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INTRODUCTION

Purchasing and installing a CIP system for your processing facility is a considerable undertaking, requiring analysis, planning, and above all, partners. The best “first step” you can take is to create a team of knowledgeable operators, managers from multiple departments, and most importantly a trusted company that has vast experience in designing and building process and CIP systems.

Making food and pharmaceuticals safe is a primary goal for all processing plants, and cleaning in place is an important tool for reaching that goal. CIP systems designed especially for the food, dairy, beverage, and pharmaceutical processing industries deliver the efficient cleaning processes you need to avoid risks to product quality and purity.

This Buyers Guide for Clean-in-Place Solutions is a comprehensive resource for production managers, project managers, quality managers, and purchasing managers who design, own, or operate processing systems and want information about all aspects of CIP Systems. CIP equipment from CSI helps you control, monitor, and document the cleaning methods that are essential to sanitary processing. As clean-in-place technologies have become more efficient and cost-effective, cleaning your process system in place not only helps ensure product safety but can also add to your bottom line by adding efficiencies to your cleaning process.
CIP TO FIT YOUR INDUSTRY

CIP systems vary widely in configuration, capacity, quality, and level of automation. They also vary by industry. Differences in product characteristics and regulatory considerations between the various processing industries will strongly impact the design of your CIP system.

FOOD, DAIRY, AND BEVERAGE

The number of CIP applications for food, dairy, and beverage process systems has grown dramatically in recent years. Processors in these industries recognize the importance of fast, efficient CIP. The range of product types and cleaning requirements in these industries is virtually endless, so when you are looking to install or upgrade a CIP system it is imperative to consider your particular cleaning needs. Resist the urge to buy a “cookie cutter” solution. While it might purport to sufficiently clean any application, this might not necessarily be the proper solution for your system.

In most food, dairy, and beverage systems, the surface finish for product contact areas tends to be the standard sanitary surface finish of 32Ra minimum. This is rougher than the finishes required in the pharmaceutical world, but it is smooth enough to allow most product residues to release fairly easily. Requirements for validation and recording of cleaning data vary from product to product, but as data monitoring, tracking, and recording technology becomes more user-friendly and affordable, more and more food, dairy, and beverage processors are electing to incorporate it into their CIP controls.

The CIP cycles to clean common food, dairy, and beverage products may include pre-wash, detergent, acid, and various rinse cycles, but may also include a sterilization cycle for an extended shelf life (ESL) product. Sterilization is more common for pharmaceutical CIP.

Many beverage CIP applications require less time and energy and fewer chemicals when the product is less viscous and doesn’t contain proteins or fats. The acidity of many beverages also naturally inhibits the growth of microorganisms, which could mean cleaning less frequently.

Milk and dairy products are particularly vulnerable to spoilage and the rapid growth of bacteria. Clean-in-place systems in dairies must be very specific regarding temperatures, cycle times, and chemical concentrations to effectively prevent contamination from harmful microorganisms such as salmonella, listeria, and E. coli. Additional acid washes may also be needed to eliminate milk scale buildup. Pasteurizers and other equipment containing heating surfaces (known as “hot components”) may require separate cleaning programs from the non-heated components of the system such as tanks and piping.

RESIST THE URGE TO BUY A “COOKIE CUTTER” SOLUTION. WHILE IT MIGHT PURPORT TO SUFFICIENTLY CLEAN ANY APPLICATION, THIS MIGHT NOT NECESSARILY BE THE PROPER SOLUTION FOR YOUR SYSTEM.
BREWERIES
Most modern breweries are highly automated closed systems, so they lend themselves well to cleaning in place. The tanks and vessels used in brewing sometimes have a large capacity and may require multiple high capacity spray devices to be properly cleaned. A phosphoric acid wash may be required in some cases to remove beerstone buildup.

PHARMACEUTICAL
The highest level of CIP technology and state-of-the-art controls are usually found in pharmaceutical CIP systems. The exacting standards of the industry demand a level of hygiene, documentation, and automation that isn’t required in other processing industries. Process line sizes tend to be smaller and the product is often less viscous than many food products, so high flow volumes and powerful spray devices may not be necessary for proper cleaning. The design of pharmaceutical process piping should be sloped properly and be free of undrainable low points. The pumps, valves, and fittings used in pharmaceutical processing generally have the highest level of clean-ability designed into them, which makes them easier to clean and less likely to have hidden, hard-to-clean areas.

Depending on the process and the product being cleaned, your CIP system could be a simple, single tank, single-pass system to clean one small circuit, or a complex multi-tank, multi-supply system to service multiple circuits or kitchens simultaneously. Before anyone embarks on the journey to purchase or upgrade a clean-in-place system, it is critical that they arm themselves with the information they need to tell the difference between a quality, efficient, and cost-effective system and a “wanna-be” system. It is possible to install a clean-in-place system that outwardly has the appearance and functionality of a cleaning system but fails to address the countless details that go into building a quality CIP system.

To ensure you get the maximum return on your CIP investment, partner with an experienced company that, above all, understands process systems and has a proven history of engineering effective custom CIP systems. A qualified cleaning system vendor will guide you through the entire process—from proper planning and design through fabrication and installation to the final steps of training and start-up. Working together with a knowledgeable vendor will provide you with a reliable, worry-free CIP system for many years.
ADVANTAGES OF CIP

In addition to maintaining hygienic standards essential to processing, CIP is key to operational safety.

INCREASED PRODUCT SAFETY

- CIP minimizes mistakes by automating cleaning to reduce chances of human error that can contribute to an unsafe product.
- CIP decreases contamination risks with monitoring sensors.

INCREASED EMPLOYEE SAFETY

- A fully automated CIP system increases employee safety by minimizing exposure to aggressive cleaning chemicals associated with CIP.
- No Vessel Entry (confined space) – With a properly designed CIP system and tank spray devices, operators will not be required to obtain special confined space permits to enter tanks for cleaning. Not only does this increase employee safety, but it also decreases facility liability.

THE BOTTOM LINE

The objective for most process environments is to maximize quality production time and minimize other activities and costs. The bigger and more difficult the cleaning job and the more frequent the cleaning cycle, the more cost-effective CIP can be. Here are some of the main economic benefits of installing a CIP system:

- More Production Time – As less production time is lost to cleaning, more time is spent making product.
- Product Quality – Reliable and repeatable cleaning leads to sustainable product quality and consistency. Less contamination means fewer product recalls and higher brand confidence.
- Employee Efficiency – More labor time is spent on productive, profitable activities.
- Utility Savings – Water and energy usage is reduced through repeatable cycle control.
- Lower Water Treatment Costs – The amount of effluent going to drain is greatly reduced.
- Lower maintenance costs – Properly cleaned equipment will potentially run longer between maintenance periods, which translates to more time producing product.

RULES & REGULATIONS

No government rules or regulations currently mandate that components of a process system be cleaned in place, only that they be sufficiently cleaned. To properly apply CIP strategies to a processing plant, the process system components themselves should conform to hygienic design criteria ensuring that they are cleanable. These design criteria are well established and documented:

- The 3A Sanitary Standards (U.S.A.)
- The European Hygienic Design and Engineering Group (EHEDGE)
- The European Standard EN 1672-2 (2005)

As the concern for public safety of food and pharmaceutical products increases, cleaning in place offers clear advantages to helping processors maintain the necessary level of hygiene. Here are a few standards that guide the design and use of CIP systems:

Food Safety Modernization Act

Signed into law in 2011, the FSMA granted the Food and Drug Administration (FDA) new authority to regulate how food is grown and processed. A major emphasis of the FSMA is the focus on prevention of practices that can lead to foodborne illnesses. Cleaning in place is a valuable tool when it comes to food safety; therefore, a quality CIP system should provide all of the necessary functionality needed to maintain the standards set forth in the FSMA.
CFR21
The Code of Federal Regulations (CFR) is a set of rules published by the U.S. government. Title 21 of the CFR (CFR21) is used by the Food and Drug Administration to establish requirements for the manufacture of food industry products and pharmaceuticals, including how equipment should be cleaned and maintained. A top quality, well-designed CIP system should adhere to these guidelines and should comply with CFR21.

S88
In recent years a set of standards known officially as ANSI/ISA-88 was developed to address batch process control procedures and provide standard organization for how systems communicate and work together. A CIP system that complies with S88 would have an advantage when it comes to integrating into a process system.

CLEANING THEN AND NOW
Until about the 1950s, cleaning the product contact surfaces of process systems was done manually, requiring all piping, vessels, and equipment be disconnected, washed by hand, and then reassembled before the next production run. Every section of piping was either placed in a COP (clean-out-of-place) tank for washing or hand scrubbed. Likewise, every pump and valve had to be completely disassembled, cleaned by hand, and then reassembled. This expensive, time-consuming process had to be repeated as frequently as necessary to maintain a safe, hygienic process system and avoid product cross-contamination.

Since then, Clean-In-Place (CIP) strategies have advanced to be a reliable way of cleaning process equipment and piping without dismantling the system. CIP is an efficient, fully automated process with multiple dedicated tanks, programmable logic controllers, highly accurate sensors, spray devices, heat exchangers, and automatic valves.

As processors embraced the CIP concept and became more knowledgeable about clean-in-place strategies, the manufacturers of processing equipment took note and started to re-engineer their product lines to make them suitable for cleaning in place. Over the years, equipment manufacturers and process industry experts have worked together to drive improvements in equipment and components to make cleaning more effective. There are still plenty of non-CIP-able pumps, valves, and fittings available in the marketplace, but today’s process engineers have little trouble finding process system components that are compatible with CIP.

As an extension of CIP, Sterilization in Place or Steam in Place (SIP) adds a sterilization step at the end of the CIP process. SIP kills microorganisms still active in the system with hot water or steam (> 121 °C).
Although many food, dairy, beverage, and pharmaceutical processors go about the business of making their products in similar ways, one thing is certain: every system is unique. There is no such thing as “one-size-fits-all” when it comes to CIP systems. Although all CIP systems may vary, several system elements are common in most systems. Here is a look at them:

**IT’S ALL ABOUT THE TANKS**

The size and number of tanks in your CIP system is determined by the size and complexity of required cleaning. Individual tanks may be used for freshwater, caustic solution, acid solution, reusable washes or rinses, product recovery, or sanitizer. Tank design will depend primarily on the industry, but the materials of construction are commonly austenitic stainless steels such as AISI 304, 316, or 316L. Using 304 stainless steel for some food, dairy, beverage, and brewery CIP tank applications is acceptable, but most quality CIP system manufacturers feature 316/316L as the standard material for all wetted components, including the tanks.

A cleaning system may use one to four tanks, or more, depending on the application. Although no formula exists for system design, some common considerations apply for most applications.

**THERE IS NO SUCH THING AS “ONE-SIZE-FITS-ALL” WHEN IT COMES TO CIP SYSTEMS. ALTHOUGH ALL CIP SYSTEMS MAY VARY, SEVERAL SYSTEM ELEMENTS ARE COMMON IN MOST SYSTEMS.**

**Single Tank System**
- Ideal for small jobs with easily cleaned soil.
- Good for special use systems that are infrequently used.
- Ideal for applications on remote equipment that make service from a large, centralized system impractical.
- Often preferred for avoiding allergens and cross-contamination issues since each cycle is dumped to the drain after a single pass.
- Requires less space and can easily be cart-mounted for mobility.

**Two-Tank System**
- Typically, one tank is for water (for pre-rinse or final rinse) and one for caustic wash solution.
- Can be cart-mounted for mobility.

**Three-Tank System**
- Allows for many more cleaning options than smaller systems.
- Water/caustic/acid: Common for many cleaning applications. Allows for pre-fill and pre-heat of all solutions, which reduces cleaning time. Caustic and acid washes can be returned and re-used, depending on the amount of soil.

**Four-Tank System**
- The additional tank provides the flexibility to recover and re-use solutions without sacrificing the convenience of individual ready-to-go caustic and acid solutions.
- Depending on the type of cleaning needed, each tank must be fitted with all necessary inlet and outlet valves as well as any instrumentation required to monitor volume, temperature, and chemical concentrations.

**Need More Tanks?** Few CIP systems require more than four tanks, but additional tanks can be added to any system as necessary to provide nearly unlimited versatility and convenience to the CIP cleaning process.
PUMPS: THE HEART OF CIP

A circulation system that keeps your processes operating at peak performance relies on properly designed and specified pumps. Process engineers take various factors into consideration such as length of CIP circuits and types of process equipment to be cleaned to properly size and specify CIP supply pumps. Several pumps are used in the CIP circuit, such as:

Supply Pump—The supply pump should be sized to provide sufficient flow and pressure to create turbulent flow throughout the piping circuit and also provide the necessary flow and pressure required by any spray devices that are installed in tanks or vessels. If a pump is supplying multiple circuits that require different flows and pressures, control of the pump speed with a variable frequency drive (VFD) may be required. Supply pumps are typically 316 sanitary stainless-steel centrifugal pumps with cleanable seals. The pump elastomers should be compatible with the product soil and cleaning chemicals such as ethylene propylene diene monomer (EPDM) or a perfluoroelastomer like Dupont’s Kalrez®.

Return Pump—Once the solution has made it through the process system, it either needs to return to one of the CIP system tanks or be pumped to drain. In either case, the return pump should be sized to quickly remove the used solution from the process lines at a rate approximately 10% greater than the supply pump. Return pumps are typically either sanitary stainless steel centrifugal pumps with cleanable seals or specially designed liquid ring pumps that allow pumping of air and liquid without damage to the pump impeller, casing or seals. The pump elastomers should be compatible with the product soil and cleaning chemicals such as EPDM or a perfluoroelastomer like Dupont’s Kalrez®.

Metering and Dosing Pumps—The addition of any chemicals to a CIP tank or system can be done automatically and accurately using metering and dosing pumps. Pumps not only guarantee accuracy, but also avoid employee exposure to potentially dangerous chemicals. Peristaltic or air-operated diaphragm pumps are commonly used for chemical addition.
SPRAY DEVICES

Proper selection and placement of spray devices is critical to the success of your tank cleaning cycles. Depending on the size of the tank and the characteristics of the product that needs to be cleaned, there are a number of different types of spray devices to choose from.

**Static Spray Balls**—As the name suggests, static spray balls are fixed in place by clamp, thread, weld or pin and therefore do not rotate inside the tank. The spray direction for the numerous small jets of solution is determined by the drilled hole pattern on the ball. Designed for relatively low flows and pressures (commonly 40gpm @ 25psi), they have a moderate amount of impingement action when used on smaller tanks but rely primarily on cascading action to clean tank surfaces. They should be constructed of 316 stainless steel and be 3A approved. A variety of diameters and hole patterns are available to suit most applications. Several standard hole patterns are available including full 360° spray, 180° upward spray or 180° downward spray, or they can be custom drilled to direct jets to specific places inside the tank (which is imperative in pharmaceutical applications).

**Rotating Spray Balls**—Combining the reliability of a static spray ball with the benefit of rotation gives rotating spray balls the advantage of better cleaning solution coverage inside the tank. The flow of cleaning solution causes the spray ball to rotate easily on ball bearings. Their heavier design permits higher flow rates than most static spray balls. This allows them to deliver more impact to the soiled tank surface for better impingement.

**Rotary Spray Heads**—Curved and straight slots in the body of the rotary spray head emit fanned jets of solution that swirl in a regular pattern throughout the entire vessel. This creates a vibrating impact effect and considerable cascading flow that can be effective for larger vessels with challenging product soil. Their hygienic construction, 3A compliance, and self-cleaning bearing make them very well suited to sanitary applications.

**Rotary Jet Heads**—When high impingement force is needed to properly clean a tank or vessel, a rotating jet spray device is the answer. Their multi-axis rotation can deliver extremely high impact streams of cleaning solution in precise 360° patterns to all areas of the tank. High-pressure capacities allow them to use considerably less water than other
HEATING SYSTEMS

Temperature is one of the four basic TACT principles essential to the cleaning process, so choosing the right heating source for your CIP system is an important decision. Elevating the temperature of your cleaning solutions will increase their soil-removing efficiency, which in turn will reduce your cleaning time and chemical costs. Your CIP heating system is responsible for accurately and efficiently bringing each wash and rinse to its proper temperature to maximize the efficiency of your wash cycles. There are several heating system strategies to choose from and each has its own advantages. When choosing yours, consider the requirements of your cleaning system and the plant resources you have available.

**Plate & Frame Heat Exchanger**—These units are highly efficient and typically have a small footprint allowing a more compact design of the CIP system. Additionally, they have a relatively low steam load requirement, making them a desirable choice for CIP systems.

**Shell & Tube Heat Exchanger**—A simple, low-maintenance in-line heating option. While these units are widely used in the food, dairy, and beverage markets, they are typically found in pharmaceutical applications where complete drainability is required.

**Direct Steam Injection**—These units inject precise amounts of steam directly into the cleaning solution as it is being pumped to the process.

**Electric Heater**—Although sometimes slower and potentially more costly to operate than other options, electric heaters can be a prudent choice if other heating options are unavailable.

PIPING AND VALVES

The network of piping and valves in a CIP system is designed to allow proper control of each process step with maximum efficiency.

**Piping**

- Should be the proper diameter to provide flow and pressure requirements.
- Should take the shortest route possible.
- Should be free from dead legs.

**Valves**

- Control the “traffic” in a system.
- Can operate manually or automatically
  - Manual valves require operator intervention for each step of the cleaning cycle.
- A number of different valves can be used depending on the industry, the application, and the amount of automation needed. Your CIP designer may choose from seat, butterfly, or diaphragm valves. Ball valves can be used; however, these are not typically a sanitary valve and can cause adverse effects within the process system if not properly utilized. The CIP system designer should be consulted prior to their use.
CIP systems must meet and maintain critical parameters for the duration of the cycle. If the specification is not met, cleaning must be repeated.

In a manual system, all activities are exposed to guesswork and inconsistencies due to human error, which leads to higher cleaning costs and potential safety risks. Each CIP system should have some degree of automation. The level of automation and control depends on your needs, but typically the more automated tasks you have in your CIP system, the better repeatability, consistency, and accuracy your system will have.

A well-automated CIP system using the appropriate calibrated instrumentation greatly reduces the risk of insufficient cleaning by allowing the operator to preset and monitor all critical parameters for proper cleaning. Visual and audible alarms can even be installed that will alert the operator of any deviation from program parameters.

**KEY INSTRUMENTATION**

**Temperature Transmitters**
- Monitor the temperature of the CIP supply and return lines, and possibly the caustic and acid solution tanks.
- Probes in the return lines detect when the return temperature has reached the desired set point and timers can be started.
- Can send a signal back to the heating system to regulate the temperature as needed.

**Level Transmitters/Level Probes**
- Monitor tank levels of wash and rinse tanks.

- Can signal to turn valves on and off to add water or chemicals automatically as needed.
- Ensure sufficient volume to run a cleaning cycle.

**Flow Transmitters**
- Ensure turbulent flow for piping and optimum flow required for spray devices.
- Totalize the amount of liquid delivered to each CIP circuit to precisely control wash and rinse steps.

**Pressure Transmitters**
- Makes sure pressure is sufficient for spray devices to operate optimally.
- Can detect if there is an obstruction or break in the circuit when pressure is too high or too low.
- Conductivity Probes & Transmitters
- Monitor chemical concentration levels in caustic and acid solution tanks and in supply and return lines.

**Turbidity Sensors**
- Determines when the pre-rinse has flushed sufficient soil from the system.
- Verify that the final rinse has removed all chemicals and soil.
- Avoid excessive water use from over-rinsing.

**Variable Frequency Drives (VFD)**
- Flow rates can be automatically reached and maintained with a control loop from the flow transmitter.
- Ensure that line circuits achieve the minimum liquid flow velocities for surface contact in the various pipe diameters and that sufficient flow is provided for the spray devices in the tank circuits.
- Control the pump speed to ensure the line circuits achieve required flow velocities.
- The flow transmitter can automatically monitor flow and adjust the VFD as needed.

"IN A MANUAL SYSTEM, ALL ACTIVITIES ARE EXPOSED TO GUESSWORK AND INCONSISTENCIES DUE TO HUMAN ERROR, WHICH LEADS TO HIGHER CLEANING COSTS AND POTENTIAL SAFETY RISKS."
DOCUMENTATION
In addition to controlling and monitoring your CIP cycles, a suitable control system should also provide documentation for batch records to verify cleaning as part of a validation and verification process. Some control systems can store records onboard for easy retrieval.

The control panel, or Human Machine Interface (HMI) must be simple and intuitive with user-friendly graphics so the operator can understand the status of the cleaning operation “at a glance.”

A touchscreen option makes viewing access even quicker and easier by eliminating the need for a separate keyboard. The controls should be able to build and store multiple programs for various circuits while also allowing changes to wash cycles in real time.

The controls system should have some form of communication capability to the overall plant management system for a truly integrated cleaning solution.
UTILITY COMPONENTS OF A CIP SYSTEM

STEAM
Your CIP system may require plant steam, clean steam, or culinary steam, and depending on the design, condensate return lines may be required.

WATER
A potable water supply needs to be able to charge the tank(s) quickly. For hygienic reasons, designs may require de-ionized water (DI), water-for-injection (WFI), or water that has been processed through reverse osmosis (RO). The level of calcium and magnesium salts in the water supply, known as “hardness,” is of critical importance to the CIP process. When heated, hard water can precipitate calcium carbonate, which can build up or stain piping and equipment which must be removed with acid cleaning. Calcium salts in hard water can also interfere with detergents, making them less efficient, requiring higher chemical concentrations to clean effectively. Experts recommend that hard water be softened to a level between 70-125 ppm.

DRAIN ACCESS
Eventually, something is going to the drain. Drain access should be convenient to the CIP system and it should have the capacity to handle the effluent volume produced by the cleaning process. Drain piping should also be composed of materials that can handle elevated temperatures and chemicals.

ELECTRICITY
An ample supply of 480VAC 3-phase power is recommended for the supply and return pumps. Valves, instrumentation, and controls may require single-phase 120VAC, 12 or 24VDC, or 4-20mA signals. Depending on the processing environment, incorporating explosion-proof housings and enclosures into the system may also be required.

AIR
Plant air, instrument air, or process air may be required to actuate and control valves, pressurize tanks, propel a product recovery projectile, or purge piping. It is imperative that the supply can keep up with the demand.
Every CIP cleaning cycle has its own unique set of parameters, so there’s really no such thing as a “typical” CIP cycle. The elements, sequence, and duration of the cleaning process can vary widely from one system to another, but some common steps are included in most cleaning cycles.

**PUSH-OUT (OPTIONAL)**
Prior to the pre-rinse cycle, pushing out residual product in the process lines using a projectile-type Product Recovery System (PRS) improves cleaning and can save valuable product from going down the drain. A PRS easily integrates into existing systems, is simple to operate, and decreases CIP cleaning times.

**PRE-RINSE**
Use potable plant water, de-ionized water (DI), water that has been processed through reverse osmosis (RO) or re-use the final rinse solution from the previous cleaning sequence. The pre-rinse wets the interior surface of the lines and tanks, removes most of the remaining residue, dissolves sugars, and partially melts fats. It also provides a non-chemical pressure test of the CIP flow path. The pre-rinse is a very important step in the CIP process because a well-monitored and well-executed pre-rinse makes the rest of the wash cycle predictable and repeatable.

**CAUSTIC WASH (140–185°F)**
The main detergent wash. Removes organics like proteins and fats. For very heavy soil, caustic wash may require a two-stage approach. The first wash is sent to the drain and the second can be recovered and re-used.

**INTERMEDIATE RINSE**
Fresh water flushes out residual traces of detergent remaining from the caustic wash. Use proper instrumentation during each step of the CIP Cycle, including rinsing, ensures proper cleaning.

**ACID WASH (OPTIONAL)**
Dissolves mineral scale from hard water deposits, protein residues, and neutralizes the system pH.

**FINAL RINSE**
Rinse with either DI, RO, or city water to flush residual cleaning agents.

**AIR BLOW (OPTIONAL)**
Removes moisture remaining after the final rinse.

**SANITIZING RINSE**
May be required to help kill microorganisms before starting the next production run.
CHEMICAL BASICS

Given the many variables that go into selecting the right chemicals for each CIP application, it is recommended you contact your CIP engineering partner to purchase chemicals that are right for your needs.

Below are more details on CIP chemicals and general guidelines for their use. The right chemical cleaning agents in the right concentrations make a significant difference in the efficiency of your CIP system. When used properly, CIP cleaning agents:

- Reduce surface tension of water, making it easier for the cleaning solution to penetrate soil.
- Break down bonding forces between soil and surface.
- Soften fats so they can be rinsed away.
- Dissolve soils for easier cleaning.
- Emulsify water-soluble soil in the cleaning solution for easier transport.

Without chemical additives most CIP systems still achieve a reasonable level of cleanliness and safety, but time, action, and temperatures required to do it increase.

In manual CIP systems, operators often add more chemicals than needed to meet cleaning requirements. This overcompensating can be costly. Understanding the role chemicals play in your cleaning regimen, and adopting automation for dosing control and concentration monitoring, help to keep those costs in check.

Cleaning procedures must be carried out safely because very strong chemicals are involved that can be harmful to people and equipment. A well-designed CIP system minimizes operator exposure to chemicals. Also, cleaning in place should be conducted with the least possible impact on the environment by minimizing water and detergent usage and by maximizing the recovery and re-use of resources.
CAUSTIC

Also known as caustic soda, sodium hydroxide, or NaOH. This is an alkali with a very high pH that is typically used in a concentration range of 0.5-2.0%. Concentrations as high as 4% may be used for highly soiled surfaces. It is typically used as the main detergent in most CIP wash cycles. Caustic softens fats, making them easier to remove. A non-foaming formulation can help reduce pump cavitation and increase efficiency.

ACID

Nitric acid is the most commonly used wash for scale removal and pH stabilization after a caustic wash. At a typical concentration of 0.5%, it can be used effectively at lower temperatures than caustic solutions, requiring less heating. Phosphoric acid is sometimes used but is somewhat less common. Many dairies use acid washes regularly to remove milk scale, also called “milk stone.” Acid is also excellent for brightening up discolored stainless steel by removing calcified mineral stains. Acids must be used with caution because they can attack some elastomers in the system like gaskets or valve seats, causing premature degradation or failure. It is important to note that an acid wash should not precede the caustic wash when removing milk deposits as acid could cause protein precipitation, thus making it more difficult to remove.

SANITIZER/DISINFECTANT

The job of a sanitizer, also referred to as a disinfectant, is to reduce microorganisms to a level that doesn’t pose a risk to food safety or public health. For many years various hypochlorite solutions (potassium, sodium, or calcium), also known as “hypo,” have been used as sanitizers in many CIP cycles. Their active ingredient is chlorine (bleach), so they are relatively inexpensive to use and are very effective as a sanitizing rinse for soils that are prone to bacterial growth such as dairy products. Although it is a reliable antibacterial agent, bleach can also be very harmful to stainless steel, causing staining, corrosion, and pitting.

Bleach-based sanitizers like hypochlorites, when dissolved in the wastewater stream, can also cause some significant environmental problems by killing vital microorganisms in streams and waterways. Chlorine dioxide has been used as an alternative to hypochlorite solutions in cleaning applications with high organic loads such as poultry or fruit processing. It has much more oxidizing power than bleach but is less corrosive to equipment and is less harmful to the environment.

In recent years more sanitation managers have turned away from bleach-based sanitizers in favor of peracetic acid (PAA). A combination of hydrogen peroxide and acetic acid, it is a strong disinfectant even at low temperatures and rinses away well leaving little or no chlorine residue to corrode stainless steel. It is effective against all microorganisms, including spoilage organisms, pathogens, and bacterial spores. It has also proven to be more eco-friendly in the wastewater stream. Peracetic acid has a strong, pungent odor, so it should only be used in well-ventilated areas.

Care should always be taken to rinse all sanitizers thoroughly from the system to reduce the risk of corroding stainless steel and potentially forming poisonous chlorine gas if mixed with acid. It should also be noted that it is possible to sanitize a system without using any chemicals at all by applying either hot water (approx. 195 - 205° F for 15-20 minutes) or low-pressure steam. Both of these non-chemical options would require a significant increase in energy costs and are relatively uncommon.

STERILIZER

Sterilizing a system means completely eliminating all living microorganisms. Sterilization can be done using chemicals, but it is usually done with high pressure steam (approx. 250° F for 30 minutes). While food, dairy, and beverage processing plants seldom require this step in their CIP process, it is a common cleaning operation for pharmaceutical or extended shelf life (ESL) products.
GETTING THE MOST OUT OF YOUR CHEMICALS

CHEMICAL TIPS: PROS & CONS

Elevating the temperature of a cleaning solution increases its soil removal efficiency.

The additional energy required to heat the solution adds cost to the process, but hot molecules with high kinetic energy dislodge soil faster than the slow-moving molecules in a cold solution. Care should be taken to prevent overheating of caustic solutions as too much heat will potentially have an inverse effect and decrease the efficacy of the chemical solution. Contact your chemical supplier for specific details regarding suitable temperatures.

A concentrated cleaning solution will clean a dirty surface better than a dilute solution.

More chemicals will mean more money, but the increased surface binding capacity of a higher concentration cleans better and faster. Conversely, chemical concentrations that are too high may result in the degradation of elastomers and stainless steel surfaces. Care should be taken to avoid the “more is better” mentality.

Longer periods of detergent contact exposure will clean better than shorter periods of exposure.

More time spent cleaning means less time making profitable product, but over time the chemicals will dissolve hard soils from the surface.

Chemical solutions can lose their strength over time.

Check the concentration of your wash solutions daily and adjust or replace them as needed.

RECOVERY AND RE-USE

Environmental impact issues and chemical costs in the 1960s and 1970s drove the move to CIP systems that could re-use caustic and acid solutions. In situations with light to moderate soiling, wash solutions can be returned to their appropriate CIP tank and be re-used for subsequent cycles. The number of re-uses varies by the amount of soiling and the chemical concentration, but re-using some solutions for dozens of washes is not uncommon.

For heavy soiling applications, re-using the wash solution isn’t practical so it is typically sent to drain after a single use. Also, a single-use system should always be used if your cleaning protocols demand that absolutely no cross-contamination occurs between batches.

In many systems, it is common for the final rinse water to be recovered and re-used as the pre-rinse solution for the next cleaning cycle. The residual heat and chemicals it retains from the final rinse will help make the following pre-rinse more effective and economical. However, the solution from the sanitizing rinse cycle should never be re-circulated under any circumstances. Sanitizers reduce bacterial growth but don’t completely kill all pathogens in the system. Since it is the last step in the cleaning process, re-circulating the sanitizing solution could run the risk of spreading leftover contamination. Sanitizers can also be sensitive to high temperatures and can lose their effectiveness rapidly once they are in solution.
TEMPERATURE

Calculating accurate solution temperature is critical to effectively cleaning your system while reducing energy costs. Some studies have shown that for every one-degree reduction in CIP solution temperatures, reduces energy needs by 1%, which can result in significant savings over the course of a year.

We know that higher solution temperatures can increase the effectiveness of chemicals and mechanical action; they can also reduce the amount of time needed to clean properly. But considering the cost of energy to heat the solution, it is important the temperature of each individual cleaning stage be calculated and controlled as accurately as possible.

Each stage of the cleaning process has its own optimum temperature range to balance effective cleaning with energy conservation. Below are some typical CIP temperature ranges.

<table>
<thead>
<tr>
<th>CIP STAGE</th>
<th>APPROX. TEMP RANGE</th>
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</thead>
<tbody>
<tr>
<td>Pre-Rinse</td>
<td>104°–140° F</td>
</tr>
<tr>
<td>Caustic Wash</td>
<td>140°–185° F</td>
</tr>
<tr>
<td>Intermediate Rinses</td>
<td>Ambient–140° F</td>
</tr>
<tr>
<td>Acid Wash</td>
<td>130°–150° F</td>
</tr>
<tr>
<td>Final Rinse</td>
<td>Typically Ambient</td>
</tr>
<tr>
<td>Sanitizer</td>
<td>Typically Ambient</td>
</tr>
</tbody>
</table>

- CIP is only for equipment and piping that is CIP-able. Not everything is designed for CIP, such as tanks with lift-off lids.
- Whenever possible, run piping circuit cleaning cycles separate from tank cleaning cycles.
- Extremely long piping circuits may have to be cleaned in shorter circuit sections.
- Don’t try to clean large-diameter piping and small diameter piping at the same time.
- Always ensure that every component in the line receives a turbulent flow rate.
CHOOING THE RIGHT TYPE OF CIP SYSTEM

CENTRALIZED VS. DISTRIBUTED

Designing a custom CIP system for your specific process starts with deciding whether your system should be centralized or distributed.

A centralized CIP system is a single system that delivers cleaning solutions to an entire process facility. It can supply many different circuits and coordinate a large number of operations from a single location so operators can manage processes using a central set of controls. The location of a centralized CIP system in a plant is important. If all processing areas are relatively close in proximity, and they all have similar cleaning requirements, a centralized system can be cost effective. Centralized systems tend to be larger in size and scope than distributed systems.

A distributed CIP system uses local dedicated systems to service individual sections of the plant. This strategy works well for:

- Manufacturers that have process areas in remote locations that are difficult or costly to reach with piping from a centralized CIP unit.
- Manufacturers that have operations with very specific cleaning requirements that are incompatible with the cleaning requirements of the other operations, such as stringent cross-contamination demands.
- Manufacturers who are new to clean-in-place operations.
- Manufacturers that want to clean-in-place but are limited by budget constraints.

Transportable CIP skid systems can be especially useful for the above applications. On transportable skids, all of the necessary equipment needed to clean-in-place is mounted on a compact, self-contained skid that can be easily transported to any location in the plant. The mobility of these systems, such as CSI’s “Compact CIP” unit, gives the user considerable flexibility in their cleaning operations. They can also be an excellent solution for processors who are budget conscious or is cleaning in place for the first time. For more information on CSI’s Compact CIP system, go to www.csidesigns.com.

BASIC VS COMPLEX

At its most basic, cleaning in place can be a manual one-tank, single-use system that sends solution one time through a single circuit and then sends it to drain. This strategy isn’t very environmentally friendly and is relatively expensive in terms of chemicals, water usage, and effluent costs, but it can be a valid strategy for small systems and for avoiding cross-contamination. Single-use systems can also be well suited for cleaning heavy soil loads that would make solution recovery and re-use impractical. A single tank system carries a smaller initial price tag than a multi-tank system, but the cleaning can be much slower since operators must wait for the tank to fill and drain for each step.

At the other end of the spectrum, a CIP system can be as complex as a fully automated multi-tank, multi-circuit apparatus that recovers and re-uses solutions while cleaning in parallel with processing activities. All the cleaning and rinsing solutions can be pre-charged into their own tank and pre-heated to their optimum preset temperature, ready to go. The initial investment for complex systems can be higher, but they are designed to be ultra-cost-effective by reducing downtime, reclaiming and re-using solutions and closely monitoring water, chemical, and energy usage. Highly automated systems that systematically conserve resources provide a much higher overall return on investment than simpler manual systems.
Making the right system choice depends on three key questions: what kind of product are you cleaning, what equipment are you cleaning, and how often do you need to clean?

**WHAT KIND OF PRODUCT ARE YOU CLEANING?**

Different types of food and chemical soils present different types of cleaning challenges. Identifying the kind of product soil you are cleaning helps you identify what you need from your CIP system.

**Light Cleaning**

Product soil in this category is the easiest to clean and requires a less complex cleaning system. This type of soil is easily soluble and doesn’t adhere tightly to the walls of tanks and piping. In many cases, a majority of the soil can be removed with a thorough pre-rinse. The remaining soil is easily dissolved with a caustic wash. Lower temperatures and fewer chemicals are required since the nature of the product soil allows the action of the fluid to dislodge and carry away most of the soil and a single caustic wash cycle finishes the job. A single or two-tank system may suffice in most cases.

**Moderate to Heavy Cleaning**

Less soluble products require stronger detergent concentrations and higher temperatures to adequately remove the soil. Fats and proteins, particularly when exposed to high heat, must be broken down in order to be flushed from the system. Dairy products can also leave behind a tough scale that will require an acid wash.

Dense, dried, or insoluble material can be the most demanding to clean. For these products, it may be cost-effective to clear a majority of the residual product in the lines by using a projectile product recovery system prior to cleaning. The savings in time, water, chemical, and energy costs could easily offset the cost of the projectile system in just weeks or months. Pre-rinsing dense material typically removes less soil, so it may be possible to re-use the same pre-rinse on multiple washes. Multiple high temperature caustic and acid washes may be required.

<table>
<thead>
<tr>
<th>LIGHT SOIL TYPE CHARACTERISTICS</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Liquid Soluble product</td>
<td>• Sugars and salts</td>
</tr>
<tr>
<td>• Low bacterial growth risk</td>
<td>• Sports drinks &amp; sodas</td>
</tr>
<tr>
<td>• Unheated organic soils</td>
<td>• Suspended grease, fats, &amp; oils</td>
</tr>
<tr>
<td>• Liquids w/ dissolved or suspended solids</td>
<td>• Fruit juices</td>
</tr>
<tr>
<td></td>
<td>• Fresh wet vegetable or meat product</td>
</tr>
<tr>
<td></td>
<td>• Dirt or extraneous non-food material</td>
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<table>
<thead>
<tr>
<th>MODERATE TO HEAVY SOIL TYPE CHARACTERISTICS</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Wet carbohydrate material</td>
<td>• Burnt grease, fats, &amp; oils</td>
</tr>
<tr>
<td>• Dried liquids with suspended or dissolved solids</td>
<td>• Dairy proteins</td>
</tr>
<tr>
<td>• Heated organic soils</td>
<td>• Meat slurries or pastes</td>
</tr>
<tr>
<td>• Wet or semi-dry fruit material</td>
<td>• Cheese</td>
</tr>
<tr>
<td>• Dried or semi-dried carbohydrate material</td>
<td>• Limescale</td>
</tr>
<tr>
<td>• Ground or emulsified proteins</td>
<td></td>
</tr>
<tr>
<td>• Wet or semi-dry proteins</td>
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</tbody>
</table>
WHAT EQUIPMENT ARE YOU CLEANING?

The size and design of your CIP system are heavily influenced by the piping and equipment you are cleaning. A CIP system is designed to clean only piping and equipment that is specifically CIP-able. Processors should ensure their process circuits and equipment are designed to be cleaned in place. A CIP system can only work well when used with a CIP-able process system of piping, valves, and tanks.

Piping

Proper cleaning of your piping, tubing, and in-line fittings is a primary focus for any clean-in-place system. The strategy for satisfactorily cleaning them is fairly straightforward. The key is the second letter of the TACT acronym: Action. Regardless of the time, temperature, and chemical concentration of your cleaning fluid, the flow velocity must be high enough to create turbulent flow, or “action.” This mechanical action is primarily responsible for dislodging residual product from the interior surface of the process lines and fittings. The correct supply flow rate creates enough turbulence throughout the complete circuit, to give you the cleaning results you need.

The larger the line size, the more flow required to achieve required velocity. Pipe size is therefore a factor in pump selection. Variables such as internal surface finish, piping elevations, and the number and type of fittings all play a part in the final calculation and equipment specification.

To be cleaned in place, all parts of the process system must be drainable, which means that piping should be sloped properly to allow for drainage. Ideally ¼ inch per foot. Tank bottoms must be designed correctly to be fully draining. And eccentric reducers used appropriately to reduce liquid holdup in process lines. Proper draining helps avoid bacterial growth and potential corrosion of the piping.

The inside surface finish of the piping can greatly impact cleaning cycle requirements. The smoother the surface finish, the more easily the soiling will release from the surface. EHEDG and 3A both require a surface roughness average of no greater than 32Ra µin (0.8Ra µm). All interconnecting piping should also have cleanable joints that are sanitary and CIP-able with elastomers that are compatible with the CIP chemicals and the product. Any piping or fittings that cannot be cleaned adequately by CIP such as dead legs or instrument connections must be removed from the circuit and cleaned by other means.

Valves

Much like the process lines they are mounted in, cleaning process valves in place is primarily dependent on turbulent flow rushing through the valve to dislodge residual product.

All internal areas of a valve that have been exposed to product must be exposed to the cleaning solution; therefore, all valves must be specifically designed for CIP. Valves that are not explicitly designed for CIP lack design features that allow flow through the valve to adequately clean all internal surfaces. Any valve that is not specifically designed for CIP must be removed from the circuit and cleaned by other means. In most cases, they could be replaced during the CIP cycle by a simple spool piece.

Valves must also be cycled through their full stroke length during cleaning to ensure proper cleaning. This step can be labor intensive for manual valves but is easily programmable for automated systems.

Tanks

Tanks and vessels present their own unique challenges. Proper selection and placement of the spray devices used to wash the interior surface of the tank is a complicated process and should only be done by an experienced tank cleaning expert. Some spray device manufacturers have developed computer programs that can run a virtual cleaning cycle on your tank using a number of different spray devices. These programs can be a big advantage in determining the best device for the job and optimal positioning as well.
The interior surface of the tank should be a smooth, cleanable surface. Any internal components that are not essential to the manufacturing process should be removed, if possible, to avoid blind spots or “shadows” that might be blocked from exposure to the cleaning solution. For best results, all corners should have a radius and all weld seams should be located on flat areas, not in the corners.

Take additional care to ensure that all port locations and recesses inside the tank are sufficiently exposed to the cleaning solution, which can be difficult to reach and may receive inadequate cleaning as a result. All spray devices should be located and oriented so that the cleaning solution is directed precisely at the intended location with sufficient flow and pressure. Without adequate volume or force the cleaning solution is unable to do its job. For example, spray devices are commonly installed to direct their spray upward to the top of the tank so the solution can clean the sides as it cascades downward. Frequently there is far too little volume supplied to the spray device and as a result, the top of the tank is well cleaned but the rest of the tank is poorly cleaned. The remedy for this common mistake is to increase pump capacity to provide enough flow and pressure to the device.

Your process system may also contain other equipment that may not be easily CIP-able. Your cleaning system designer will evaluate each component, including fillers, mixers, coaters, spray dryers, totes, blenders, vats, ovens, or freezers, and determine whether they can be cleaned in place adequately. Some equipment may require installing a custom piping component or removing some element of the circuit completely in order to facilitate cleaning in place.

HOW OFTEN DO YOU NEED TO CLEAN?
CIP cycles are typically run either after a processing run that has produced normal soiling or when changing over a processing line from one product to another. The frequency must be sufficient to ensure product safety and quality, bearing in mind that cleaning cycles that are run more frequently than necessary can waste valuable time and resources. That’s why it is important to consider the nature of the product when determining frequency of CIP cycles.

Some products are not prone to bacterial growth and may not require a CIP cycle following every production run. Products such as carbonated soda and vinegar are acidic and do not represent a high risk for bacterial growth, so less frequent CIP cycles may be possible. Dairy products, on the other hand, can quickly grow harmful bacteria and must be cleaned regularly and thoroughly.

Products that are exposed to high temperatures during processing can pose additional cleaning concerns. Dried or burnt-on soils can be difficult to remove, so cleaning cycles should be frequent enough to minimize build-up.

CLEANING THE CLEANING SYSTEM
Periodically the cleaning system itself needs to be cleaned. It is important to include this aspect in the CIP design if you plan on installing dedicated piping and spray devices in the CIP tanks. Alternately, facility standard operating procedures should be put in place for operators to manually clean and inspect the CIP system. If the CIP system utilizes spray devices, the control system can be set up with a self-cleaning recipe. Auto cleaning removes build-up of cleaning products and residue in the piping and tanks, enabling the CIP system to operate at maximum efficiency.
The more sophisticated a CIP system is (the more tanks, the more advanced the controls), the greater the initial investment to purchase and install a system. CIP is an investment that provides consistent long-term returns. If properly implemented, every time you run an efficient cleaning cycle; you are getting back valuable production time previously lost to slow, inefficient cleaning practices. Saving just a few minutes of cleaning time each week can generate thousands of dollars in additional production. Depending on cleaning frequency and product value, many processors commonly see a full payback on their CIP system in 1-2 years by saving cleaning time each week.

VALIDATION & VERIFICATION

Although they are often used interchangeably and are closely related concepts, validation and verification are two separate and distinct documentation requirements for CIP. Cleaning is an essential part of assuring the health and safety of food products and the customers that use them, so documented proof of your cleaning process and its effectiveness may be required by law, by industry, or by customer certification. Some of the more advanced CIP control packages can capture data automatically for use in validation and verification.

CONTRACTED SERVICE AND REPAIR IS THE BEST VALUE

Two realities advise against in-house service and repair for CIP systems: 1) The costs in time, tools, and equipment for maintaining systems and 2) risks of damage to equipment from inexpert practices.

Typical service and repair contracts include timely replacement of parts, service kits for valves, and pumps (seals, O-rings, and other parts subject to wear), a check of all instrumentation, plus diagnosis of causes when parts show unusual wear.

Maintenance contracts ensure that systems undergo thorough review and testing, which CIP experts can perform faster and more safely than untrained staff. Some of the most common repairs for outsourcing include pump repair and remanufacture, heat exchanger service and testing, process valve service and repair. Contracts may include onsite repair and preventative maintenance for CIP skids.

The decision to repair rather than purchase new pumps should be based on expert evaluation of current equipment and CIP function. The repair service will disassemble the pump and prepare a quote for the recommended repairs and include a mechanical run test prior to returning it. Check for providers who provide new warranties on new parts and waive the evaluation fee if they provide the repairs.
Purchasing and installing a CIP system for your processing facility is a considerable undertaking, requiring analysis, planning and above all, partners.

**The best first steps are:**
- Create a team of knowledgeable operators.
- Create a team of managers from multiple departments.
- Connect with a trusted company that has vast experience in designing and building process and CIP systems.

That's where we come in.

CSI has the ability to engineer, design, and fabricate a custom Clean-in-place System to meet your exact hygienic processing needs. CIP equipment from CSI helps you control, monitor, and document the cleaning methods that are essential to sanitary processing.

With CSI’s state-of-the-art, climate-controlled fabrication shop, the quality of equipment leaving our facility is second to none. We offer in-house, Level II inspection in accordance with the latest ASNT recommended Practice No. SNT-TC-1A, so you can be certain your equipment meets industry standards.

To speak with a CIP expert call 417.831.1411 or email sales@csidesigns.com