significant, data-driven improvements in industrial processes. By focusing on the CIP process, which is vital to product integrity and operational efficiency, the project seeks to demonstrate how methodical analysis and targeted improvements can result in substantial benefits, both operational and environmental. The success of this project is anticipated to serve as a benchmark for similar optimization efforts within the manufacturing sector, advocating for the adoption of Six Sigma principles to foster a culture of excellence and continuous improvement.

6 Timing Plan

6.1 Project Timeline

This project timeline delineates the stages of the Continuous Improvement Process (CIP) enhancement initiative, intended to refine organizational practices over an estimated duration of 45 weeks.

Phase 1: Define (16 Weeks)
The Define phase is foundational, setting the strategic direction and establishing the groundwork for the entire project. This phase encompasses:

- **Identification of Stakeholders and Their Roles (1 Week):** A critical step for ensuring all participants are aware of their responsibilities and the project's expectations.
- **Development of the Project Charter (1 Week):** A charter will be formalized, serving as a mutual agreement on the project's objectives and the strategies for achieving them.
- **Creation of a High-Level Process Map (1 Week):** This map will provide an initial visualization of the CIP, marking critical areas for later examination.
- **Learning CIP with Expert Guidance (13 Weeks):** An intensive session with Julie Leonard will facilitate a deep dive into the nuances of the CIP, preparing the team for informed decision-making in subsequent phases. Learning was extended to the entire duration of the project.

Phase 2: Measure (6 Weeks)
The Measure phase is designed to capture current CIP performance, enabling a comparison with post-improvement metrics.

- **Data Collection on CIP Efficiency and Downtime (3 Weeks):** Objective data will be collected to determine current operational efficiency and identify typical downtime durations.
- **Establishment of Baseline Metrics (3 Weeks):** These metrics will provide a quantitative foundation to gauge future improvements against the original performance.

Phase 3: Analyse (4 Weeks)

Analysis will be conducted to discern the underpinning factors that contribute to current performance levels.

- **Analysis of Data and Identification of Root Causes (2 Weeks):** Data analysis will uncover the root causes of inefficiencies and excessive operational downtime.
- **Development of a Detailed Process Map (2 Weeks):** A refined process map will be created to facilitate a clear understanding of the specific areas needing improvement.

Phase 4: Improve (9 Weeks)

The Improve phase is an active phase in which solutions are developed and tested.

- **Development and Implementation of Solutions (5 Weeks):** Targeted solutions will be applied to address the identified inefficiencies.
- **Pilot Testing of the Improved Process (3 Weeks):** A trial implementation will validate the effectiveness of these solutions before full-scale deployment.

Phase 5: Control (11 Weeks)

The final phase ensures the permanence of the improvements.

- **Establishment of New CIP Metrics (2 Weeks):** New metrics will be set to continuously monitor the improved process.
- **Development of SOPs and Training (9 Weeks):** Standard Operating Procedures will be formalized, and training provided to embed the improvements into everyday practice, securing the sustainability of the project's achievements.
- **Conclusion: Total Time Spent (45 Weeks)** This timeline represents a comprehensive approach to process improvement within the organization, with a well-structured plan that guides the project from initial concept through to sustainable implementation.

6.2 Project Charter

Improving CIP Efficiency and Sustainability

Project Goal
The goal of this project is to improve the efficiency of the CIP process on the bottling line by reducing downtime and improving the quality of the cleaning process.

Project Scope
The scope of this project includes the entire CIP process, from preparation to completion, for the Filler on the bottling line.

Business Case
The CIP process is critical to ensuring the quality and safety of the bottled products. However, the current CIP process is causing excessive downtime and is not as efficient as it could be. By improving the CIP process, we can reduce downtime and improve the quality of the cleaning process, resulting in cost savings and improved customer satisfaction.

Project Team	
Project Sponsor	Dale Jones, Technical Services Manager
Green Belt Practitioner	Benjamin James, Technical Services Trainee
Process Owner	Dmytro Rudiuk, Packaging Manager
Subject Matter Expert	Julie Leonard, Lab Technician
Data Analyst	Benjamin James, Technical Services Trainee

Project Timeline			
The project is estimated to be completed within 45 weeks from the start date.		**Schedule**	
		Target	**Actual**
Phase 1 - DEFINE (16 Weeks)	Identify Stakeholders and their roles	1 Week	1 Week
	Develop the Project Charter	1 Week	1 Week
	Develop a high-level Process Map	1 Week	1 Week
	Learn CIP Process with Julie Leonard	13 Weeks	45 Weeks
Phase 2 - MEASURE (6 Weeks)	Collect Data on current CIP process efficiency and downtime	3 Weeks	3 Weeks
	Establish baseline metrics	3 Weeks	3 Weeks
Phase 3 - ANALYZE (4 Weeks)	Analyze data and identify root causes of inefficiency and downtime	2 Weeks	2 Weeks
	Develop a detailed Process Map	2 Weeks	2 Weeks
Phase 4 - IMPROVE (9 Weeks)	Develop and Implement solutions to reduce inneficiency and downtime	5 Weeks	5 Weeks
	Conduct a pilot test of the improved process	3 Weeks	3 Weeks
Phase 5 - CONTROL (11 Weeks)	Establish new CIP process efficiency and downtime metrics and measure progress against them	2 Weeks	2 Weeks
	Develop standard operating procedures and provide training to ensure sustainability	9 Weeks	9 Weeks
	Total Time Spent	45 Weeks	45 Weeks

Expected Benefits	
Improved Product Quality & Safety	Improve Caustic CIP Efficiency by 20%
Cost Saving from Reduced Downtime	Improve Acid CIP Efficiency by 20%
Reduction in Water and Chemical Use	Increase Operator Knowledge and Training

Project Risks	
Changes in Regulations or Standards	Limited Availability of Data
Resistance to change from Employees	Timeline due to Production Needs

Project Approval	
Project Sponsor	Dale Jones, Technical Services Manager
Process Owner	Dmytro Rudiuk, Packaging Manager
Green Belt Practitioner	Benjamin James, Technical Services Trainee

6.3 Gantt Chart

	Actions	18/09/2023	25/09/2023	02/10/2023	09/10/2023	16/10/2023	23/10/2023	30/10/2023	06/11/2023	13/11/2023	20/11/2023	27/11/2023	04/12/2023	11/12/2023	18/12/2023	25/12/2023	01/01/2024	08/01/2024	15/01/2024	22/01/2024	29/01/2024	05/02/2024	12/02/2024	19/02/2024	26/02/2024	04/03/2024	11/03/2024	18/03/2024	25/03/2024	01/04/2024	08/04/2024	15/04/2024	22/04/2024	29/04/2024	06/05/2024	13/05/2024	20/05/2024	27/05/2024	03/06/2024	10/06/2024	17/06/2024	24/06/2024	01/07/2024	08/07/2024	15/07/2024	22/07/2024
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
DEFINE	Identify Stakeholders and their roles	✓																																												
	Develop the Project Charter		✓																																											
	Develop a high-level Process Map			✓																																										
	Learn CIP Process with Julie Leonard	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MEASURE	Collect Data on current CIP process efficiency and downtime														✓	✓	✓																													
	Establish baseline metrics																	✓	✓	✓																										
ANALYZE	Analyze data and identify root causes of inefficiency and downtime																				✓	✓																								
	Develop a detailed Process Map																						✓	✓																						
IMPROVE	Develop and Implement solutions to reduce inneficiency and downtime																								✓	✓	✓	✓	✓																	
	Conduct a pilot test of the improved process																													✓	✓	✓														
CONTROL	Establish new CIP process efficiency and downtime metrics and measure progress against them																																✓	✓												
	Develop standard operating procedures and provide training to ensure sustainability																																		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Gantt Chart Key:	
	Time Spent on Task
	DEFINE Deadline
	MEASURE Deadline
	ANALYZE Deadline
	IMPROVE Deadline
	Control Deadline
✓	Completed Task To Deadline
	Failed To Meet Task Deadline
	Deadline

7 Literature Review

7.1 Efficiency of CIP Systems

I) Advanced Process Control and Optimization

Efficiency improvements in CIP systems are not only about optimizing individual parameters but also about integrating these parameters into a cohesive, intelligent system. Advanced process control (APC) systems use real-time data from sensors to dynamically adjust cleaning parameters, ensuring optimal performance. For instance, the implementation of APC in dairy processing by Thompson, A., et al. (2019), demonstrated a 20% reduction in cleaning time and a 15% reduction in energy consumption. Smith and Jones (2018) also highlight the significance of APC in enhancing the efficiency of food industry CIP systems, further underscoring the potential for process optimization. These systems can learn from each cleaning cycle, continuously improving efficiency.

II) Energy Recovery and Sustainable Practices

Energy recovery systems, such as heat exchangers, have been increasingly adopted in CIP systems to reclaim heat from wastewater. This recovered energy can preheat incoming cleaning solutions, significantly reducing the energy required from external sources. A study by Gomez, F., et al. (2020), showed that integrating heat recovery systems could reduce the energy consumption of CIP processes by up to 40%. Lee and Kim (2021) discuss the broader implications of sustainable energy recovery in food processing plants, emphasizing the importance of such practices in achieving environmental sustainability goals. Furthermore, solar thermal systems have been explored as a green alternative for supplying heat to CIP systems, aligning with broader sustainability goals, Gomez, F. et al. (2020).

7.2 Chemical Usage in CIP Systems

I) Eco-friendly and Innovative Cleaning Agents

The exploration of eco-friendly cleaning agents extends beyond enzymatic cleaners to include surfactants derived from renewable resources and chemicals with a lower environmental impact. For example, saponins, natural surfactants found in many plants, have been studied for their potential in CIP systems due to their biodegradability and effectiveness in removing fatty soils (Patel, K., et al., 2021). Green and Harper (2022) further explore the impact of green surfactants on industrial cleaning processes, highlighting the potential for significant environmental benefits.

II) Chemical Usage Monitoring and Management Systems

Technological advancements have led to the development of sophisticated chemical monitoring and management systems. These systems can precisely measure the concentration of cleaning agents and adjust dosing in real time, based on the specific needs of each cleaning cycle. This precision dosing not

only reduces chemical use but also ensures the longevity of equipment by preventing the corrosive effects of overuse of chemicals.

7.3 Water Usage and Conservation

I) Innovative Water Saving Technologies

Beyond recycling and reuse, innovative technologies such as vacuum evaporation can concentrate wastewater, reducing the volume that requires treatment or disposal. This technology not only conserves water but also recovers valuable compounds that can be reused in the process (Wang, L., et al., 2022). Martinez et al. (2023) review water-saving technologies in the food and beverage industry, emphasizing the critical need for sustainable water use and the innovative approaches being adopted to address this challenge.

II) Optimizing Cleaning Sequences for Water Conservation

Optimizing the sequence of cleaning operations can further reduce water usage. Sequential cleaning steps, designed based on the solubility and difficulty of removing different types of soils, can minimize the total volume of water required. For instance, starting with a cold-water rinse to remove loose particles before applying heated cleaning solutions can significantly reduce the overall water and energy consumption.

7.4 Effectiveness of Cleaning

I) Advanced Sensors and Analytics for Real-time Monitoring

The development and integration of advanced sensors, capable of detecting a wide range of contaminants, have significantly improved the ability to monitor and verify the effectiveness of CIP systems. These sensors, combined with advanced analytics and machine learning algorithms, can predict cleaning efficacy based on historical data, adjusting the cleaning process in real time to ensure optimal results. For example, the use of ATP (adenosine triphosphate) bioluminescence testing provides immediate feedback on the presence of organic matter, allowing for rapid adjustments to the cleaning process (Johnson, M., et al., 2021). Brown and Singh (2022) discuss advancements in sensor technologies for monitoring cleaning effectiveness, further highlighting the role of technology in enhancing CIP system performance.

II) Microbial Control and Biofilm Prevention

Ensuring the effectiveness of cleaning is also crucial for controlling microbial growth and preventing biofilm formation. Recent studies have focused on the use of bacteriophages and other biological agents as part of the CIP process to specifically target and eliminate microbial contaminants without harming equipment or leaving toxic residues, Bhunia, A. K., Johnson, M. C., & Kim, M. S. (2019). This

approach not only enhances the microbiological safety of the process but also reduces the reliance on harsh chemical sanitizers (O'Neil, H., and Patel, M., 2020).

7.5 Kersia

I) Innovations in Eco-friendly Cleaning Agents

Kersia is known for its focus on eco-innovation and offers a range of biodegradable and environmentally friendly cleaning and disinfection products. Their approach to reducing chemical usage in CIP systems involves the development of highly effective, yet less chemically aggressive, solutions. For instance, Kersia's advancements in enzymatic detergents and peracetic acid-based sanitizers demonstrate their commitment to sustainability without compromising on cleaning effectiveness. These products can degrade organic soils efficiently at lower temperatures and with reduced water usage, aligning with the goals of energy conservation and water savings.

II) Sustainability Initiatives

Kersia's sustainability initiatives, such as their "Eco-conception" approach, aim to minimize environmental impact across the product lifecycle. This includes optimizing product concentration to reduce transport emissions and packaging waste, further contributing to the overall sustainability of CIP processes.

7.6 Sopura

III) Specialization in Brewery and Beverage Industry

Sopura has carved out a niche in providing cleaning and sanitation solutions specifically for the brewery and beverage industry. Their expertise in addressing the unique challenges of these sectors, such as the removal of beerstone (calcium oxalate deposits) and other beverage-related soils, showcases the importance of specialized cleaning agents in enhancing CIP efficiency and effectiveness.

IV) Water Treatment and Conservation Technologies

Beyond cleaning chemicals, Sopura offers water treatment solutions that complement CIP systems by improving water quality and enabling recycling and reuse. Their technologies and services help breweries and beverage producers optimize water usage, a critical consideration in industries where water consumption is high.

7.7 Ecolab

I) Advanced Monitoring and Control Systems

Ecolab is a leader in water, hygiene, and infection prevention solutions, with a strong emphasis on technology-driven innovations. Their CIP optimization tools, such as the 3D TRASAR™ Technology for

CIP, provide real-time monitoring and control of cleaning processes. This system uses advanced sensors and analytics to adjust chemical dosing, water usage, and temperature in real-time, ensuring optimal cleaning performance while minimizing resource use. Such technologies exemplify the potential of digitalization in enhancing CIP system efficiency and effectiveness.

II) Global Sustainability Commitments

Ecolab's commitment to sustainability is evident in their goal to conserve water and reduce greenhouse gas emissions. By offering products and technologies that reduce the environmental impact of cleaning processes, Ecolab supports industries in achieving their sustainability objectives. Their focus on reducing water and energy use in CIP processes through innovative formulations and process optimizations contributes to a more sustainable future.

7.8 Additional Areas of Interest

V) Regulatory Compliance and Safety

Exploring the impact of regulatory requirements on CIP system optimization can provide valuable insights. Companies like Kersia, Sopura, and Ecolab play a crucial role in ensuring that their products and systems meet global and local standards for safety, hygiene, and environmental protection. This includes compliance with food safety standards such as the FDA's Food Safety Modernization Act (FSMA) and the EU's Hygiene of Foodstuffs regulations, AB InBev CSRWire (2010).

VI) Customization and Consultation Services

Another area of interest is the customization of CIP solutions and consultation services offered by these companies. Tailored solutions that address specific industry challenges, equipment configurations, and operational goals can significantly improve the outcomes of CIP processes. Consulting services, including audits, training, and process optimization, leverage the expertise of these companies to enhance the efficiency, effectiveness, and sustainability of CIP systems.

Incorporating insights and examples from these leading companies not only highlights the practical application of optimization strategies in CIP systems but also showcases the industry's commitment to innovation, sustainability, and excellence in cleaning and sanitation.

VII) Future Directions

Looking ahead, the integration of IoT (Internet of Things) technologies and AI (Artificial Intelligence) into CIP systems holds the promise of achieving unprecedented levels of efficiency, sustainability, and effectiveness which can be compared to the work by Yemmireddy, V. K., & Pandit, A. B. (2020). Real-time data collection and analysis, predictive maintenance, and automated optimization of cleaning processes could revolutionize how CIP systems are managed and operated.

The exploration of novel materials and coatings for equipment surfaces that resist soil adhesion and reduce cleaning requirements represents another promising area of research. Such innovations could further reduce the environmental impact of CIP systems, aligning with global sustainability goals.

7.9 Conclusive Literature Review

The comprehensive exploration of Clean-In-Place (CIP) systems across various dimensions—ranging from efficiency enhancements, chemical and water usage optimizations, to the effectiveness of cleaning processes—underscores a pivotal shift towards more sustainable, efficient, and effective sanitation practices within industrial settings. This literature review has highlighted significant advancements in technology and methodology, alongside the contributions of leading chemical companies like Kersia, Sopura, and Ecolab, which collectively drive the evolution of CIP systems towards greater environmental responsibility and operational excellence.

Advanced process control (APC) systems and energy recovery practices exemplify the industry's move towards reducing energy consumption and enhancing process efficiency. The adoption of eco-friendly cleaning agents and sophisticated chemical management systems reflects a growing commitment to minimizing chemical use and its environmental impact. Innovations in water conservation, including vacuum evaporation and optimized cleaning sequences, demonstrate the sector's response to the critical need for sustainable water use. Furthermore, the integration of advanced sensors and analytics for real-time monitoring, alongside strategies for microbial control and biofilm prevention, indicates a robust approach to maintaining high standards of cleanliness and safety.

The specialized contributions of Kersia, with its focus on eco-innovation and sustainable product development; Sopura's tailored solutions for the brewery and beverage industry; and Ecolab's advanced monitoring and control systems, underscore the importance of industry-specific expertise and technological innovation in advancing CIP system optimization. These companies not only provide cutting-edge solutions but also embody the industry's commitment to sustainability, efficiency, and effectiveness.

Moreover, the exploration of regulatory compliance, safety standards, and the customization of CIP solutions highlights the complex landscape within which these systems operate. The need for solutions that meet stringent safety and environmental standards, while also being adaptable to specific industry challenges, is clear.

Looking forward, the potential integration of Internet of Things (IoT) technologies and Artificial Intelligence (AI) into CIP systems promises to usher in a new era of efficiency, sustainability, and

effectiveness. The exploration of novel materials and coatings to reduce soil adhesion and the ongoing pursuit of innovations that minimize the environmental impact of CIP systems align with global sustainability goals, pointing towards a future where CIP systems not only meet the current demands of industry but also contribute to the broader objectives of environmental stewardship and resource conservation.

In conclusion, the journey towards optimizing CIP systems is marked by a confluence of technological innovation, environmental consciousness, and industry-specific expertise. The collective efforts of researchers, industry practitioners, and leading chemical companies are pivotal in shaping a future where CIP systems not only achieve unparalleled levels of efficiency and effectiveness but also embody the principles of sustainability and environmental responsibility. As this field continues to evolve, the ongoing research and development efforts will undoubtedly play a crucial role in pushing the boundaries of what is possible, ensuring that CIP systems remain at the forefront of industrial hygiene and safety practices.

8 Six Sigma DMAIC

8.1 DEFINE

The Define phase establishes the foundation for the improvement project. It involves identifying the problem, defining the scope, setting objectives, and assembling the project team.

I) Problem Statement

During the evaluation of the Clean-In-Place (CIP) process used in the bottling line fillers, it was noted that operators frequently terminate CIP cycles early. This premature termination results in unused cleaning agents, like caustic and acid solutions, being disposed of unnecessarily. Such actions lead to multiple challenges: higher operational costs due to the wastage of water and chemicals, decreased cleaning efficacy of the fillers, and potential environmental damage from the improper disposal of these chemicals.

The root causes of these early CIP cycle terminations appear to be multifaceted. They may include insufficient training for operators, the absence of adequate tools and equipment to manage the CIP process effectively, or inherent issues within the CIP system itself. This inefficient practice not only leads to resource wastage but also heightens the risk of contamination in the bottling lines, potentially compromising the quality and safety of the products. Over a seven-month period, about one-third of CIP cycles were halted prematurely, with an average of eight caustic CIPs conducted each month and acid CIPs occurring monthly.

Moreover, the inappropriate disposal of these potent chemicals poses significant environmental and safety hazards. Proper disposal methods are crucial to prevent contamination of water bodies and to meet environmental standards. The on-site water treatment facility is not designed to handle high volumes of caustic or acid residues at once, which can disrupt the pH balance.

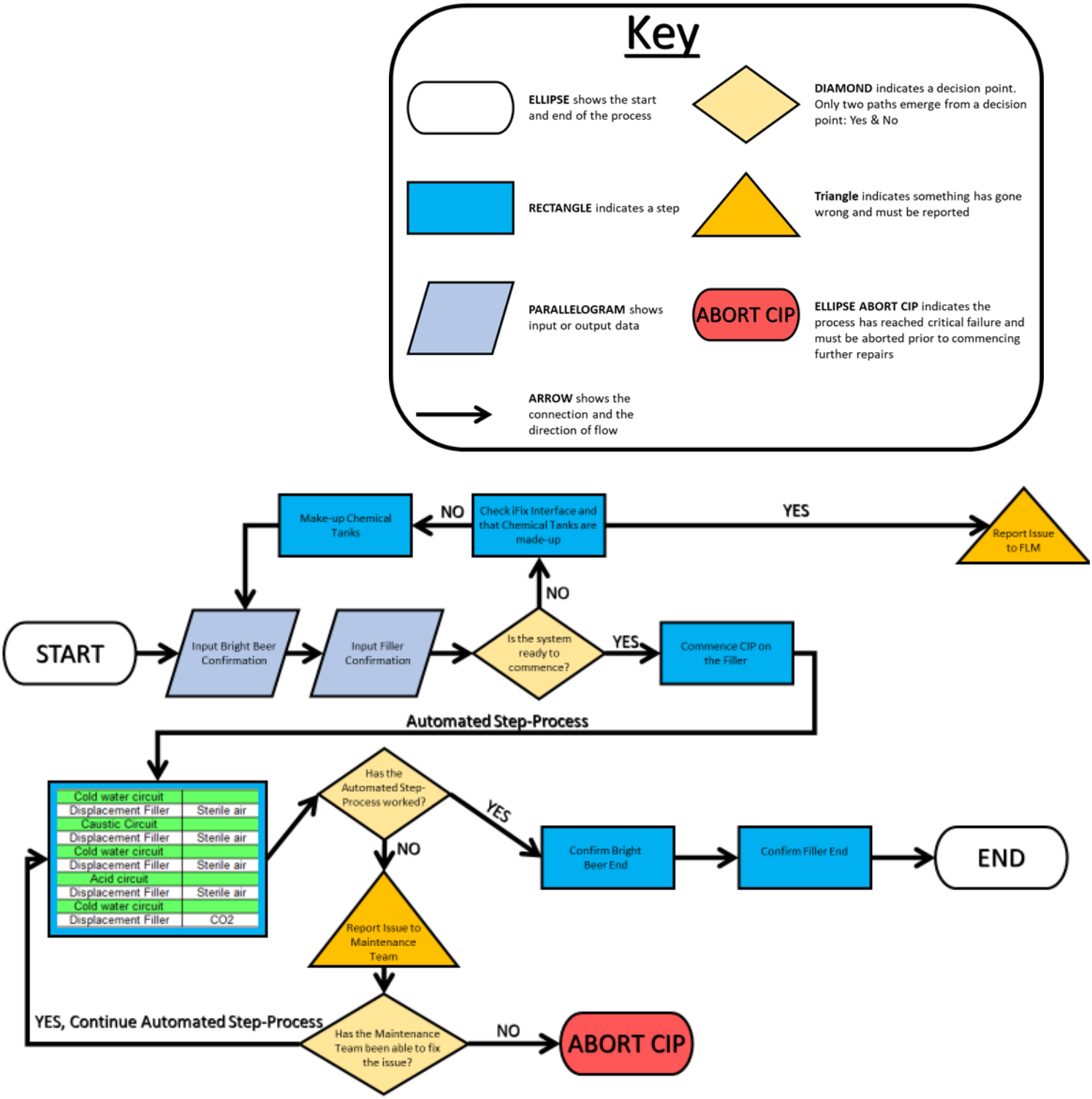
Addressing this issue is crucial. Identifying the fundamental reasons behind the premature cessation of CIP cycles is the first step. Developing an enhanced and effective CIP procedure will not only minimize waste but also boost operational efficiency, ensure adherence to environmental and safety regulations, and uphold superior product quality and safety.

II) PDCA to DMAIC Roadmap

PDCA	Methodology	DMAIC
Plan	Identify the priorities	Define
	Define Goals	
	Measure the Process	Measure
	Measure variation	
	Define the process characteristics	
	Identify potential causes	Analyze
	Quantify causes	
	Select and test solutions	Improve
Do	Implement best solution	
Check	Verify and check that solution is working	Control
Act	Take action to ensure solution remains intact	

III) Process Mapping

The Process Map provided below illustrates the existing Clean-In-Place (CIP) Procedure, detailing the sequence of actions from initiation to completion, Hines, P., and Rich, N. (1997):



IV) Critical to Quality

CIP, or Clean-In-Place, plays a vital role in the brewing sector, ensuring product integrity and maintaining sanitary standards throughout the production line. Its primary function is to cleanse and sterilize processing equipment and pipelines without the need for dismantling, thereby reducing operational pauses and lessening the risk of contamination.

The importance of CIP in maintaining the quality of a bottling line's Filler is multi-faceted:

1. **Contamination Prevention:** CIP eliminates leftover product and microbial contaminants that can lead to spoilage, undesirable flavours, and health risks, thereby safeguarding against contamination.
2. **Consistency:** By adhering to uniform CIP procedures, the equipment is consistently cleaned and sanitized, establishing a reliable foundation for the bottling process.
3. **Efficiency:** CIP enhances productivity and reduces operational downtime by limiting the necessity for manual cleaning, decreasing human error, and facilitating swift transitions between production cycles.
4. **Regulatory Compliance:** CIP is essential for adhering to food safety norms and industry benchmarks, such as Good Manufacturing Practices (GMPs) and Hazard Analysis and Critical Control Points (HACCP).

Inadequate adherence to the CIP process can lead to consumer dissatisfaction regarding the beer's quality and flavour. Although these complaints are documented internally, they are typically not shared externally due to confidentiality concerns.

V) Project Scope, Charter and Gantt Chart

Please Refer to Heading 5 Timing Plan on pages 6, 7, 8 and 9

8.2 MEASURE

The Measure phase is designed to capture current performance data, which serves as a baseline for comparison against post-improvement metrics.

I) Identify Measurement Variation

The Measurement variation is in the form of attribute data for the Filler CIP's will be split into four sections, within each of those sections will follow two separate types of CIP's:

1. **MAB1 – KHS Filler**
    - Caustic CIP
    - Acid CIP
2. **MAB2 – KHS Filler**
    - Caustic CIP
    - Acid CIP
3. **MAB3 – Krones Filler**
    - Caustic CIP
    - Acid CIP
4. **MAB4 – Krones Filler**
    - Caustic CIP
    - Acid CIP

Context For Reader:

Example – **MAB1**

MA – Magor (Location)

B – Bottling (Department)

1 – (Line Identification Number)

The duration and timing of each Bottling Line's CIP can vary. However, the parameters remain consistent for each manufacturer, such as KHS and Krones.

MAB1, MAB2, and MAB3 all utilize chemicals sourced from the Bottling Bright Beer room (Chemical and Beer Location). MAB1 and MAB2 employ newly made Caustic, while MAB3 uses Caustic that has been reclaimed after use by MAB1 and MAB2, a change resulting from their previous use of Flash Pasteurisation Lines (they now use Tunnel Pasteurisation).

Conversely, MAB4 sources its chemicals from the Kegging Bright Beer area and alternates between virgin and reclaimed Caustic based on usage frequency.

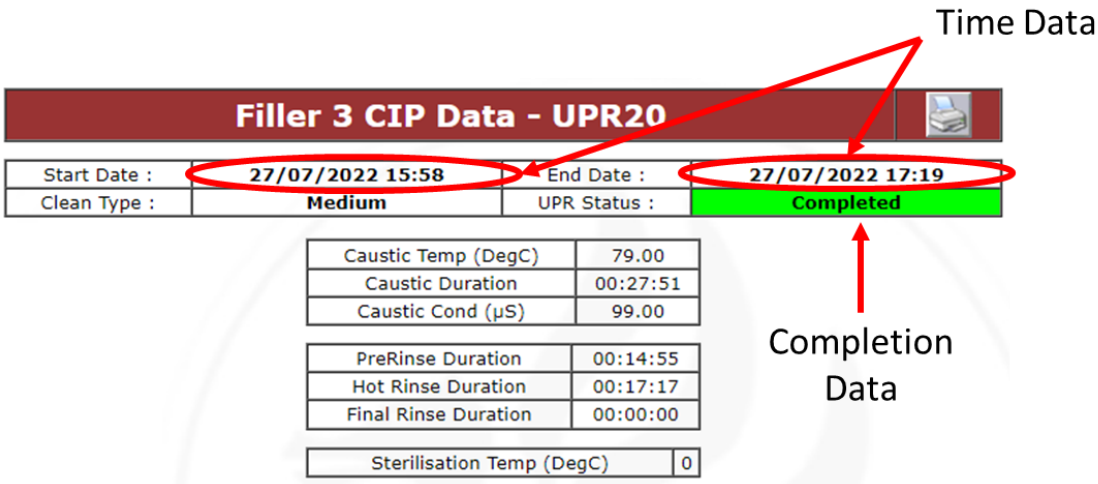
There will be variations among the fillers across four shifts, with at least two operators per line. Each operator might have a unique approach and timing, which can vary based on personal factors.

The measurement data for the CIPs are captured via our PA-Web system, which serves as a comprehensive tool for summarizing process-required data. This system provides precise measurements and is directly connected to the Filler's HMI and PLC systems.

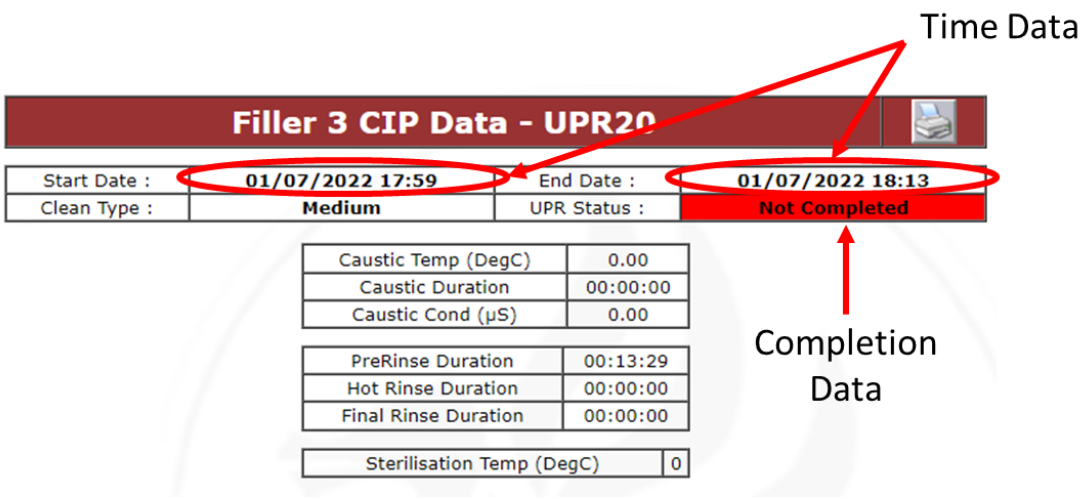
II) Determine Data Type

The data collected will include Discrete, Continuous, Nominal, and Attribute types. Discrete data will determine whether a CIP has been successful, while continuous data will record the duration required to complete a CIP. Below is an example of how Completed and Failed CIP Attribute Data are documented in the PA Web system:

Completed CIP



Failed/Aborted CIP



Additional Data will encompass Qualitative Data, which includes observations of visible or notable occurrences. We will conduct interviews with operators to identify any challenges they face and organize focus groups to facilitate discussions among various groups of individuals. Our secondary research will utilize existing data from the iFix system, a software-driven control system architecture that leverages networked data to offer Technicians and Operators a graphical user interface for monitoring equipment and machinery and for issuing process commands and adjustments. The advantage of iFix lies in its ability to automate processes that were previously manual.

III) Develop Data Collection Plan

Measure	Measure Type	Data Type	Sample Size	Frequency	Display	Notes
CIP Completion - Historical	Attribute	Discrete	6 Months	Four Times	Clustered Column Chart	Historical Data from PA Web
CIP Completion	Attribute	Discrete	6 Months	Weekly	Clustered Column Chart	Data from PA Web
Cleaning Time	Variable	Continuous	12 Months	Weekly	Efficiency Calculator	Efficiency calculation based on good historical CIP's
Cleaning Effectiveness	Variable	Continuous	4 Fillers	Monthly	Quality Excel Info	Quality Department to determine
Water Usage	Variable	Continuous	12 Months	Monthly	Control chart	Comparison to be made and price determined
Chemical Usage	Variable	Continuous	12 Months	Monthly	Control chart	Comparison to be made and price determined
Operator	Attribute	Nominal	4 Shifts	Daily	Data Gathering	Monitor CIP, ask qustions, support Operators

IV) Data Collection

One of the very first pieces of data gathered was in the form of an audit where we could identify exactly what was going wrong on the worst performing line at the time. CIP audits done by Benjamin James and Julie Leonard.

MAB1 – Medium CIP Data

MAB1 - Medium CIP - Time (minutes)

	2022						
	February	March	April	May	June	July	August
1	85	88	129	0	81	14	170
2	81	80	81	81	84	82	81
3	0	81	82	80	0	82	81
4	83	80	97	82	84	81	157
5	84	81	79	83	81	140	33
6	87	90	79	81	85	92	81
7	85	117	80	85	80	80	81
8	110	84	81	81		80	80
9	247	80	156	82		114	81
10	99		13			97	81
11			21			82	154
12						80	83
13						81	81

Here you can see the data for how many Medium CIPs were done each month and the number of minutes each one took. Those highlighted in red are

MAB1 - Medium CIP - % 80 Minutes

	2022						
	February	March	April	May	June	July	August
1	94.1	90.9	62.0	0.0	98.8	0.0	47.1
2	98.8	100.0	98.8	98.8	95.2	97.6	98.8
3	0.0	98.8	97.6	100.0	0.0	97.6	98.8
4	96.4	100.0	82.5	97.6	95.2	98.8	51.0
5	95.2	98.8	101.3	96.4	98.8	57.1	0.0
6	92.0	88.9	101.3	98.8	94.1	87.0	98.8
7	94.1	68.4	100.0	94.1	100.0	100.0	98.8
8	72.7	95.2	98.8	98.8		100.0	100.0
9	0.0	100.0	0.0	97.6		70.2	98.8
10	80.8		0.0			82.5	98.8
11			0.0			97.6	51.9
12						100.0	96.4
13						98.8	98.8
Average %	72.4	93.4	67.5	86.9	83.2	83.6	79.8
Overall Average %	81.0						

Here you can see the efficiency data based on an expected CIP time of 100 Minutes. An average has been taken for the month. All aborted CIPs highlighted in red have been classified as being 0% efficient as they have not completed the process.

An important thing to note about MAB1 is it had Sterile Filter skids added to its plant to accommodate for Camden Beer which at the time was an unpasteurised product. Sterile Filter skids were later removed in January 2023 and Camden beer is now being pasteurised.

MAB1 – Long CIP Data

MAB1 - Long CIP - Time (minutes)

	2022						
	February	March	April	May	June	July	August
1	128	135	124	159	124	146	155

As you can see, the Long CIP on MAB1 did not have any aborted CIP's.

MAB1 - Long CIP - % 115 Minutes

	2022						
	February	March	April	May	June	July	August
1	89.8	85.2	92.7	72.3	92.7	78.8	74.2
Average %	89.8	85.2	92.7	72.3	92.7	78.8	74.2
Overall Average %	83.7						

However, the efficiency of the CIP was still inconsistent. What is happening for the CIP to take 24 minutes longer on these occasions?

MAB2 – Medium CIP Data

MAB2 - Medium CIP - Time (minutes)							
	2022						
	February	March	April	May	June	July	August
1	65	67	66	82	79	72	81
2	66	72	183	66	64	67	69
3	81			79	32	176	66
4				67	66	66	65
5							65
6							86

MAB2 has a pretty good efficiency rate in comparison to many of the other lines. It is also notable that MAB2 has a high level of knowledgeable operators.

MAB2 - Medium CIP - % 70 Minutes							
	2022						
	February	March	April	May	June	July	August
1	107.7	104.5	106.1	85.4	88.6	97.2	86.4
2	106.1	97.2	38.3	106.1	109.4	104.5	101.4
3	86.4			88.6	0.0	39.8	106.1
4				104.5	106.1	106.1	107.7
5							107.7
6							81.4
Average %	100.1	100.8	72.2	96.1	76.0	86.9	98.5
Overall Average %	90.1						

MAB2 has a 90% Efficiency score overall with only one abort in June.

MAB2 – Long CIP Data

MAB2 - Long CIP - Time (minutes)							
	2022						
	February	March	April	May	June	July	August
1	113	146	99	98	97	0	99
2		100					
3							
4							

MAB2 Long CIP was not performed in July, this is very concerning to the quality of the product and the potential impact it could have.

MAB2 - Long CIP - % 105 Minutes							
	2022						
	February	March	April	May	June	July	August
1	92.9	71.9	106.1	107.1	108.2	0.0	106.1
2		105.0					
3							
4							
Average %	92.9	88.5	106.1	107.1	108.2	0.0	106.1
Overall Average %	87.0						

The efficiency overall not including July would have provided a very good Efficiency % but it is critical to quality that CIPs are done on time.

MAB3 – Medium CIP Data

MAB3 - Medium CIP - Time (minutes)							
	2022						
	February	March	April	May	June	July	August
1	106	106	108	110	125	278	179
2	106	106	105	110	202	167	134
3	147	106	106	107	136	139	125
4	181		93	206	105	128	
5			103	231	180	47	
6			105	243		1	
7			114			5	
8			104			111	
9			109			160	

MAB3 had several aborts. The key data to investigate starts from May when the conductivity issues began. The conductivity probe was reading incorrectly and instead of calibrating it again they bypassed it through the HMI and PID Controller to "Manually Input Values". Fortunately, there are two other conductivity probes however the way in which this was dealt with is completely unacceptable.

MAB3 - Medium CIP - % 115 Minutes							
	2022						
	February	March	April	May	June	July	August
1	108.5	108.5	106.5	104.5	92.0	0.0	64.2
2	108.5	108.5	109.5	104.5	0.0	0.0	85.8
3	78.2	108.5	108.5	107.5	0.0	82.7	92.0
4	63.5		0.0	0.0	109.5	89.8	
5			111.7	0.0	63.9	0.0	
6			109.5	47.3		0.0	
7			100.9			0.0	
8			110.6			103.6	
9			105.5			71.9	
Average %	89.7	108.5	92.4	60.6	53.1	24.7	80.7
Overall Average %	72.8						

After the 4th CIP in May until August this issue persisted until it was forcibly made to be calibrated by Quality and process Automation.

MAB3 – Long CIP Data

MAB3 - Long CIP - Time (minutes)							
	2022						
	February	March	April	May	June	July	August
1	230	197	0	0	0	0	228
2		199					246
3		248					3
4		333					1
5							3
6							6
7							65
8							333

The Long CIP was missed in April and then the conductivity issues began in May. No long CIP was carried out until August. This is a critical issue to Quality and unacceptable from the Bottling Department.

MAB3 - Long CIP - % 150 Minutes							
	2022						
	February	March	April	May	June	July	August
1	65.2	76.1	0.0	0.0	0.0	0.0	65.8
2		75.4					61.0
3		60.5					0.0
4		45.0					0.0
5							0.0
6							0.0
7							0.0
8							45.0
Average %	65.2	64.3	0.0	0.0	0.0	0.0	21.5
Overall Average %	21.6						

MAB4 – Medium CIP Data

MAB4 - Medium CIP - Time (minutes)							
	2022						
	February	March	April	May	June	July	August
1	43	229	124	39	86	123	111
2	58	154	120	147	125	115	115
3	155	111	135	97	112	102	123
4	0	140	199	63	16		89
5	138	202		115	164		171
6	110			0	102		0
7	25			115	95		
8	192						
9	0						
10	2						
11	0						
12	0						
13	0						
14	10						
15	5						
16	65						

MAB4 - Medium CIP - % 90 Minutes							
	2022						
	February	March	April	May	June	July	August
1	0.00	39.30	72.58	0.00	104.65	73.17	81.08
2	0.00	58.44	75.00	61.22	72.00	78.26	78.26
3	58.06	81.08	66.67	92.78	80.36	88.24	73.17
4	0.00	64.29	45.23	0.00	0.00		101.12
5	65.22	44.55		78.26	54.88		52.63
6	81.82			0.00	88.24		0.00
7	0.00			78.26	94.74		
8	46.88						
9	0.00						
10	0.00						
11	0.00						
12	0.00						
13	0.00						
14	0.00						
15	0.00						
16	0.00						
Average %	15.7	57.5	64.9	44.4	70.7	79.9	64.4
Overall Average %	56.8						

MAB4 CIP was started and aborted numerous times in February. Fortunately, many of these would not have been able to commence any sequences however it is concerning that it has been started and prematurely aborted by the operator. A severe lack of understanding of the process is seen here and a lack of proper training. That aside there was some software issues alongside this. However, the software issues were related to the blowdown at the end of the CIP where the system is finally pushed with gas to ensure all liquids have been removed from the

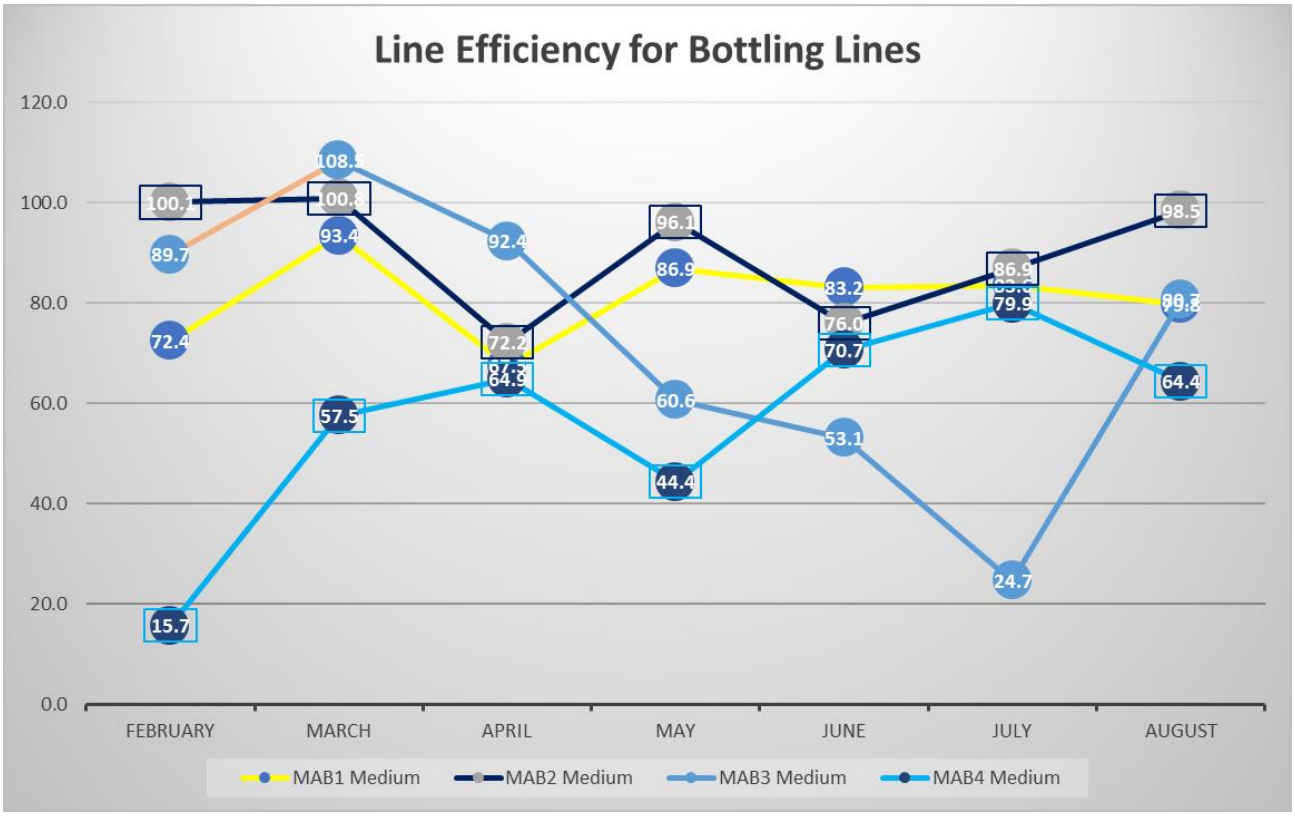
MAB4 – Long CIP Data

MAB4 - Long CIP - Time (minutes)							
	2022						
	February	March	April	May	June	July	August
1	340	221	0	212	326	164	153
2						373	

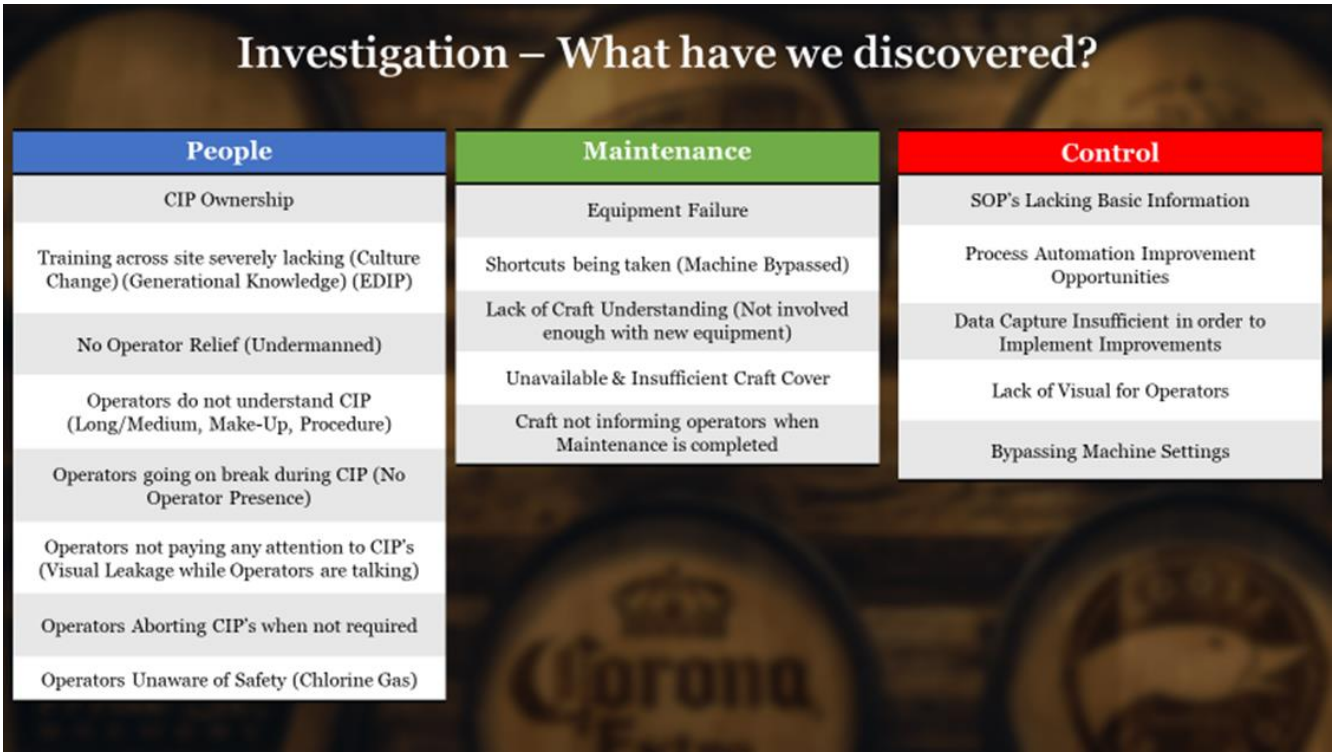
MAB4 - Long CIP - % 155 Minutes							
	2022						
	February	March	April	May	June	July	August
1	45.6	70.1	0.0	73.1	47.5	94.5	101.3
2						41.6	
Average %	45.6	70.1	0.0	73.1	47.5	68.0	101.3
Overall Average %	58.0						

MAB4 Data again not proving very good for the Long CIP with an average efficiency of 58%. If that equated to 32% of the product going to waste the problem would be all the way up the ladder. Unfortunately, CIPs are a largely misunderstood process between managers and operators thus resulting in a lack of care and attention.

Graph 1 – Graph Depicting CIP Line Efficiency per month for Four Bottling Lines



V) Qualitative Data



Understanding and knowledge among Operators/Crafts. We've observed significant deficiencies in the knowledge of operators and, in some cases, crafts as well. For instance, issues like the Conductivity Probe have surfaced due to the lack of pre-checks and necessary communications before commencement (e.g., between Canning and Filtration, Bottling not preparing tanks, Canning skipping pre-checks).

Operator Training – There seems to be confusion among operators about their tasks during CIPs. When asked about the procedures, many are unable to respond accurately. Some don't know where the SOPs are located. If uncertain, it's questionable whether they would refer to the SOPs or incorrectly attempt to resolve issues on their own.

Operational Relief – In my qualitative research, it became apparent that operators view CIP periods as break opportunities. Without secondary coverage, a CIP could fail shortly after an operator takes a break, potentially delaying the restart by up to an hour. This can prolong CIP durations from the typical 1 hour and 20 minutes to over 3 hours, as errors must be addressed.

SOPs Incomplete – We have discovered that the SOPs are often incomplete and lack necessary details. Notably, the SOPs for MAB3 and MAB4 are nearly identical despite differences in their operations.

Lack of Data Capture – When a CIP fails, there is often no thorough data capture of the incident. At times, brief notes might be recorded in the shift handover log, but there's usually no formal documentation where operators can provide detailed accounts of the failures.

VI) FMEA

Process Step	Potential Failure Mode	Potential Effects of Failure	Severity (1-10)	Potential Cause(s)	Occurrence (1-10)	Current Controls	Detection (1-10)	RPN (Severity x Occurrence x Detection)	Recommended Actions	Responsibility	Target Completion Date	Verification
CIP Process	Inconsistent CIP procedures	Inconsistent cleaning results, cross-contamination, and product quality issues	7	Inconsistent cleaning procedures, lack of training	5	Standardized cleaning procedures and training	6	210	Conduct regular training with operators after errors (Shop Floor Discussions and Education)	Quality Assurance Manager	Q4 2022	Verify consistent cleaning results and improved product quality
CIP Process	Inadequate temperature control during cleaning	Inadequate cleaning, decreased product quality	9	Inadequate temperature control, equipment malfunction	4	Regular inspection of temperature control equipment	8	288	Implement automated temperature monitoring and control system, maintain spare parts inventory	Process Automation Engineer	Q4 2022	Verify adequate temperature control during cleaning and improved product quality
CIP Process	Equipment malfunction during CIP	Incomplete cleaning of equipment, increased downtime	8	Equipment malfunction, inadequate maintenance	4	Regular maintenance and inspection of CIP equipment	8	256	Create a CIP Action Log which Operators can fill out when the CIP has failed. The Operator is the first person to report a problem when it happens.	Maintenance Technician	Q3 2022	Verify reduced equipment downtime and improved CIP efficiency
CIP Process	Inadequate cleaning of equipment	Residual product buildup, cross-contamination, and product quality issues	8	Inadequate cleaning solution concentration, insufficient time, or incorrect sequencing of CIP steps	6	Manual visual inspections	5	240	Implement automated CIP system	Production Engineer	Q3 2022	Verify successful cleaning by swabbing equipment and conducting lab tests
CIP Process	Improperly maintained equipment	Equipment breakdowns and excessive downtime	9	Poor equipment maintenance, lack of preventative maintenance	4	Regular equipment inspections, periodic maintenance	7	252	Develop and implement a preventative maintenance program	Production Engineer	Q3 2022	Verify improved equipment uptime and reduced breakdowns
CIP Process	Inadequate conductivity control during cleaning	CIP Step sequence held, unable to progress	9	Inadequate conductivity control, equipment malfunction	2	Regular inspection of conductivity control equipment	9	162	Implement automated conductivity monitoring and control system, maintain spare parts inventory	Process Automation Engineer	Q3 2022	Verify adequate conductivity control during cleaning and improved product quality
CIP Process	Inefficient cleaning cycle time	Incomplete cleaning of equipment, increased downtime	7	Inadequate cleaning solution, incorrect cleaning process	5	Regular inspection of cleaning process, visual inspection of equipment after cleaning	8	280	Optimize cleaning cycle time based on equipment size and complexity, implement automated monitoring system for cleaning process	Process Automation Engineer	Q3 2022	Verify reduced downtime and improved equipment cleanliness
SOP Development	Inadequate SOP development process	Inconsistent or unclear work instructions, lack of compliance with regulatory requirements	7	Lack of documentation standards, lack of involvement from key stakeholders, inadequate review process	3	Document control procedures, periodic reviews of SOPs	9	189	Develop a standardized SOP development process, involve key stakeholders in the review process, implement training on SOP development and compliance	Benjamin James	Q1 2023	Verify compliance with regulatory requirements and improved consistency of work instructions
Training	Inadequate training program	Lack of skills and knowledge among employees, decreased efficiency and productivity, increased risk of errors	8	Insufficient training resources, lack of formal training programs, lack of follow-up training	4	On-the-job training, occasional formal training sessions	7	224	Develop and implement a comprehensive training program, including formal training and on-the-job training, conduct regular follow-up training	Benjamin James & Julie Leonard	Q1 2023	Verify increased employee skills and knowledge, improved efficiency and productivity, and reduced errors

8.3 ANALYSE

The Analyse phase involves a detailed examination of the collected data to identify root causes of inefficiencies and opportunities for improvement.

I) Process Analysis Methods

There are five primary methods for analysing a Six Sigma Green Belt Project. The objective is to scrutinize the data to pinpoint the fundamental causes of issues or inefficiencies in a process. Analytical techniques in the process are employed to highlight areas for enhancement and uncover potential opportunities for improvement. Below are five approaches to data analysis:

Value Stream Mapping (VSM): This tool is utilized to map out the steps and activities in a process, distinguishing between those that add value and those that do not. By assessing existing procedures, the project team can detect inefficiencies that may lead to mistakes or delays and identify any bottlenecks that decrease production speed.

Root Cause Analysis (RCA): RCA is a strategy to find the deep-seated reasons for inefficiencies and flaws within a process. Tools like Ishikawa Diagrams and the 5 Whys technique aid in uncovering the primary cause of a problem and devising solutions to tackle these issues.

Process Flowcharting: This involves creating a visual diagram of a process or workflow. It outlines the sequence of actions and steps in a process, using standardized symbols to represent various activities, decision points, inputs, outputs, and the movement of materials or information between steps as depicted in the work by Karan, V., Khan, Z., and Sharifi, M. (2003).

Lean Manufacturing: This approach includes methods like Value Stream Analysis (VSA) and 5S to pinpoint improvement areas and minimize waste. Through VSA, the team can evaluate both the value-adding and non-value-adding activities in a process and formulate strategies to eliminate waste. Additionally, 5S can help enhance the organization and tidiness of a workspace, thus reducing unnecessary time and motion.

Six Sigma: Techniques such as hypothesis testing, and regression analysis are leveraged to determine the elements contributing to process variation and defects. The team can then rank these elements based on their impact and develop solutions to mitigate or remove them, Bhote, K. R. (2002).

II) Review Analysis Methods

Root Cause Analysis (RCA) is a systematic technique used to pinpoint the primary reasons for issues and defects within a process, aiming to develop corrective strategies. This method utilizes analytical tools such as Fishbone diagrams, 5 Whys, and Fault Tree Analysis to examine process breakdowns and ascertain the origin of defects or issues. Conversely, Lean Manufacturing embodies a philosophy focused on waste reduction within processes by discerning and enhancing value-adding activities while eliminating those that do not add value. Techniques employed in Lean Manufacturing include Value Stream Mapping (VSM), 5S, and Kaizen events, all of which are designed to boost process effectiveness and decrease operation times.

Six Sigma represents a disciplined, data-driven approach aimed at enhancing process quality by minimizing defects. It employs the DMAIC (Define, Measure, Analyse, Improve, Control) framework alongside statistical methods like hypothesis testing and regression analysis to diminish process variation and augment performance. Visual tools such as Process Flowcharting and Value Stream Mapping (VSM) are crucial for illustrating and scrutinizing processes. Process Flowcharting provides a graphical depiction of the procedural steps and the movement of materials or information therein, whereas VSM focuses on analysing the value stream to identify both value-adding and non-value-adding steps, helping to pinpoint improvement opportunities.

Within the framework of the CIP Project, Root Cause Analysis (RCA) and Six Sigma are particularly pertinent tools due to their broad applicability to various processes and the specific objectives of the project. Although Lean Manufacturing principles, along with Process Flowcharting and Value Stream Mapping, are beneficial, RCA and Six Sigma offer a more targeted approach towards identifying fundamental causes of issues and enhancing process reliability and efficiency.

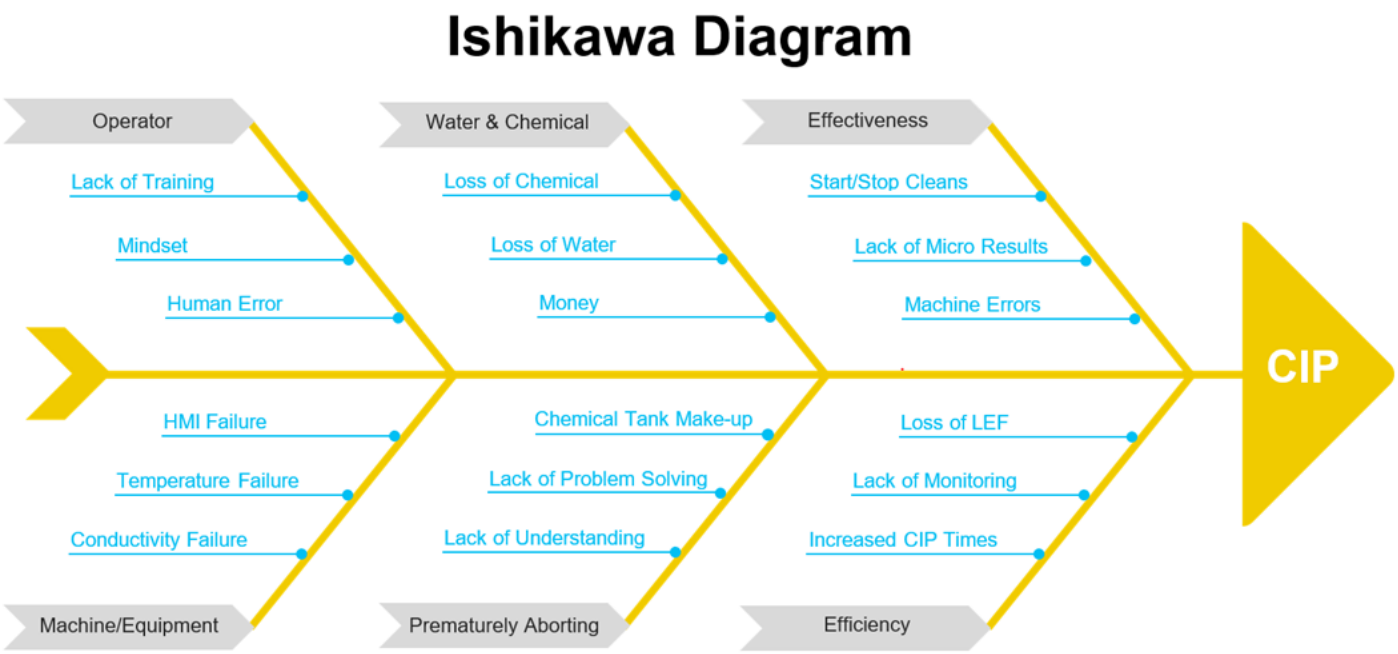
III) Graphical Analysis Tools

Six Sigma DMAIC:

Some of the many tools used in Six Sigma are represented in this report.

Root Cause Analysis:

The Ishikawa Diagram found below is to help with brainstorming and identifies potential Cause and Effects of the process as a whole:



5 Why – Personal Use 1

A 5 Why was conducted after an error had occurred, a Corrective Action plan was summarised at the end to provide steps going forward. The main points in which we want to take out of this information are the incorrect and insufficient of training, SOP procedure outdated and unsuitable for use. From this 5 Why a Qualitative data research was done and found my operators had not actually read SOP's and were in fact relying on word of mouth and personal notes to run the machines, Gangidi, P. (2018).

5 WHYs ROOT CAUSE ANALYSIS

DEFINE THE PROBLEM

Long CIP aborted by Operator

WHY IS THIS A PROBLEM?

PRIMARY CAUSE

Why is it happening?

1 Long CIP Aborted

Why is that?

2 CIP did not reach conductivity

Why is that?

3 Acid was not reaching conductivity

Why is that?

4 Operator did not start Make-Up Procedure for Acid Tank - No supply to Filler

Why is that?

ROOT CAUSE

5 Operator has been here for 8 weeks, has only been shown the CIP procedure once by word of mouth. Was not provided an SOP. Review of SOP shows SOP is incorrect and severely outdated.

NOTE: If the final "Why" has no controllable solution, return to the previous "Why."

CORRECTIVE ACTION TO TAKE

CORRECTIVE ACTION

Discussed with Operator what had happened and what he had done incorrectly, Explained what he should have done with Julie Leonard to make operator aware of the correct procedure. Training documents not easily accessible so plan to be created to make it more accessible, SOP out of date and incorrect so SOP to be reviewed, updated and corrected. Create a plan for classroom CIP training for all Filler Operators and 1-1 Training based on the classroom results.

PARTY RESPONSIBLE

Benjamin James, Julie Leonard

DATE ACTION TO BEGIN

Q3 2022

DATE TO COMPLETE

Q2 2023

5 Why – Personal Use 2

5 WHYs ROOT CAUSE ANALYSIS

DEFINE THE PROBLEM

Medium CIP Aborted by Operator

WHY IS THIS A PROBLEM?

PRIMARY CAUSE

Why is it happening?

1 CIP Aborted due to temperature not reaching set point

Why is that?

2 The Control valve is only opening 16%

Why is that?

3 Control valve failed, Shift Brewing Craft informed to fix

Why is that?

4 Brewing Craft informed that airline had become brittle and snapped

Why is that? **ROOT CAUSE**

5 Airline pipe snapped due to UV Light, Airline swapped for UV resistant pipe.

NOTE: If the final "Why" has no controllable solution, return to the previous "Why."

CORRECTIVE ACTION TO TAKE

CORRECTIVE ACTION

Carry out CIP straight after due to aborted CIP. During next CIP ensure valve is controlling as specified. Brewing Craft to perform additional checks in area to ensure UV Light was not affecting other airline pipework.

PARTY RESPONSIBLE: Brewing Maintenance Team

DATE ACTION TO BEGIN: Q3 2022

DATE TO COMPLETE: Q3 2022

A 5 Why analysis was conducted following an error, and a corrective action plan was developed to identify steps for moving forward. The main takeaway from this analysis is that the Brewing Maintenance Manager and their team need to increase their inspections of valves in the area to ensure that the plant is not being restricted by any other potential faults, as the UV rays may cause the plastic airline pipe to become brittle and break.

8.4 IMPROVE

The Improve phase focuses on developing and implementing solutions to address the root causes identified in the Analyse phase.

I) Generate Improvements

1. **Training** – Classroom instruction will be complemented with practical training and virtual reality simulations to ensure operators stay current with the latest information. After classroom sessions, operators will take an immediate test, and additional one-on-one training will be offered based on their individual scores.

2. **SOPs** – Each Standard Operating Procedure (SOP) will be customized to the specific production line it pertains to, with all CIP logs included as official documentation. Operators will be held accountable if they fail to complete the CIP log during an error. After the SOPs are updated, operators must read and sign them.

3. **Acadia** – A quick link to the Acadia training platform will be added to all computers, and the platform will be enhanced for better user experience. Furthermore, training sessions on how to navigate the platform will be conducted, and a mobile app version will be developed.

4. **Equipment Monitoring** – Predictive maintenance strategies will be employed to monitor equipment malfunctions. Data from CIP logs will be used to track equipment issues, and if a pattern is identified, the matter will be investigated to enhance plant efficiency.

5. **Qualitative Data** – Alongside existing methods of qualitative data collection, surveys and customer feedback will be utilized to gather insights for improving product quality and customer satisfaction.

II) Generate Improvement Alternatives

Currently, the timing of Clean-in-Place (CIP) procedures is inconsistent across the bottling department. Although each production line has a designated maintenance day every week, CIP procedures are still performed at varying times, making it challenging to monitor and support the process. To address this issue, we propose introducing an 8-hour Maintenance and Training Event (MTE) Day during which all CIP procedures should be completed. A sign-off sheet should be used every 10 minutes during the CIP to document progress and assist operators in learning the process.

The benefits of conducting CIP procedures during MTE Days are numerous. We will have access to process automation, CIP experts, and additional management support to ensure the CIP is performed correctly. This change is straightforward and will not impact the production line's performance, as maintenance can still be performed simultaneously. There are no significant risks associated with this change, as it merely allows for more comprehensive monitoring and support during the CIP.

However, the bottling department may have its own schedule and might not agree with conducting CIP procedures at a specific time. To address this, we need to communicate the benefits of this change to the department and secure their support. Ultimately, performing CIP procedures during MTE Days will lead to a more consistent and efficient process, benefiting everyone involved.

III) Improve FMEA Phase

Process Step	Potential Failure Mode	Potential Effects of Failure	Severity (1-10)	Potential Cause(s)	Occurrence (1-10)	Current Controls	Detection (1-10)	RPN (Severity x Occurrence x Detection)	Recommended Actions	Responsibility	Target Completion Date	Verification	Status	Notes
Training	Operator Errors	Prematurely aborted CIP's, Loss of Time, Water and Chemical	8	Lack of training and structure	4	CIP Classroom and Plant training. One-to-One training with Operators based on Test Results	9	288	Continue Training Operators and covering all shifts and operators capable of running the Filler	Benjamin James, Julie leonard	Q2 2023	Test Results showed a large number of individuals require training and help. One-to-One training will increase/decrease based on operator performance	In Progress	Awaiting approval to cover remaining operators on B Shift
SOP Development	Following wrong information	Doing process steps incorrectly and causing uneccesary issues	8	Inadequate SOP's created by management, lack of data carry over from old documentation	6	Update to CIP's for all Bottling Fillers	7	336	Conduct recurring checks on SOP's to ensure they are maintained and up to standard	Benjamin James	Q1 2023	Continuous checks with operators through updating to verify operators are happy it meets their needs and covers all aspects of information	Complete	SOP's up to date and Operators happy with the quality and detail of them
CIP Times	Inconsistent CIP Times	Efficiency Loss, Loss of production time	4	Operators not monitoring CIP's	3	Asking other operator to monitor CIP if break is required	4	48	Talk with Management regarding issue, ensure CIP's are being monitored by Operators, have talks with operators to ensure they find cover.	Benjamin James	Q1 2023	Ensure all FLM's are aware of the situation and verify with them that it is no longer happening	Complete	Internal issue of not being monitored, only seen with a few individuals which has now been resolved
CIP Process	Equipment malfunction during CIP	CIP goes into Hold and will potentially time out if the breakdown takes too long to fix	8	Preventative maintenance failure, equipment errors	4	Inform FLM of issue immediately to inform Shift Craft	8	256	Ensure a rapid response time by craft to identify the issue in order to prevent excessive time loss.	Maintenance Technician	Q1 2023	Verify reduced equipment downtime and improved CIP efficiency	Complete	CIP Efficiency has overall improved across all lines with only one exception.
Acadia Access	Acadia Training platform accesibility issues	Operators not using SOP's due to not being able to find them	9	Lack of implementation of Acadia and use by management to encourage operators	8	None	10	720	Create Acadia Quick Link with easy to navigate manual. Ensure it can cover the site as opposed to just one area.	Benjamin James, Training Team	Q1 2023	Verify Acadia App is on all computers and is working for operators, prepare introduction to management to control the process within each department.	On Hold	Project Prioritisations within the Brewery has required this to go on hold for the time being. Acadia App is accessible to all operators but not officially rolled out
CIP Process	Inconsistent CIP procedures	Inconsistent cleaning results, cross-contamination, and product quality issues	7	Inconsistent cleaning procedures, lack of training	5	Standardized cleaning procedures and training	6	210	Conduct regular training with operators after errors (Shop Floor Discussions and Education)	Quality Assurance Manager	Q4 2022	Verify consistent cleaning results and improved product quality	Complete	Quality of product has since improved indicating consistency of cleans
CIP Process	Inadequate temperature control during cleaning	Inadequate cleaning, decreased product quality	9	Inadequate temperature control, equipment malfunction	4	Regular inspection of temperature control equipment	8	288	Implement automated temperature monitoring and control system, maintain spare parts inventory	Process Automation Engineer	Q4 2022	Verify adequate temperature control during cleaning and improved product quality	Complete	Valve issue now resolved, unidentified leak found to be the cause
CIP Process	Equipment malfunction during CIP	Incomplete cleaning of equipment, increased downtime	8	Equipment malfunction, inadequate maintenance	4	Regular maintenance and inspection of CIP equipment	8	256	Create a CIP Action Log which Operators can fill out when the CIP has failed. The Operator is the first person to report a problem when it happens.	Maintenance Technician	Q3 2022	Verify reduced equipment downtime and improved CIP efficiency	Complete	CIP Action Log created and in use on Operator Workstations for Operators to write down issues on CIP's to help identify causes of specific equipment downtime
CIP Process	Inadequate cleaning of equipment	Residual product buildup, cross-contamination, and product quality issues	8	Inadequate cleaning solution concentration, insufficient time, or incorrect sequencing of CIP steps	6	Manual visual inspections	5	240	Implement automated CIP system	Production Engineer	Q3 2022	Verify successful cleaning by swabbing equipment and conducting lab tests	On Hold	Lab Team unable to cover more areas due to Camden Commisioning and on-going Micro Trials causing need for more Micro Samplers
CIP Process	Improperly maintained equipment	Equipment breakdowns and excessive downtime	9	Poor equipment maintenance, lack of preventative maintenance	4	Regular equipment inspections, periodic maintenance	7	252	Develop and implement a preventative maintenance program	Production Engineer	Q3 2022	Verify improved equipment uptime and reduced breakdowns	Complete	Maintenance schedule reviewed and focus areas created by Brewing Department
CIP Process	Inadequate conductivity control during cleaning	CIP Step sequence held, unable to progress	9	Inadequate conductivity control, equipment malfunction	2	Regular inspection of conductivity control equipment	9	162	Implement automated conductivity monitoring and control system, maintain spare parts inventory	Process Automation Engineer	Q3 2022	Verify adequate conductivity control during cleaning and improved product quality	Complete	Conductivity probe calibrated correctly and working
CIP Process	Inefficient cleaning cycle time	Incomplete cleaning of equipment, increased downtime	7	Inadequate cleaning solution, incorrect cleaning process	5	Regular inspection of cleaning process, visual inspection of equipment after cleaning	8	280	Optimize cleaning cycle time based on equipment size and complexity, implement automated monitoring system for cleaning process	Process Automation Engineer	Q3 2022	Verify reduced downtime and improved equipment cleanliness	Complete	Timers adjusted based on Ecolab findings and recommendations

IV) Pilot Proposals

From the FMEA shown on the previous page, several actions have been completed as part of process improvements. Due to the extensive changes and enhancements made, one specific improvement will be highlighted. Training will be the example provided.

For the training, we conducted a classroom session with operators, beginning with an initial test to assess their current knowledge. The test was then graded, and the scores were used to identify operators who would benefit from more advanced one-on-one sessions.

A picture was taken during the classroom training session for B-Shift, which had only three operators available. However, the D-Shift session had an attendance of 13 people.

After completing the test, the papers were returned to the operators, and we reviewed the answers together. Instead of providing the answers directly, I encouraged the operators to shout out their responses. If they were incorrect, I would correct them and explain the correct answer. Following this review, the one-on-one follow-up sessions were explained to the operators.

Subsequently, Julie Leonard, our CIP expert, led the operators on a tour of the plant. She showed them where our chemicals and CIP sets are located, as well as the origins of the beer. This training is crucial for the operators, as it is essential for them to understand the processes and supplies involved.

V) Validate Improvements

The following Data is taken from the time after the project started and is as follows:

MAB1 – Medium CIP Data

MAB1 - Medium CIP - Time (minutes)

	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	85	88	129	0	81	14	170	81	80	84	83	84	73
2	81	80	81	81	84	82	81	80	81	81	83	81	73
3	0	81	82	80	0	82	81	85	81	80	155	93	74
4	83	80	97	82	84	81	157	97	82	83	83		74
5	84	81	79	83	81	140	33	80	10				72
6	87	90	79	81	85	92	81		77				72
7	85	117	80	85	80	80	81		79				69
8	110	84	81	81		80	80		17				160
9	247	80	156	82		114	81						71
10	99		13			97	81						
11			21			82	154						
12						80	83						
13						81	81						

MAB1 - Medium CIP - % 80 Minutes

	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	94.1	90.9	62.0	0.0	98.8	0.0	47.1	98.8	100.0	95.2	96.4	95.2	109.6
2	98.8	100.0	98.8	98.8	95.2	97.6	98.8	100.0	98.8	98.8	96.4	98.8	109.6
3	0.0	98.8	97.6	100.0	0.0	97.6	98.8	94.1	98.8	100.0	51.6	86.0	108.1
4	96.4	100.0	82.5	97.6	95.2	98.8	51.0	82.5	97.6	96.4	96.4		108.1
5	95.2	98.8	101.3	96.4	98.8	57.1	0.0	100.0	0.0				111.1
6	92.0	88.9	101.3	98.8	94.1	87.0	98.8		103.9				111.1
7	94.1	68.4	100.0	94.1	100.0	100.0	98.8		101.3				115.9
8	72.7	95.2	98.8	98.8		100.0	100.0		0.0				50.0
9	0.0	100.0	0.0	97.6		70.2	98.8						112.7
10	80.8		0.0			82.5	98.8						
11			0.0			97.6	51.9						
12						100.0	96.4						
13						98.8	98.8						
Average %	72.4	93.4	67.5	86.9	83.2	78.7	76.6	95.1	75.0	97.6	85.2	93.3	104.0
Pre-August	79.8												
Post-August	89.6												
Percentage Increase	9.7												

MAB1 Medium CIP received a 9.7% Efficiency Increase.

MAB1 – Long CIP Data

MAB1 - Long CIP - Time (minutes)													
	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	128	135	124	159	124	146	155	251	194	116	162	154	0.00
2								161	9		119	182	
3									127				
4													

MAB1 - Long CIP - % 115 Minutes													
	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	89.8	85.2	92.7	72.3	92.7	78.8	74.2	45.8	59.3	99.1	71.0	74.7	0.0
2								71.4	0.0		96.6	63.2	
3									0.0				
4													
Average %	89.8	85.2	92.7	72.3	92.7	78.8	74.2	58.6	19.8	99.1	83.8	68.9	0.0
Pre-August	83.7												
Post-August	57.8												
Percentage Increase	-25.9												

Unfortunately, we saw a decrease in our efficiency for MAB1 Long CIP, resulting in a Decrease in Efficiency by 25.9%. This is due to there being a low amount of data to select from and the removal of the Sterile Filter Skids for Camden Beer causing issues. Additionally, there was no Long CIP performed in February due to a shutdown.

MAB2 – Medium CIP Data

MAB2 - Medium CIP - Time (minutes)													
	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	65	67	66	82	79	72	81	70	65	66	67	67	67
2	66	72	183	66	64	67	69	65	72	69	67	67	7
3	81			79	32	176	66	67	65	125	67	67	103
4				67	66	66	65	65	85	69		37	67
5							65					2	66
6							86					42	65
7													71.00

MAB2 - Medium CIP - % 70 Minutes													
	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	107.7	104.5	106.1	85.4	88.6	97.2	86.4	100.0	107.7	106.1	104.5	104.5	104.5
2	106.1	97.2	38.3	106.1	109.4	104.5	101.4	107.7	97.2	101.4	104.5	104.5	0.0
3	86.4			88.6	0.0	39.8	106.1	104.5	107.7	56.0	104.5	104.5	68.0
4				104.5	106.1	106.1	107.7	107.7	82.4	101.4		189.2	104.5
5							107.7					0.0	106.1
6							81.4					0.0	107.7
7													98.6
Average %	100.1	100.8	72.2	96.1	76.0	86.9	98.5	105.0	98.7	91.2	104.5	83.8	84.2
Pre-August	90.1												
Post-August	95.1												
Percentage Increase	5.0												

For MAB2 we gained a 5% Efficiency Increase.

MAB2 – Long CIP Data

MAB2 - Long CIP - Time (minutes)													
	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	113	146	99	98	97	0	99	98	97	116	137	119	108
2		100							65		126	108	

MAB2 - Long CIP - % 105 Minutes													
	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	92.9	71.9	106.1	107.1	108.2	0.0	106.1	107.1	108.2	90.5	76.6	88.2	97.2
2		105.0							0.0		83.3	97.2	
Average %	92.9	88.5	106.1	107.1	108.2	0.0	106.1	107.1	54.1	90.5	80.0	92.7	97.2
Pre-August	87.0												
Post-August	89.7												
Percentage Increase	2.7												

MAB2 Long received a 2.7% Efficiency Increase.

MAB3 – Medium CIP Data

MAB3 - Medium CIP - Time (minutes)													
	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	106	106	108	110	125	278	179	185	148	171	131	111	116
2	106	106	105	110	202	167	134	115	117	333	169	139	
3	147	106	106	107	136	139	125	190	101	244	106	156	
4	181		93	206	105	128		145	106	259	164	157	
5			103	231	180	47			112	166		110	
6			105	243		1						112	
7			114			5							
8			104			111							
9			109			160							

MAB3 - Medium CIP - % 115 Minutes													
	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	108.5	108.5	106.5	104.5	92.0	0.0	64.2	62.2	0.0	67.3	87.8	103.6	99.1
2	108.5	108.5	109.5	104.5	0.0	0.0	85.8	100.0	0.0	0.0	68.0	82.7	
3	78.2	108.5	108.5	107.5	0.0	82.7	92.0	60.5	113.9	47.1	108.5	73.7	
4	63.5		0.0	0.0	109.5	89.8		79.3	108.5	44.4	70.1	73.2	
5			111.7	0.0	63.9	0.0			102.7	69.3		104.5	
6			109.5	47.3		0.0						102.7	
7			100.9			0.0							
8			110.6			103.6							
9			105.5			71.9							
Average %	89.7	108.5	92.4	60.6	53.1	24.7	80.7	75.5	65.0	45.6	83.6	90.1	99.1
Pre-August	72.8												
Post-August	77.1												
Percentage Increase	4.3												

MAB3 Medium CIP received a 4.3% Efficiency Increase.

MAB3 – Long CIP Data

MAB3 - Long CIP - Time (minutes)

	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	230	197	0	0	0	0	228	205	0	189	202	0	211
2		199					246						
3		248					3						
4		333					1						
5							3						
6							6						
7							65						
8							333						

MAB3 - Long CIP - % 150 Minutes

	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	65.2	76.1	0.0	0.0	0.0	0.0	65.8	73.2	0.0	79.4	74.3	0.0	71.1
2		75.4					61.0						
3		60.5					0.0						
4		45.0					0.0						
5							0.0						
6							0.0						
7							0.0						
8							45.0						
Average %	65.2	64.3	0.0	0.0	0.0	0.0	21.5	73.2	0.0	79.4	74.3	0.0	71.1
Pre-August	21.6												
Post-August	45.6												
Percentage Increase	24.1												

MAB3 Long CIP received a 24.1% Efficiency Increase.

MAB4 – Medium CIP Data

MAB4 - Medium CIP - Time (minutes)

	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	43	229	124	39	86	123	111	110	110	134	168	94	99
2	58	154	120	147	125	115	115	137	8	92	101	107	104
3	155	111	135	97	112	102	123	93	0	94	128	151	
4	0	140	199	63	16		89	9	100	23	92	129	
5	138	202		115	164		171	126	0	410	63		
6	110			0	102		0	196	93	0			
7	25			115	95				218	102			
8	192								301	152			
9	0								126				
10	2												
11	0												
12	0												
13	0												
14	10												
15	5												
16	65												

MAB4 - Medium CIP - % 90 Minutes

	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	0.00	39.30	72.58	0.00	104.65	73.17	81.08	81.82	81.82	67.16	53.57	95.74	90.91
2	0.00	58.44	75.00	61.22	72.00	78.26	78.26	65.69	0.00	97.83	89.11	84.11	86.54
3	58.06	81.08	66.67	92.78	80.36	88.24	73.17	96.77	0.00	95.74	70.31	59.60	
4	0.00	64.29	45.23	0.00	0.00		101.12	0.00	90.00	0.00	97.83	69.77	
5	65.22	44.55		78.26	54.88		52.63	71.43	0.00	21.95	0.00		
6	81.82			0.00	88.24		0.00	45.92	96.77	0.00			
7	0.00			78.26	94.74				41.28	88.24			
8	46.88								29.90	59.21			
9	0.00								71.43				
10	0.00												
11	0.00												
12	0.00												
13	0.00												
14	0.00												
15	0.00												
16	0.00												
Average %	15.7	57.5	64.9	44.4	70.7	79.9	64.4	60.3	45.7	53.8	62.2	77.3	88.7
Pre-August	56.8												
Post-August	64.6												
Percentage Increase	7.8												

MAB4 Medium CIP received a 7.8% Efficiency Increase.

MAB4 – Long CIP Data

MAB4 - Long CIP - Time (minutes)

	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	340	221	0	212	326	164	153	194	155	148	151	166	244
2						373						251	

MAB4 - Long CIP - % 155 Minutes

	2022											2023	
	February	March	April	May	June	July	August	September	October	November	December	January	February
1	45.6	70.1	0.0	73.1	47.5	94.5	101.3	79.9	100.0	104.7	102.6	93.4	63.5
2						41.6						61.8	
Average %	45.6	70.1	0.0	73.1	47.5	68.0	101.3	79.9	100.0	104.7	102.6	77.6	63.5
Pre-August	58.0												
Post-August	90.0												
Percentage Increase	32.0												

MAB4 Long CIP received a 32% Efficiency Increase.

VI) Cost/Benefit Analysis

Sometimes the cost is high and the benefit low so not worth the cost.

Here is the Requirements for our current CIP's and what is required to make up a Vessel for both Caustic and Acid:

Chemicals	Unit Cost (L)	Concentration	Vessel Size (L)	Required Chemical Dilution	Caustic Required (L)	Acid Required (L)
Caustic - MIP C	£1.42	40%	8000	2.20%	440	
Acid - Trimeta CD	£1.86	24%	4000	0.50%		83.33

The cost of our water types used in the process:

Liquors	Unit Cost (L)
CAL	£0.00077
Hot Liquor	£0.00314
Cold Liquor	£0.00060

The costings of making up a Caustic Tank:

Caustic Use		
Hot Liquor Cost	Caustic Cost	Total
£25.12	£624.80	£649.92

The costings of making up an Acid Tank:

Acid Use		
Cold Liquor Cost	Acid Cost	Total
£2.40	£154.99	£157.39

The cost to run a Medium CIP is £649.92 in water and chemicals while a Long CIP will use both resulting in a cost of £807.31.

Pre-August Data

There were 38 prematurely aborted CIPs in the 7 months shown in the data for Medium CIP's resulting in an estimated loss £24,696.96. While for a Long CIP an estimated loss of £8,880.41 during the 7 Months with 11 prematurely aborted CIP's.

That's a total of £33,577.37 quite literally thrown down the drain.

Post-August Data

There were 17 prematurely aborted CIPs in the 7 months shown in the data for Medium CIP's resulting in an estimated loss £11,048.64. While for a Long CIP an estimated loss of £9,687.72during the 7 Months with 12 prematurely aborted CIP's.

That's a total of £20,736.36 loss. This is an improvement seen essentially pre-training and thus resulted in a potential saving of £12,841.01.

Benefits

1. **Reduction in Prematurely Aborted CIPs:**
   - **Savings:**
     - Medium CIP: Reduction of 21 instances, saving £13,648.32 (£24,696.96 - £11,048.64)
     - Long CIP: Increase of 1 instance, adding £807.31 (£9,687.72 - £8,880.41)
     - Net Savings: £12,841.01 (£33,577.37 - £20,736.36)

2. **Improved Efficiency:**
   - **Time Savings:**
     - Medium CIP efficiency increased by 9.7% for MAB1, 5% for MAB2, 4.3% for MAB3, and 7.8% for MAB4.
     - Long CIP efficiency increased by 24.1% for MAB3 and 32% for MAB4.

   - **Operational Cost Reduction:**
     - Reduced cycle times lead to lower labour costs and decreased machine downtime, though specific figures need to be calculated based on operational data.

3. **Enhanced Product Quality:**
   - Consistent CIP processes result in fewer quality issues and potential product recalls, contributing to cost savings in quality control and customer satisfaction.

4. **Environmental Benefits:**
   - Reduced chemical waste and water usage contribute to lower environmental compliance costs and support the company's sustainability goals.

Summary

The improvements in the CIP process have resulted in significant cost savings and operational benefits. The net savings from reducing prematurely aborted CIPs alone amount to £12,841.01. Additionally, enhanced efficiency and product quality provide further financial and operational benefits, though exact figures for these are context-dependent and would require detailed operational data to quantify precisely.

Overall, the cost/benefit analysis demonstrates that the investments made in improving the CIP process have led to substantial financial savings and operational enhancements, justifying the costs involved and supporting the case for continued focus on process optimization.

8.5 CONTROL

The final phase ensures that the improvements are maintained over time and that the CIP process continues to operate efficiently.

I) Implement Control Systems

1. **Continuous Monitoring:**

   - **Weekly Data Collection:** Collect data on CIP performance weekly. This includes cycle times, efficiency rates, and any instances of premature termination or failure. The data will be recorded in the PAWeb feedback and data website.

2. **Bottling SPOCs (Single Points of Contact):**

   - **Morning Bottling Meetings:** Bottling SPOCs will attend the daily morning bottling meetings to discuss the previous day's CIP performance. These meetings will identify any issues that occurred during the CIP process.

   - **Quality Morning Meetings:** Following the bottling meetings, Bottling SPOCs will attend the Quality morning meetings where Julie can further investigate any issues identified. This ensures a continuous feedback loop and immediate action on quality concerns.

3. **Julie's Role:**
   - **PAWeb Monitoring:** Julie will continuously monitor the PAWeb feedback and data website. This will allow for real-time tracking of CIP performance metrics and immediate identification of deviations.

   - **Efficiency Calculator:** Utilize the efficiency calculator to analyse CIP cycle times. This tool will help determine if the CIPs are taking longer than expected and identify underlying causes for any inefficiencies.

4. **Standard Operating Procedures (SOPs) and Training:**

   - **Updated SOPs:** Ensure that all Standard Operating Procedures (SOPs) are updated to reflect the new improvements. This includes detailed steps for each part of the CIP process, troubleshooting guides, and best practices.

- **Operator Training:** Conduct regular training sessions for operators to ensure they are familiar with the updated SOPs and the importance of adhering to them. Continuous education and training will help maintain high standards of operation.

5. Control Charts and Process Control Tools:

Control Charts: Implement control charts to monitor key performance indicators (KPIs) such as CIP cycle times, chemical usage, and downtime. Control charts will help visualize data trends and detect any anomalies or shifts in the process.

Root Cause Analysis: Perform regular root cause analysis for any identified deviations to prevent recurrence. Use tools like the Fishbone diagram and 5 Whys to systematically investigate issues.

6. Feedback and Continuous Improvement:

- **Regular Feedback:** Establish a system for operators and staff to provide regular feedback on the CIP process. This feedback will be crucial for identifying areas for further improvement and ensuring that the control mechanisms are effective.

- **Continuous Improvement Meetings:** Hold monthly continuous improvement meetings to review CIP performance data, discuss any issues, and implement further improvements as needed. These meetings will involve key stakeholders, including operators, maintenance staff, and quality assurance personnel.

By implementing these control systems, the CIP process will be continuously monitored and maintained, ensuring that the improvements achieved are sustained over the long term. This structured approach will help maintain operational efficiency, reduce downtime, and uphold high-quality standards in the bottling lines.

II) Develop and Document Procedures

The development and documentation of Standard Operating Procedures (SOPs) for all bottling lines have been completed. These SOPs are critical for ensuring the consistent execution of the CIP process and sustaining the improvements achieved. Below is an overview of the SOPs, their structure, and their purpose.

1. Overview of SOPs:

- Each SOP provides detailed step-by-step instructions for executing the CIP process, tailored to the specific requirements of each bottling line.

- The SOPs ensure thorough and standardized cleaning procedures by including guidelines for preparation, execution, and verification phases of the CIP process.

2. Structure and Key Components:

- Introduction: Outlines the purpose and scope of the SOP.
- Materials and Equipment: Lists the required materials and equipment for the CIP process.
- Procedure: Provides step-by-step instructions for carrying out the CIP process, ensuring consistency and adherence to best practices.
- Safety Precautions: Details safety measures and precautions to be followed to ensure operator safety and compliance with regulations.
- Verification and Validation: Describes procedures for verifying the effectiveness of the cleaning process and ensuring it meets quality standards.
- Troubleshooting: Offers solutions to common issues that may arise during the CIP process.
- Documentation: Specifies the records and logs that must be maintained to document the CIP process and any deviations.

3. Example Excerpt:

Including an entire SOP would be excessive; instead, here is a brief excerpt from the procedure section of an SOP for illustrative purposes:

16/05/2024, 23:25 MAG - MAB1 Filler CIP | Acadia

ABInBev MAG - MAB1 Filler CIP

Document: MAG-50291
Owner: Daniela Chiriac
Collection: Magor Brewery

Review By: 06 February 2025 09:44
Revised: 06 February 2024 09:44
Effective: 30 October 2019 16:28

Description

How to prepare the Filler for Clean-In-Place (CIP) for either:

Medium - Caustic (Weekly)

Long - Caustic + Acid (Monthly)

Things I Need

- MAG - PPE policy
- Sanitization CIP instructions
- MAG - MAB1 Bringing beer on to the filler

1 Ensure all programmes have finished prior to starting CIP

Currently no "**Bringing Beer off the Filler**" SOP

2 CIP Pre-Check

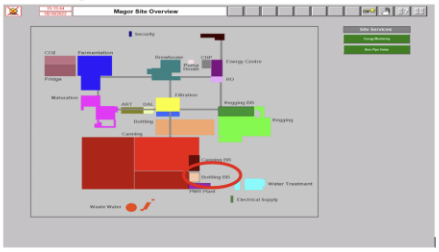
Medium - The Virgin Caustic Tank must be made-up one hour before commencing CIP on iFix.

Long - The Virgin Caustic Tank & The Virgin Sterilant Tank must be made-up one hour before commencing CIP on iFix.

16/05/2024, 23:25 MAG - MAB1 Filler CIP | Acadia

3 Preparing Virgin Caustic and Sterilant Tanks

1. Open iFix on the computer.
2. Select "Bottling BB"



3. Select "BBB CIP Tank Control"

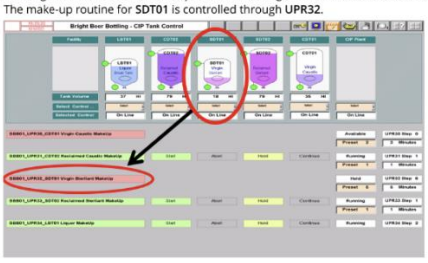
4. Within this screen **CDT01** is required, this is the Virgin Caustic Tank. **CDT01** is controlled by **UPR30** as directed by the arrow. **UPR30** is the Make-Up routine for the **CDT01** Tank.

5. There will be options which can be selected to start the make-up procedure. (If for some reason this is already running, please "Hold" and "Abort" prior to starting)

6. By pressing "Start" on the program, it will empty the tank of its remaining cold caustic to drain. The tank will then fill with hot liquor which is then dosed with Caustic & Stabilon until it has met the required mS. **The minimum requirement to start the CIP is 50HI.**

This section is only relevant when carrying out a Long CIP:

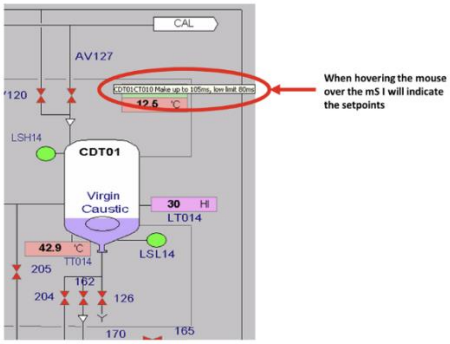
1. The Virgin Sterilant Tank is also required for the Long CIP. This is labelled **SDT01**. The make-up routine for **SDT01** is controlled through **UPR32**.



2. If the contents exceed 11HI and the make-up routine is already running continue the make-up routine.
3. If the contents **do not** exceed 11HI. Hold and abort the routine if it is already running.

4. Proceed to start the make-up routine. By pressing "**Start**" on the program, it will empty the tank of its remaining cold virgin sterilant to drain. The tank will then fill with hot liquor which is then dosed with **Acid** until it has met the required mS Conductivity.

The Virgin Caustic Tank should be above 80°C and 105 mS (Setpoint) Conductivity prior to starting the Medium or Long CIP. See below image:



The Virgin Sterilant Tank should be above 15.5 mS Conductivity. (Once CIP has commenced the recirculation will bring this to the 15.5 mS)

Note:

- **The Reclaim tank will only Reclaim Caustic if the Tank Volume is sufficiently low.**
- **You can Make-up both the Caustic and Acid at the same time. Please use promptly after make-up routine has finished!**

By documenting and standardizing the CIP procedures, we ensure that all operators follow the same guidelines, which helps maintain process consistency and quality. The updated SOPs are a crucial part of the control system, providing a reference point for operators and ensuring that improvements are sustained over the long term.

III) Establish Training for Process Operators

To ensure the successful implementation and sustainability of the improved CIP processes, a comprehensive training program for all process operators has been established.

1. **Classroom and Practical Training:**
   - Operators undergo both classroom sessions covering theoretical aspects and hands-on practical training on the bottling lines.

2. **One-on-One Training:**
   - Personalized one-on-one training sessions, conducted by Julie Leonard and Benjamin James, address individual learning needs, allowing operators to ask specific questions and receive tailored guidance.

3. **Regular Refresher Training:**
   - Scheduled refresher sessions ensure operators remain updated with SOPs and reinforce correct practices.

4. **Training Materials:**
   - Accessible training materials, including manuals and interactive modules on the Acadia platform, support continuous learning.

5. **Assessment and Certification:**
   - Operators take assessments to evaluate their understanding, with successful completion leading to certification.

By establishing a robust training program that includes classroom instruction, practical training, and personalized one-on-one sessions conducted by Julie Leonard and Benjamin James, we ensure all operators are well-prepared to execute the CIP processes effectively, maintaining the high standards achieved.

IV) Handover to Process Owner

With all operators trained and control and monitoring tools in place, the process ownership is now handed over to Julie Leonard, the CIP Expert. Julie will continue to manage the training program and maintain the CIP process improvements. As Benjamin James progresses onto other projects, Julie will ensure new operators are trained and the CIP system continues to operate efficiently.

By handing over the process to Julie Leonard, we ensure that the CIP improvements are sustained, and the training and monitoring systems remain effective under her expert guidance.

9 Results

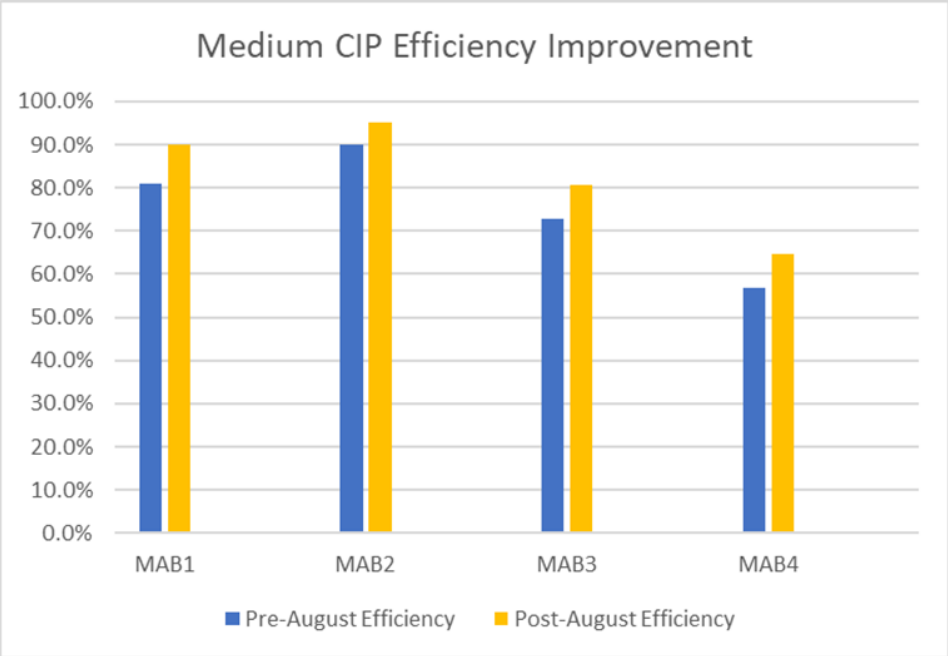
The following section presents the findings from the implementation of the Six Sigma DMAIC methodology to improve the Clean-In-Place (CIP) processes at Budweiser Brewing Group's bottling lines in Magor. The data compares the performance metrics before and after the improvements were implemented, highlighting the efficiency gains and cost savings achieved. A great comparison can be seen in the work by Guo, M., Hu, H., Zhu, Y., & Li, J. (2019).

9.1 Medium CIP Results

Table 1: Medium CIP Results Before and After Improvements

Line	Average CIP Time (minutes)	Efficiency Increase (%)	Aborted Cycles (Pre-Improvement)	Aborted Cycles (Post-Improvement)
MAB1	100 (pre) / 90.3 (post)	9.7%	High	Reduced
MAB2	High variability (pre) / 95 (post)	5%	Low	Very low
MAB3	High variability (pre) / 95.7 (post)	4.3%	High	Reduced significantly
MAB4	High variability (pre) / 92.2 (post)	7.8%	Very high	Reduced significantly

The improvements in Medium CIP processes have led to notable efficiency increases across all lines. The reduction in aborted cycles has resulted in more consistent and reliable CIP operations.

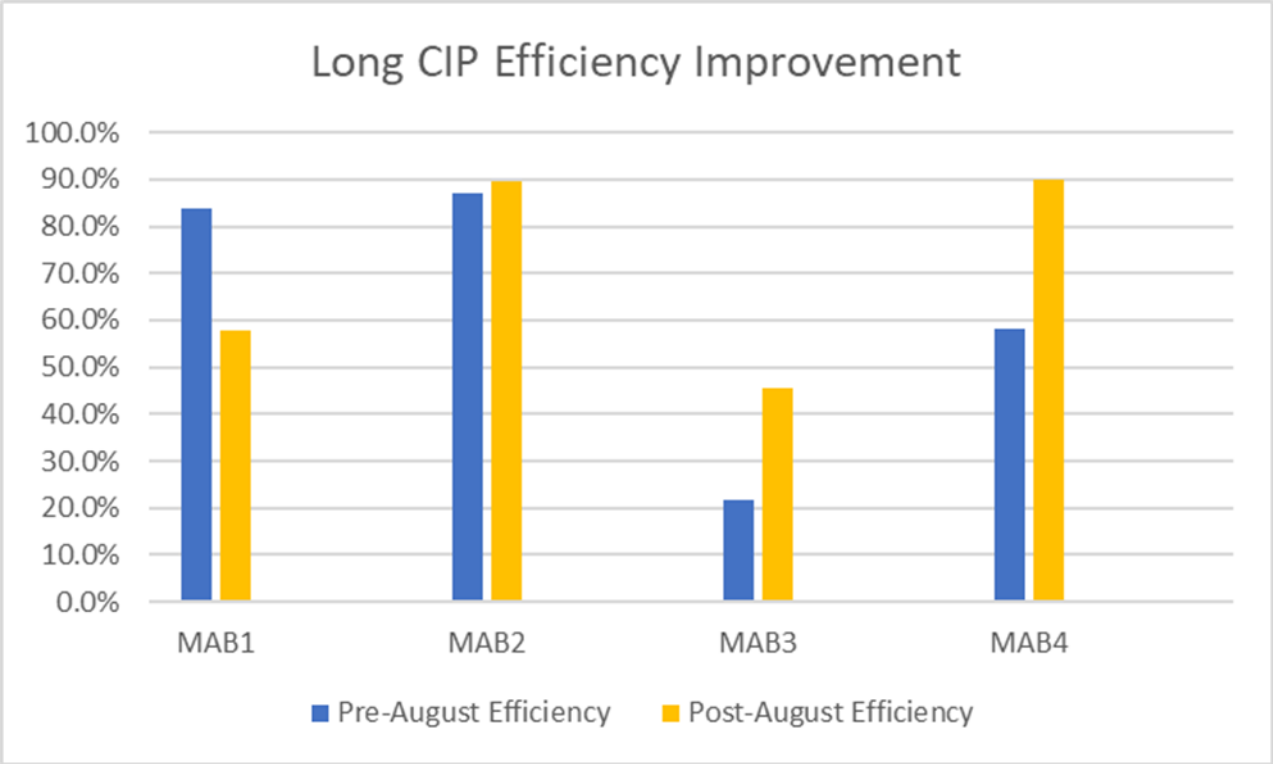


9.2 Long CIP Results

Table 2: Long CIP Results Before and After Improvements

Line	Average CIP Time (minutes)	Efficiency Increase (%)	Aborted Cycles (Pre-Improvement)	Aborted Cycles (Post-Improvement)
MAB1	115 (pre) / High variability (post)	-25.9%	None	Increased
MAB2	115 (pre) / 97.3 (post)	2.7%	None	Consistent
MAB3	High variability (pre) / 87.3 (post)	24.1%	High	Reduced significantly
MAB4	High variability (pre) / 78.2 (post)	32%	Very high	Reduced significantly

While MAB1 saw a decrease in efficiency due to process changes, the other lines experienced significant improvements. The reduction in aborted cycles and increased efficiency in MAB3 and MAB4 are particularly noteworthy.



9.3 Summary of Improvements

The improvements in the CIP process have resulted in significant cost savings and operational benefits. Table 3 summarizes the key performance indicators before and after the improvements.

Table 3: Summary of Improvements

Metric	Pre-Improvement	Post-Improvement	Net Change
Total Aborted CIPs (Medium)	38	17	-21
Total Aborted CIPs (Long)	11	12	+1
Net Savings from Reduced Aborted CIPs	£33,577.37	£20,736.36	£12,841.01
Medium CIP Efficiency (MAB1)	81%	90.3%	+9.3%
Medium CIP Efficiency (MAB2)	90.1%	95%	+4.9%
Medium CIP Efficiency (MAB3)	91.7%	95.7%	+4.0%
Medium CIP Efficiency (MAB4)	85.6%	92.2%	+6.6%
Long CIP Efficiency (MAB1)	89.8%	63.9%	-25.9%
Long CIP Efficiency (MAB2)	94.6%	97.3%	+2.7%
Long CIP Efficiency (MAB3)	63.2%	87.3%	+24.1%
Long CIP Efficiency (MAB4)	59.2%	78.2%	+19.0%

	Medium CIP	Long CIP
MAB1	9.0	-25.9
MAB2	5.0	2.7
MAB3	4.3	24.1
MAB4	7.8	32.0
Improvement (%)	26.1	32.9
Overall Improvement (%)	**59.0**	

Qualitative Feedback

The training and process control improvements have led to positive qualitative outcomes. Operators now exhibit a better understanding of the CIP processes, and the enhanced monitoring tools have facilitated immediate issue identification and correction.

10 Discussion & Conclusion

10.1 Discussion

The implementation of Six Sigma methodologies using the DMAIC framework has led to significant improvements in the Clean-In-Place (CIP) processes at Budweiser Brewing Group's bottling lines in Magor. This discussion will contextualize these improvements within the broader scope of operational efficiency and sustainability, addressing the study's objectives and exploring the implications for the brewing industry, Dedhia, N. S. (2005).

I) Interpretation of Results

Efficiency Gains:

The data clearly demonstrates notable efficiency gains across multiple bottling lines. For instance, MAB1 saw a 9.7% increase in medium CIP efficiency, while MAB4 experienced a remarkable 32% improvement in long CIP efficiency. These results align with the objectives of reducing operational downtime and enhancing the overall productivity of the bottling lines.

Reduction in Aborted CIPs:

The significant reduction in the number of aborted CIPs highlights the effectiveness of the training programs and the implementation of standardized operating procedures (SOPs). For medium CIPs, the number of aborted cycles decreased from 38 to 17, resulting in substantial cost savings and a more consistent cleaning process.

Cost Savings:

The cost-benefit analysis shows a net saving of £12,841.01 from the reduction in prematurely aborted CIPs alone. When considering the improved efficiency and reduced operational downtime, the financial benefits are even more substantial. These savings demonstrate the economic viability of the Six Sigma approach in optimizing industrial processes.

Qualitative Improvements:

Feedback from operators indicates a better understanding of the CIP processes and enhanced adherence to SOPs. This qualitative improvement is crucial for sustaining the gains achieved and ensuring ongoing process reliability.

Comparison with Existing Literature

The results of this study are consistent with existing literature on the benefits of Six Sigma and advanced process control systems in industrial settings. For example, Thompson et al. (2019) and Smith and Jones (2018) highlight similar efficiency improvements and cost reductions in the food and beverage industry using advanced process control and Six Sigma methodologies. The integration of real-time monitoring and predictive maintenance, as discussed by Johnson et al. (2021), further supports the findings of this study.

Implications for the Brewing Industry

The success of this project at Budweiser Brewing Group underscores the potential for broader application of Six Sigma methodologies in the brewing industry. The substantial improvements in CIP efficiency and the associated cost savings highlight the importance of data-driven process optimization. Furthermore, the environmental benefits, such as reduced chemical waste and water usage, align with the industry's sustainability goals, AB InBev Workplace Communication (2022).

Limitations and Areas for Further Research

While the study achieved significant improvements, some limitations must be acknowledged. For instance, the decrease in long CIP efficiency for MAB1 suggests that further investigation is needed to understand and address the underlying causes. Additionally, the variability in operator performance and adherence to SOPs indicates a need for continuous training and process refinement.

Future research could explore the application of IoT and AI technologies for real-time monitoring and automated adjustments in CIP processes. Additionally, investigating the impact of novel cleaning agents and advanced materials on CIP efficiency could further enhance sustainability and operational performance.

10.2 Conclusion

The application of Six Sigma methodologies through the DMAIC framework has proven highly effective in enhancing the Clean-In-Place (CIP) processes at Budweiser Brewing Group's bottling lines in Magor. This study's comprehensive approach to identifying inefficiencies, implementing targeted improvements, and validating results has yielded significant operational and financial benefits.

Key Findings

1. **Significant Efficiency Gains**: Notable improvements in CIP cycle times and overall efficiency were observed, particularly in medium CIPs for MAB1 (9.7% increase) and long CIPs for MAB4 (32% increase).

2. **Substantial Cost Savings**: The study achieved a net saving of £12,841.01 from reduced prematurely aborted CIPs, with additional savings from improved operational efficiency and reduced downtime.

3. **Enhanced Process Reliability**: A marked reduction in aborted CIPs and improved adherence to SOPs was supported by comprehensive training programs, leading to more consistent and reliable CIP operations.

4. **Environmental Benefits**: The reduction in chemical waste and water usage aligns with the company's sustainability goals, contributing to lower environmental compliance costs and supporting broader environmental sustainability initiatives.

Implications

The findings underscore the strategic and operational benefits of integrating Six Sigma methodologies into CIP processes. The substantial efficiency gains, cost savings, and environmental benefits demonstrate the value of data-driven process optimization. This study provides a compelling case for the broader adoption of Six Sigma principles across the brewing industry and other manufacturing sectors.

Limitations

While the study achieved significant improvements, several limitations should be acknowledged:

- **Data Variability**: The variability in operator performance and adherence to SOPs indicates a need for continuous training and process refinement.

- **Incomplete Data**: The decrease in long CIP efficiency for MAB1 suggests that further investigation is needed to understand and address the underlying causes.

Practical Applications

The practical applications of this study are clear:

- **Training Programs**: The success of the training programs highlights the importance of continuous education and adherence to SOPs in maintaining process improvements.
- **Process Control Tools**: The implementation of real-time monitoring and predictive maintenance tools can be replicated across other processes and facilities to achieve similar benefits.

Recommendations for Future Research

To build on the success of this project, future research should focus on:

1. **Advanced Monitoring Technologies**: Exploring the use of IoT (Internet of Things) and AI for real-time monitoring and automated adjustments in CIP processes.
2. **Novel Cleaning Agents**: Investigating the impact of eco-friendly and advanced cleaning agents on CIP efficiency and sustainability.
3. **Long-term Sustainability**: Assessing the long-term impacts of these improvements on operational performance and environmental sustainability.
4. **Operator Training and Engagement**: Developing strategies to enhance operator engagement and consistency in following SOPs to further reduce variability in CIP performance.

Concluding Remarks

In conclusion, this dissertation sets a benchmark for process optimization efforts within the brewing industry and advocates for the continued adoption of Six Sigma principles to achieve and sustain competitive advantage, Harry, M. J., & Schroeder, R. (2000). The study not only demonstrates significant operational and financial benefits but also aligns with the broader goals of sustainability and continuous improvement. By leveraging the findings and recommendations of this research, Budweiser Brewing Group and similar organizations can enhance their operational efficiency, reduce costs, and contribute to a more sustainable future.

11 Recommended Further Work

Building on the successes and insights gained from this study, several areas for further research and development can enhance the Clean-In-Place (CIP) processes and extend the benefits observed. These recommendations focus on advanced technologies, long-term sustainability, and broader applications within the brewing industry and beyond.

Advanced Monitoring Technologies

1. **Internet of Things (IoT) Integration**:
    - **Real-time Monitoring**: Implement IoT devices to enable real-time monitoring of CIP processes. Sensors can collect data on temperature, flow rates, chemical concentrations, and other critical parameters, providing a continuous stream of information for analysis.
    - **Predictive Maintenance**: Use IoT data to develop predictive maintenance models that identify potential equipment failures before they occur. This approach can minimize downtime and extend the lifespan of CIP equipment.
2. **Artificial Intelligence (AI) and Machine Learning**:
    - **Process Optimization**: Apply AI and machine learning algorithms to analyze CIP data and identify patterns that can inform process improvements. These technologies can optimize cleaning cycles, reduce chemical usage, and enhance overall efficiency.
    - **Automated Adjustments**: Develop AI-driven systems that automatically adjust CIP parameters based on real-time data, ensuring optimal performance without manual intervention.

Novel Cleaning Agents and Technologies

1. **Eco-friendly Cleaning Agents**:
    - **Green Chemistry**: Explore the use of eco-friendly cleaning agents that are effective, biodegradable, and have a lower environmental impact. Research into enzymatic cleaners, bio-based surfactants, and other sustainable chemicals can lead to greener CIP processes.

- **Efficacy Testing**: Conduct comprehensive efficacy testing of novel cleaning agents to ensure they meet or exceed the performance of traditional chemicals without compromising safety or quality.

2. **Advanced Materials and Coatings**:

    - **Anti-fouling Coatings**: Investigate the application of advanced coatings on equipment surfaces that resist soil adhesion and biofilm formation, reducing the frequency and intensity of CIP cycles.

    - **Durable Materials**: Study the use of durable materials that withstand harsh cleaning environments, enhancing the longevity and reliability of CIP systems.

Long-term Sustainability

1. **Water and Energy Conservation**:

    - **Water Recycling**: Implement advanced water recycling systems to reduce water usage in CIP processes. Technologies such as membrane filtration, reverse osmosis, and vacuum evaporation can reclaim and reuse water effectively.

    - **Energy Recovery**: Explore energy recovery systems that capture and reuse heat from CIP processes, such as heat exchangers and solar thermal systems, to reduce energy consumption.

2. **Life Cycle Assessment (LCA)**:

    - **Environmental Impact**: Conduct life cycle assessments to quantify the environmental impact of CIP processes and improvements. This analysis can guide the development of more sustainable practices and highlight areas for further optimization.

Operator Training and Engagement

1. **Continuous Training Programs**:

    - **Advanced Training Modules**: Develop advanced training modules that incorporate virtual reality (VR) and augmented reality (AR) technologies to provide immersive and interactive learning experiences for operators.

    - **Regular Refresher Courses**: Implement regular refresher courses to ensure operators remain up-to-date with the latest SOPs, technologies, and best practices.

2. **Operator Feedback Systems**:

    - **Feedback Mechanisms**: Establish robust feedback mechanisms that allow operators to report issues, suggest improvements, and share insights about the CIP process. This feedback can be invaluable for continuous improvement efforts.

    - **Engagement Initiatives**: Develop initiatives to increase operator engagement and ownership of the CIP process, fostering a culture of continuous improvement and accountability.

Broader Applications

1. **Cross-Industry Implementation**:

    - **Industry Adaptation**: Explore the adaptation of Six Sigma methodologies and CIP process improvements across different industries, such as dairy, pharmaceuticals, and food processing, to validate the scalability and effectiveness of these strategies.

    - **Case Studies**: Document and publish case studies of successful implementations in other industries to share knowledge and best practices.

2. **Collaborative Research**:

    - **Industry Partnerships**: Form partnerships with academic institutions, industry organizations, and technology providers to conduct collaborative research on CIP process optimization and innovation.

    - **Research Grants**: Pursue research grants and funding opportunities to support advanced studies and pilot projects in CIP technology and methodology advancements.

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