CIP Automation Practices: Mild to Wild

Malisko Engineering, Inc.

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Section I
Introduction

Clean-in-place (CIP) systems are used in a wide variety of process industries, including food, beverage, dairy, brewing, pharmaceutical and life science industries. Their purpose is to eliminate the soil load buildup during normal production, which can lead to cross-contamination and microbial growth. CIP systems vary widely in configuration, operation and the level of automation. CIP is critical to the sustainability of safe and reliable processing — so critical that a team of stakeholders should be engaged in discussions early on in the design and specification process. The team should include plant operations, quality, compliance, corporate engineering, IT, their partner integrators as well as chemical and equipment suppliers. Each stakeholder has specific needs that a robust automated CIP system must deliver, such as improving CIP operations by reducing cycle times as well as reducing water and chemical usage. The Automation Techies (Integrators) can help production in many ways by using the most current technologies for fault-tolerant computers, process controls, instrumentation, software, networking, and security in CIP. These platforms are currently being integrated into comprehensive systems, providing high levels of efficient and effective CIP operations, data capture, operational traceability and real-time information analysis. To contribute directly to a company's bottom line, varieties and combinations of these tools are applied to automating CIP systems.

Section II
CIP Equipment Configurations

The basics of CIP equipment configurations — and the flaws of manual control

Equipment configurations and operations vary for CIP systems, from small self-contained skids with small tanks to 'kitchens' with very large tanks for alkaline, acid, rinse water, sanitizer and recovery, multiple pumps and heat exchangers for simultaneously servicing multiple CIP systems. Costs for these, along with their capabilities, vary widely as well. Factors determining the configuration and size of the CIP systems include the process type, ingredients used in the process, production capacity and throughput as well as time in the production cycle allowed for CIP'ing the process systems. Whether a CIP system is a small 'skid' or a massive 'kitchen,' it can consist of the following equipment:

- One Tank – combined rinse and wash
- Two Tank – separate rinse and wash tanks
- Three Tank – rinse, wash, recovery
- Four Tank – any combination of rinse, wash, alkaline, acid, sanitizer, recovery
- In-line or in-tank chemical dosing for one-pass chemical usage systems
- Separate chemical tanks for alkaline, acid, and sanitizer for multi-pass chemical usage

Components common to the variety of CIP systems include water supply source; supply pump; supply-side heat exchanger and corresponding temperature transmitter at the discharge of the heat exchanger; tank inlet, outlet, and recirculation valves; chemical addition pumps; and data recorder with paper-based chart recorder(s) or an electronic historian for critical operating parameters, at a minimum, temperature over time.

The most basic mode of CIP operation is complete manual control. This method requires a high degree of constant monitoring and intervention by the operators to ensure effective and safe operation. Numerous opportunities exist for unintended mistakes, oversights and human error when running CIP systems in 'manual mode.' Production facilities that leave a lot of responsibility on the shoulders of the operator to properly monitor and control the many steps and functions of CIP experience routine difficulty maintaining consistency of wash temperatures and times, chemical concentrations and rinse water quantities. Worse yet, operators might routinely overcompensate the operation by adding more chemicals during wash cycles to ensure minimum cleaning requirements are met, or, running at higher temperatures, longer wash times, and greater rinse water quantities. The negative effects to operating costs are both short term and long term. Short term in that more chemicals are used, which costs more money, water is wasted and cleaning times become excessively long — thus taking away from precious actual production time. Long term in that excessive use of chemicals can attack metals and prematurely degrade the pipes, tanks and other process equipment — thus requiring plants to spend money sooner rather than later to replace damaged process components.

SECTION III
CIP System Design

CIP system design: making your operator and CIP system more efficient

Manufacturing plants can significantly increase efficiency and reduce operating costs for CIP by enhancing their systems with automation tools designed to relieve some of the burden from the operator's shoulders. More robust CIP systems will have the following components:

- Supply side flow transmitter – rinse and wash steps can be precisely controlled by totalizing the liquid quantities delivered to each CIP circuit.
- Variable frequency drive on the supply pump – supply side flow rates can be precisely controlled with a loop control tied to the flow transmitter above. The benefits gained are ensuring line circuits achieve minimum liquid flow velocities for surface contact in the various pipe diameters, and sufficient flow through spray balls for tank circuits.
- Supply side line pressure transmitter – monitor point to detect if an obstruction in the circuit is present when pressure is too high or a break in the circuit exists when pressure is too low.
- Level transmitters or level probes on the tanks – used to signify when action needs to be taken, especially when low levels are reached before or during a CIP operation.
  - Fresh water tanks – refill to a mid or high level.
  - Chemical tanks – add more water and the appropriate chemical to have sufficient solution for the appropriate wash step(s).
  - On high level – stop filling the tank.
- pH transmitters for alkaline and acid tank makeup – monitor point used when combining water with the alkaline and acid chemicals to the desired concentrations and pH levels.

- Proximity sensors – for all possible connections made at manual hook-up stations, or "swing panels"
  - Monitor point used when initiating a cleaning circuit to verify all connections are properly in place for the specific circuit.
  - Also, monitor point used during the cleaning sequence as a safety monitor in the event a hook-up connection comes loose, potentially spraying hot water and/or dangerous chemical solutions in an area.
- Return side temperature transmitter – monitor point to ensure the entire circuit is being cleaned at the required minimum temperature.
- Return side liquid flow switch – monitor point to detect liquid is returning to the skid or kitchen from the circuit being cleaned. Typically used in conjunction with a timer creating a notification to the operator to stop the system and check for leaks or to check for incorrect circuit hook-up points.
- Return side conductivity transmitters – monitor points to detect the absence or presence of chemicals. Rinse step times can be shortened when chemicals are not detected in the liquid returning to the skid or kitchen. Conversely, wash steps can be initiated sooner when chemicals are detected at the required concentration level in the return solution. In some applications, a second, more sensitive conductivity transmitter is used to sense the complete absence of chemicals in the final rinse step.
- Return side turbidity meter – monitor point to detect the amount of solids in the return liquid stream, used to prevent liquids with high solids content from being directed into a recovery tank.
- Off-the-Shelf process controllers, such as a PLC, is used to control the CIP steps and operating parameters along with checking for limits and alarms. This topic is covered in more detail below.
- Off-the-Shelf Human-Machine Interface (HMI) – the operator's window into the system for controlling and monitoring the CIP process while operating. Again, this topic is covered in more detail in the following pages.

SECTION IV
CIP Automation

CIP automation: controllers and HMIs can make for better CIP

Two key elements of automation drive the improvements in efficiency and consistency of your CIP: controllers and HMIs.

CIP control platforms

PLCs are well suited for controlling the range of simple to robust CIP systems. Simple CIP systems many times have a small stand-alone PLC. More operational complexity and additional instrumentation in the CIP system generally sets the need for more powerful controllers. PLCs offer features attractive to users from different perspectives and preferences. The more common attributes of the PLC family of controllers are the ability to handle a variety of field devices found in today's manufacturing environment; ability to interface to multiple device communication networks such as EtherNet/IP, ControlNet, DeviceNet, Profibus, AS-i Bus, Foundation FieldBus; ability to create structured code along with intuitive labels and tags within the programming; and ability to provide closer integration with the HMI's, data historians, event archivers, and relational databases (covered below).

Process controllers no longer live on the plant floor as separate "islands of automation." Rather, process controllers closely work together. Controllers are tightly integrated for both process and CIP. For high availability and high-criticality applications, process controllers can be set up in redundant "hot-backup" configurations addressing the concerns over "single-point" hardware failure.

Human machine interface

The user interface between the operator and the CIP process, commonly referred to as the HMI, continues to be the most dominant window into the CIP process. The typical, traditional HMI hardware platform was a stand-alone proprietary device or a Windows-based computer tied to either a proprietary bus or a simple Ethernet network. The preference in hardware platforms for HMI's is rapidly changing in the process industries as greater demand for information, response time of screen refresh and easier maintenance of the hardware become 'absolute musts' by the plant's operational and technical support groups. Thin clients and terminal servers are being used in both new applications and upgrades to legacy process control systems for CIP.

Thin clients are, generally, disk-less processors that interface over an Ethernet network to a computer server where terminal server HMI software and application files reside. Thin client hardware requires minimal configuration and minimal ongoing support compared to thick clients (traditional Windows-based computers or proprietary stand-alone HMIs). Different process and CIP screens can be simultaneously viewed by operators at different HMI workstations (thin clients). Replacement of hardware due to component failure is handled in minutes, not hours, with thin clients.

Plant operations have seen measurable savings using terminal services and thin client technologies. Process manufacturers have seen 33 percent savings in PC costs for operator workstations, 55 percent reduction in power consumption by the operator workstations; and reduction from four hours to less than 30 minutes for a technician to replace an operator workstation.

Combining the two for more bang

These robust controller and HMI technologies, combined with additional instrumentation, can provide plant operations with more efficient and maintainable CIP operations. Consider the following additional time and money-saving enhancements.

Recipe-based CIP circuits

Recipe-based CIP circuits make CIP circuit operating parameters part of a selectable recipe through the HMI. The parameters can include rinse and wash times/quantities, drain times, flow rate and temperature set points per step, line pressure limits per step, conductivity and turbidity limits per step, quantities of chemical additions, and alarm limits for all operating parameters.

Systems can be configured to allow these CIP circuit recipes to be created and edited by an authorized process or production person without the intervention of a programmer. All parameters can be made viewable and accessible via security from menu screens on the HMI. Each CIP circuit recipe is then stored in the controller.

Real-time monitoring of the entire CIP process

Using real-time monitoring, the operator sees an intuitive view of the progress and condition of the cleaning process. Information on the HMI includes:

- The CIP circuit being run
- Current step being run
- Condition to complete the step
- Next step to run
- Elapsed step time
- Time remaining in the step
- Target and current flow rate
- Supply pump speed reference
- Target and actual supply and return temperatures

- Conductivities
- Pressures
- pH’s
- Tank levels
- Valve positions
- Liquid flow path
- System notifications, warnings and alarms

The operator is constantly shown when the CIP system is operating as intended and is immediately notified when wash and rinse parameters are outside allowable limits or an abnormal operating situation occurs. The ultimate step to take is to make this same information available as a secure webpage accessible to supervisors and managers on a ‘need-to-know’ basis.

Real-time trending

Real-time trending allows the operator to view graphs on the HMI that show the performance over time of flow rate, temperatures, pressures, conductivities, pH’s, and turbidity during the CIP process. Again, go the extra mile and publish this same information via secure web access and add the ability for ad hoc queries of data to create the opportunity for creative analysis of CIP effectiveness.

SECTION V
Advancing CIP Technology

Advancing CIP technology

Using advanced CIP technology by deploying historians enables producers to collect operating data and maintain accurate event archiving.

CIP process data

Traditional methods for recording process parameters, such as CIP temperatures, to meet regulatory compliance relied on paper-based circular or strip chart recorders. Maintenance of these electro-mechanical devices was always a top priority to ensure their reliability, accuracy, and repeatability. Yet despite the plant's technical support group's tireless efforts at maintaining high uptime, each chart recorder had multiple points of mechanical failure, including the ink dispenser, ink supply, and pen driver mechanisms.

Today, processing plants are eliminating paper-based chart recorders and replacing them with historians, which are software-based data recorders that extract CIP process operating parameter values from the PLCs on a continuous basis. Today's data historians can simultaneously and continuously record tens of thousands of individual process parameter points per second. Most data historians use data compression algorithms to optimize the use of mass storage, either on a local computer server or in the cloud. Where regulatory compliance is a key requirement, established methods exist for validating the historians in order to rely on the data harvested from them.

Trends of the CIP parameters, such as temperatures and flows, set points and the actual values, can be displayed on the HMI as well as printed out for inclusion with paper CIP records. The raw data is electronically stored and available for review and analysis days, weeks, months, or years later.

CIP event archiving

Traditional methods for recording events, such as CIP circuit start time and end time or target and actual wash times and quantities, have been paper records created by the operator using the old fashion black ink pen. These manual records do meet regulatory compliance but are very labor intensive. Their accuracy and completeness rely entirely on the operator. Maintaining paper records becomes critical for traceability of the cleaning process to meet regulatory compliance.

Like the historians described above, process manufacturers are moving away from the paper-based CIP records and embracing software-based event archivers and report generators. Similar to the historians, the event archivers (or transaction managers), record events germane to the CIP process. Typical recorded events include CIP circuit start and completion times, wash times and quantities, and operator interventions, such as putting the system in "hold," advancing a step, repeating a step, or aborting the circuit. The significant advantage to using software-based transaction managers in lieu of paper records is the critical event data is automatically captured via the process controllers and HMIs then stored in a relational database, such as Microsoft's SQL Server. Once the event data is captured, CIP and other reports can be generated. Like the historians, the event archivers can be validated using well-established methods to meet regulatory compliance.

The event archiver and reports can be created and configured to be compliant with FDA requirements for electronic records, Title 21 CFR Part 11. Executing this step provides the process manufacturer the ability to work toward eliminating paper records for CIP.

Summary

Manufacturers in the process industries can improve their CIP operations and efficiencies by effectively utilizing current technologies for CIP process automation. These technologies have already been used in applications. Critical to reaping the benefits of using these newer platforms is to have the system designers, production, maintenance, compliance and quality work closely together from a project's inception to completion so all system requirements, specifications, documentation, and regulatory requirements are cohesive and uniform. Success is achievable for those willing to take advantage of the proven technology platforms already available today.

More about Malisko Engineering

Malisko Engineering, Inc. was founded in 1994 from humble beginnings. We've grown into a multi-disciplined team of engineers, designers, programmers, automation, network, and validation specialists. We deliver cutting-edge automation technology in rapid project time-frames at competitive pricing. We deliver our work on time and on budget. We help our clients meet their goals with well-planned system design and implementation.

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