CIP for CPGs

Clean-in-Place Guidelines for Consumer Packaged Goods Manufacturers
CIP for CPGs: Clean-in-Place Guidelines for Consumer Products Manufacturers

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Leadership Network
Moving Operational Excellence Forward

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NOTE: Websites are hyper-linked throughout this document.
1. OVERVIEW

Clean-in-place (CIP) is the removal of soil from product contact surfaces without disassembly by circulating, spraying or flowing chemical solutions onto and over the surfaces in the processing configuration. It is a widely utilized practice, especially for systems that process food, dairy, beverages, cosmetics, personal care, pharmaceutical, nutraceuticals, pet food, bio-tech.

A goal of this document is to outline generic definitions, equipment considerations, best practices, and protocols for CIP that can be leveraged across multiple process lines to drive improved operation, product quality, consumer safety, and sustainability results.

Consumer Packaged Goods (CPG) quality assurance & operations, sanitation suppliers, and Original Equipment Manufacturers (OEMs) will find value in this “clear language document” with accessible examples, checklists, and protocol outlines.

An important highlight of the document is the clarity in purpose, techniques and terms regarding CIP system validation. Well-designed CIP systems can meet the challenges of the Food Safety Modernization Act (FSMA) recommendations on cleaning and sanitation, as well as Sanitation Preventive Controls and verification.

Currently, FSMA rules do not have a mandatory validation requirement for CIP cleaning and sanitation. This document provides an outline for CPG companies, if they desire, to have initial validation evidence of their CIP cleaning programs are effective. Developing a verification plan and documenting the results of CIP cleaning procedures can satisfy the needs the company’s food safety personnel, corporate management, consumers and support the argument that a company is proactive in its food safety measures.

The following document is intended to provide practical guidance to food facilities of any size.

This CIP guidance for CPG companies is specifically developed for those manufacturers that use “wet” cleaning procedures. Operations that avoid water and moisture for cleaning, using “dry” cleaning techniques, use practices and procedures that are not the focus of this CIP document.

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Facilitated by PMMI, the OpX Leadership Network is a dynamic community of manufacturing, engineering and operations professionals dedicated to operational excellence. Through open dialogue between CPG manufacturers and OEMs, the OpX Leadership Network provides an exceptional forum where the best minds come together to identify and solve common operational challenges, and apply best practices and innovative solutions to the real-world context of manufacturing.

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LIMIT OF LIABILITY

This document is not a comprehensive document on “how to” develop and validate a CIP cleaning procedure nor is it a summary of all the various cleaning and sanitation procedures, but rather is a tool to assist in the many activities associated with CIP systems. The intent of this document is to outline major activities that should take place and identify needs if any deficiencies are found. Several resources are listed to assist with CIP activities. For sanitation strategies, it will be important to work closely with chemical suppliers in choosing the compounds and procedures used for cleaning equipment and food contact surfaces to remove target soils. In many situations, they can provide proven solutions to meet cleaning and sanitation needs.

This document does not outline the only approach to organizing, developing and validating a CIP system. Companies use different approaches to meet corporate, customer and regulatory requirements. The methods and approach taken in the development of a CIP system should reflect the conditions mandated by the product, production schedule, or other special needs. In all cases the CIP system should provide precise instructions that will ensure the proper cleaning and sanitizing of all equipment to remove contaminants and microorganisms that could cause harm to consumers.

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3 CLEANING

3.1 DEFINITION

Cleaning is the process of removing soils.

SOILS
- Product liquids, solids, and particulates (fats, sugars, proteins, etc.)
- Denatured product
- Viscous and semi-viscous product
- Allergens
- Scales and films
- Mineral deposits (water hardness, calcium, titanium dioxide, etc.)
- Microbiological organisms and biofilms
- Physical hazards (metal shavings, plastics, wood, lubricants, etc.)

METHODS
- Fully automated, partially automated, manual
- Clean in Place (CIP)
- Clean out of Place (COP) (wash tunnel, tub)
- Hand or manual
- Dry clean or wet clean
- Assisted Circulation System (ACS)

FACTORS
- Time
- Temperature
- Mechanical action or force
- Chemical action/concentration
- Procedures (SSOP, preparation etc.)
- Equipment design & materials of construction
- Equipment installation
- Water chemistry
- Internal/external cleaning methods

Sanitizing is the process of reducing the number of microorganisms present on a clean surface to an acceptable level.

METHODS
- Heat (steam, hot water, or hot air)
- Radiation (ultraviolet)
- Chemicals (chlorine, iodine, hydrogen peroxide, alcohol etc.)

FACTORS
- Concentration
- Temperature
- Contact time
- Equipment design, materials of construction, installation
- Residual soils after cleaning
3 CLEANING

3.2 REASONS TO CLEAN

Cleaning is necessary to eliminate food hazards, meet regulatory requirements, and assure product quality attributes resulting in safe, high quality food. These hazards and circumstances include:

**CHEMICAL**
- Allergens
- Gluten
- Residual cleaning or sanitation chemicals
- Lubricating chemicals

**LABEL CLAIM COMPLIANCE**
- Organic
- Kosher
- Halal
- “Free of” claims
- GMO/Non-GMO

**PHYSICAL**
- Foreign material

**PRODUCT QUALITY**
- Product sensory characteristics

**BIOLOGICAL**
- Pathogens
- Spoilage organisms
- Pests

**OPERATIONAL**
- Product build up that affects equipment functionality/reliability
- Batch/Lot segregation
- Worker safety

**REGULATORY**
- FDA
- USDA
- FSIS
- PMO
- State Health Departments
3 CLEANING

3.3 DETERMINING CLEANING APPROACH

What is the reason for cleaning?
See section 3.2

What do I want to accomplish?
Cleaning | Cleaning + Sanitizing

What am I trying to remove?
Protein | Allergens | Carbohydrates | Fats/ Oils | Minerals | Biofilm

What is the physical state of soil?
Viscous | Solids | Fouling | Scale

What is my chemistry?
Water Only | Alkali | Acid | Sanitizer | Additive

How can I accomplish the task?
CIP (Automated) | ACS (Assisted) | COP | Manual
4 CLEANING-IN-PLACE

OVERVIEW

First, the design of processing systems must include cleaning methods. It is important to remember that only systems that have been properly designed, installed, and maintained can be effectively and consistently cleaned in place.

⚠️ It is imperative for safety of personnel, products, and longevity of equipment to assure the entire team (operators, sanitation, maintenance, etc.) are all properly trained and aligned with the operational protocols and objectives of CIP.

For a system to truly be cleanable in place it must abide by 5 rules:

1. The unit operations and equipment components used in the system have been designed for CIP and have been verified to clean in place, by 3-A-SSI, EHEDG, or an acceptable alternative method.

2. The system must have been installed so that it maintains its clean in place integrity. This includes not only the materials and craftsmanship but also the proper fluid dynamics for the CIP solution supply and return to the process equipment.
   ⚠️ 3A-SSI accepted practice 605 is a good guideline.

3. The process piping and equipment must be able to receive the prescribed flow, temperature, time, chemical concentration and pressure of cleaning solution required by the manufacturer or process design engineer. Active monitoring and adjustment of these critical process parameters throughout the cleaning cycle is important.
   ⚠️ Often the process lines are not capable of delivering the CIP flow required of the equipment and additional design considerations should be made.

4. Once a CIP process has been validated, proper change control procedures should be in place to maintain an accurate record of the critical process parameters (e.g. time, temp, flow, pressure, and conductivity/concentration). Routine visual inspection, chemical residual verification on final rinses, and microbial verification are common safeguards to ensure system performance is consistently achieving proper cleaning.
   ⚠️ The validation plan is developed and maintained by the facility.

5. A preventative maintenance and instrument calibration program must be in place to ensure the equipment and process is maintained as designed. Periodic inspection of in-line filters and magnetic traps is required to mitigate potential threats from foreign materials.
   ⚠️ Worn elastomers, leaking seals, corrosion of stainless steel and mechanical damage to equipment can all create concerns for cleaning.
4 CLEANING-IN-PLACE

4.1 PREPARATION

The cleaning process begins with proper description and preparation of the system and supplies for cleaning. Product should be emptied/drained from the equipment to be cleaned, using methods specific to the equipment and product. Effective removal of gross amounts of product will reduce the time and water demands of the subsequent pre-rinse step.

Preparation of the system may also include:

- Verification with other departments that cleaning can take place
- Ensuring a proper maintenance and safety plan is in place including:
  - Chemical storage and handling plan
  - All safety measures are addressed (e.g. proper personal protective equipment, venting)
  - Lock out Tag out (LOTO)
- Changing positions of transfer panel swings
  - Use of electronic proximity sensors to detect transfer panel position and provide safety interlocks is recommended.
- Verify adequate cross connection control. This may include manual connections (with or without proximity sensors) and valves (mix-proof or other), to provide safe separation of cleaning materials from other products, product contact materials, and utilities.
- Use of product recovery or air blow systems
- Connection of any equipment bypass loops
- Removal of COP components of equipment (e.g. pump rotors, strainers, etc.)
- Shut down of cooling or heating media to process heat exchangers or jackets
- Verification of available cleaning chemical for automated dosing systems
- Preheating of the CIP system
4 CLEANING-IN-PLACE

4.2 PRE-RINSE

The purpose of the pre-rinse is to remove gross residual product soils prior to introducing cleaning chemicals.

Turbidity Sensors
The use of a turbidity sensor on the CIP return piping is a good way to determine when pre-rinse has been completed. Conductivity and pH sensors can also be used.

Rinse Water Recovery
A common practice for water conservation is to utilize an additional tank to recover the final rinse water and use it as the pre-rinse for the next cleaning cycle. Allergen, microbial contamination and other cross contamination concerns should be considered in the water recovery design.

A best practice in some applications when using recovered wash and post rinse water is to begin the pre-rinse with potable water and verify for return flow before stepping to recovered pre-rinse water.

Waste Recovery
Efficient recovery of waste (chemical, product waste, etc.) should be considered to ensure that environmental, regulatory and corporate requirements have been met.

4.3 WASH

The wash cycle introduces chemical solutions that aid in the release and removal of soils. An example of a wash cycle typically consists of alkaline cleaning, followed by an intermediate rinse and acid cleaning when necessary for release of minerals or other contaminants. In some instances of heavy mineral deposits, an acid wash is prerequisite to the alkaline cycle. Wash cycles are commonly heated with the temperature of the wash cycle dictated by the chemical used and the equipment being cleaned. Equipment and chemicals may have a maximum allowable temperature for cleaning.

A rinse sufficient to separate chemicals should always be used between any alkaline and acid wash, as the reaction of the chemicals can have harmful effects on the equipment and/or personnel.

Water Source
A chemical supplier should be consulted, and a water sample should be analyzed to determine if any additional treatment is needed to make the cleaning water more effective. Hard water, for instance, can leave deposits on the equipment and may require more cleaning chemicals to be effective. Considerations should be made to ensure that all environmental, regulatory and corporate requirements have been met and to ensure that contaminants are not introduced into the system from the water.
4 CLEANING-IN-PLACE

4.3.1 ALKALINE WASH
The alkaline wash is customarily performed with sodium hydroxide, potassium hydroxide or other alkaline detergents. Alkaline cleaning is most effective when cleaning proteinaceous soils and other organic-based soils. Concentrations may vary by application - lower concentrations at moderate temperatures for circuits with low level of soil post pre-rinse, and higher concentrations at higher temperatures for circuits that have been exposed to high processing temperature and denaturation of proteins is prevalent.

Chemical selection is critical and complex therefore consult experts for proper selection and safety.

Conventionally, a single chemical step cleaning is adequate. However, a system with heavy soil load may require multi-step cleaning – a pre-alkaline wash followed by regular alkaline cleaning. In some cases, additional chemicals, such as surfactants and chelating agents, are used.

4.3.2 INTERMEDIATE RINSE
A post alkaline wash rinse is often required to remove the alkaline solution, as well as any surfactants or wetting agents, before introducing an acidic solution in the subsequent wash step. The rinse ensures cross contamination of chemical solutions does not occur within the processing equipment. An alkaline solution residue may precipitate when acid wash is introduced, resulting in longer acid wash and final rinse. An effective rinse can be determined by pH or conductivity instrumentation in the CIP return piping.

4.3.3 ACID WASH
An acid wash is commonly used post-alkaline wash to remove mineral deposits and neutralize residual sodium hydroxide. Acid at the right concentration and temperature is most effective in removing mineral deposits. It is important that strong acids or chlorinated solutions be well controlled, properly rinsed and drained.

Overdosing can cause catastrophic damage to equipment and even destroy common grades of 300 series stainless steel.

4.3.4 FINAL RINSE
A final potable (ingredient quality) water rinse is required after the last chemical wash to avoid adulteration of product. An adequate rinse can be measured and ensured with proper pH, conductivity, and/or turbidity instrumentation.

4.4 CLEANING SOLUTIONS
Choosing the correct chemicals or with combination of chemicals for the soils and the method and timing to incorporate each chemical are critical to achieve effective cleaning. It is recommended to determine the type of cleaning solutions to be used before designing the system in order to properly design the equipment with compatible materials of construction.

The organization should determine who is responsible for these decisions.
4 CLEANING-IN-PLACE

4.5 FLUID CHARACTERISTICS & TIME

The efficacy of each CIP process step is dependent on duration of the step and the fluid characteristics of the wash solution or rinse water. Time, temperature, flow, and chemical concentration can be varied to achieve clean equipment. For example, if a shorter cycle time is desired, then temperature, chemical concentration or flow can be increased to some degree.

4.5.1 TIME

In general, time required to clean is directly proportional to degree of difficulty to remove the soil load from the surfaces - light, water soluble products take less time to clean than fatty products and denatured or burned on proteins. Time is usually the least available, yet most impactful variable of CIP. It is the only variable that does not have an upper limit, although there is a point of diminishing return.

Time spent within acceptable ranges for chemical concentration, temperature, and flow is a critical parameter of each step in the cleaning sequence. As such, step time does not start until all required fluid parameters have been achieved. Time to achieve temperature, stabilize concentration, should be accounted for the total time of a cleaning sequence. The actual time required to clean any circuit or piece of equipment can only be truly determined once the system is in place and in use.

4.5.2 TEMPERATURE

In general, warmer temperatures are more effective for cleaning. However, excessively high or low temperature can be detrimental to chemical performance. The recommended temperature of the chemical manufacturer should be followed. Rinses typically utilize ambient water. The system should be designed to minimize drastic temperature changes between the wash and rinse fluids which could cause equipment damage. For proper measurement of CIP fluid temperatures, the CIP system should have two temperature indicators - one on the supply line and one on the return line. The return line indicator should be used for recording and verification as it indicates the minimum temperature experienced by the entire system. The supply line temperature transmitter is used to control the CIP fluid supply temperature. Delay in response of the return line temperature can be alarmed to indicate loss of fluid or other failure mode.

4.5.3 TURBULENT FLOW

Turbulent flow is critical to provide the mechanical action necessary for the removal of soils in piping, heat exchangers, and processing equipment. Turbulent flow is defined as a flow regime where the particle velocity at a given point varies erratically in magnitude and direction compared to laminar flow. A fluid velocity of 5 ft/sec (1.52 m/s) is minimum recommended velocity to achieve turbulent flow of aqueous solutions in sanitary process piping systems. Fluid velocity can be increased for more mechanical action on hard to clean soils, but velocity should not exceed 10 ft/s as hydraulic shock can begin to occur. The piping diameter determines the flow required to achieve the desired fluid velocity. Manufacturers of heat exchangers and other specialty equipment will recommend CIP flow required to achieve turbulence within their equipment.

4.5.4 FLOW RATE

Flow rate measurement is a critical parameter and cannot be replaced by pressure measurement. It is recommended to measure flow rate at the supply and return of the CIP system. This recommendation is not always possible or practical if equipment, such as a tank, disrupts the continuous flow of fluid. An alternative practice is to measure flow on the supply and detect flow in the return with a flow switch or indicator. Sequential pulsing of valves and flow diversions can cause the measured flow to fluctuate below the nominal flow. These fluctuations must be accounted into the validated time duration of a cleaning cycle. Flow measurement can also be used to detect and alarm system leakage.
4 CLEANING-IN-PLACE

4.5.5 CHEMICAL CONCENTRATION
The chemical concentration required to achieve effective cleaning depends on the characteristics of the particular soil. Chemical concentration can be achieved with metering pump and timed pulses or flowmeter delivery and measured on supply and return. Chemical concentration is typically measured in-line with a conductivity or pH meter. When a conductivity meter is used, a correlation of titration data must be used to calibrate the meter and routinely maintain meter accuracy.

4.5.6 PRESSURE
Pressure, when used in conjunction with flow measurement, is a good indicator of performance consistency. Pressure should be measured at the discharge of the CIP system. By monitoring system pressures, inconsistencies between different runs of the same circuit can be easily recognized. A change in pressure from baseline may indicate a mechanical change, such as a system leak, spray device not in place, or a strainer blockage, that may affect the cleaning performance. Some equipment, such as spray devices, requires a minimum and maximum pressure range to clean properly.

4.6 SANITIZATION
For some industries and applications, a sanitization step may be included in the CIP process. Sanitization is the application of effective treatment or method to already cleaned product contact surfaces for ensuring destruction of pathogens and other microorganisms. The sanitization step may be required by a regulatory agency. The procedure utilized must be acceptable by the respective regulatory agency and not adversely affect the equipment, product, or the health of consumers.

Sanitization can be accomplished by chemical or thermal means. Common methods for sanitization in the food & beverage industry are chemical sanitizers, steam, and hot water. The selection of a sanitization method, including chemical selection, is highly dependent on the application and applicable regulatory requirements.

Chemical Methods
There are several chemical compounds that may be used for sanitization. For applications governed by FDA or USDA, approved sanitizers are required. A list of approved sanitizers and respective concentration limits are contained in 40 CFR 180.940. As with all chemicals and must be used in accordance with manufacturer’s recommended use.

Thermal Methods
When thermal methods are used, such as with steam and hot water, flow must be maintained, and the lowest system temperature measured above a determined limit for a determined time period. Alternative fluids, such as hot oil, may be used in particular applications.

Note that in some cases, sanitization may not be required to have a final rinse, for example, when hot water or steam is used. All sanitizers must comply with manufacturer’s recommendation. It is a violation of Federal law to use sanitizer in a manner inconsistent with its labeling.
4 CLEANING-IN-PLACE

4.7 FINAL RINSE

The final rinse is typically process water. After successful rinsing of wash chemicals, a small amount of “no rinse” sanitizer can be added to the rinse water. The purpose of the sanitizer is to resist growth of microorganisms in any residual rinse water. This final rinse can be captured and stored in a recovery tank to be used for the pre-rinse of the next cycle if allowed for by the regulating authorities.

- When using a rinse recovery tank be extremely cautious that acid and alkaline are not conmingled.
- The final rinse is that last step in most cleaning regimen. An improper final rinse can result in product adulteration. It is good practice to use instrumentation to actively determine that all chemicals have been rinsed from the system.
- Rinse recovery is not typically permissible when Kosher processing is mixed with non-Kosher processing.
- When a conductivity meter is used to measure residual chemical, it is important to have temperature compensated data. When rinse water is recovered, caution must be taken for extended storage of this recovered water as micro-contamination may occur.

4.8 INSPECTIONS AND TESTING FOR EFFICIENCY AND RESIDUALS

The CIP system should be capable of accurately recording time, temperature, chemical concentration, and flow rate of each and every cycle. Monitoring of pressure is important in some applications. Additional quality assurance measurements of the final rinse water should be made either by automated or manual means. For example, an ATP swab test, or similar, should be done on the production equipment at prescribed intervals to verify that the established cleaning procedures remain effective.

- Sanitation, operators and QA should visually inspect process and CIP equipment regularly for proper maintenance including integrity of elastomers and seals. CIP instrumentation devices should be regularly inspected and tested to verify accurate measurement.
- Visual Inspection: It is essential in tank cleaning that the vessel being cleaned is completely drained between each CIP step and at the end of the CIP cycle.
5 CIP EQUIPMENT AND SANITARY DESIGN

Relevant CIP Standards and Guidelines

<table>
<thead>
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<tr>
<td>FDA - HACCP Principles &amp; Application Guidelines</td>
<td><a href="https://www.fda.gov/Food/GuidanceRegulation/HACCP/ucm2006801.htm#execsum">https://www.fda.gov/Food/GuidanceRegulation/HACCP/ucm2006801.htm#execsum</a></td>
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<tr>
<td>ANSI/3-A 00-00-2014</td>
<td>General Requirements</td>
</tr>
<tr>
<td>ANSI/PMMI B155.1-2016</td>
<td>Safety Requirements for Packaging and Processing Machinery&lt;br&gt;Note – This standard is about the iterative process of risk assessment.</td>
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<tr>
<td>EN ISO 14159:2008</td>
<td>Safety of machinery - Hygiene requirements for the design of machinery&lt;br&gt;Note – Harmonized standard listed in the Official Journal of the European Union for demonstrating compliance with the requirement of the EU Machinery Directive 6006/42/EC</td>
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<tr>
<td>3-A 78-01 (11/2003)</td>
<td>Spray Cleaning Devices Intended to Remain in Place</td>
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<tr>
<td>3A 604-05 Accepted Practice (8/1994)</td>
<td>Permanently Installed Product and Solution Pipelines and Cleaning Systems Used in Milk and Milk Product Processing Plants</td>
</tr>
<tr>
<td>ASME BPE – 2016</td>
<td>Bioprocessing Equipment&lt;br&gt;Note – This ASME Standard provides the requirements applicable to the design of equipment used in the bioprocessing, pharmaceutical and personal-care products industries, as well as other applications with relatively high levels of hygienic requirements. It covers materials, design, fabrication, inspections, testing and certification</td>
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Others include USDA, cGMP, ASME (U&R), BPE, FDA and API standards

5.1 CIP EQUIPMENT

5.1.1 SINGLE TANK, MULTI-TANK SYSTEMS

Typically, CIP systems will utilize one or more dedicated tanks in their operation. The tanks serve multiple purposes and can vary in quantity, size, and construction based on the design and needs of the system. It is important to note that although CIP tanks are not used for production, their construction should be of similar hygienic design to the system they are cleaning.

Single tank / single use systems are often used for systems where water and chemical consumption are not a concern as the single tank must perform multiple functions. These are common in small or mobile systems, when CIP operations are infrequent, or when there are concerns for allergen cross contact through CIP solution.

Additional tanks are utilized for recovery of cleaning or sanitizing solutions, where a tank is dedicated for a specific solution. As well, additional tanks can be utilized for recovery of rinse water or for pH stabilization of waste prior to being sent out of the system.

Sanitizer solution is normally incompatible with the alkaline or chlorinated alkaline wash solutions and not recovered to be used as a pre-rinse.
5 CIP EQUIPMENT AND SANITARY DESIGN

5.1.2 SPRAY BALLS, NOZZLES & ACCESSORIES
Many pieces of equipment, like tanks and vessels, require specific devices for delivery and distribution of cleaning solutions to provide adequate surface coverage. These can be items such as spray balls, rotary jet cleaning heads, and other types of nozzles or accessories. Proper selection of these devices, based on the product and process equipment being cleaned is critical.

- Removal of particulates before CIP is critical. Establish pre-rinse time during validation process to evacuate majority of the particulate matter. Additionally, apply strainers at CIP supply and return headers to capture any residual matter. Extend pre-rinse time to automated systems or add manual pre-cleaning steps to your SSOP if particulates are found in spray balls.

- It should be noted that the standard cleaning devices supplied on equipment may not always be suitable for the application and should be reviewed and verified. For proper operation of cleaning devices, specified pressure and flow is required and a preventive maintenance plan is implemented.

- When choosing a spray device there are many factors to consider. For proper cleaning, selecting the proper spray devices for complete coverage to all surfaces and repeatable spray patterns are important. Riboflavin or similar type testing is good indicator for complete spray coverage and effectively identifies shadows or blind spots.

5.1.3 CONTROLS AND AUTOMATION, DOCUMENTATION
Effective CIP depends on consistently achieving critical process parameters. Reliable and accurate records should be captured and kept for every CIP operation on every circuit. Properly calibrated instruments are essential. CIP instrumentation devices should be regularly inspected and tested to verify accurate measurement.

The control system should be robust and well vetted, as well as protected from unauthorized override or modification. A good control system should be easy to use and easy to interpret for the operator and maintenance personnel. Proper operator training should be given and procedures in place for handling alarm conditions. If electronic records methods are used, they should comply with the PMO Appendix H or CFR 21 part 11 and should be securely stored and backed up.

5.2 CIP SYSTEMS

5.2.1 SINGLE-USE CIP SYSTEMS (Single Use of Water, Chemicals & Solutions)
The single use CIP systems have evolved from early days of sanitary cleaning of dairy manufacturing to meeting the compliance requirements of the USDA, 3-A SSI, and PMO (Pasteurized Milk Ordinance) for equipment cleaning. Its use has been widely accepted in mitigating micro challenges and allergen controls cleaning. Since caustic and acid are used one time, the risk of cross contamination within circuits is mitigated. However, single-use systems will use more chemicals, water and energy.

- Depending on the equipment being cleaned and with respect to remaining product load, lower concentration can be used to clean with adjuvant chemicals to aide in effective cleaning to reduce chemical usage.
5 CIP EQUIPMENT AND SANITARY DESIGN

Selection of single-use or re-use CIP system is based on a particular product, available equipment and application.

The advantages of single-use systems include:
- Operational flexibility
- Multiple detergents and chemical concentrations Fresh wash solutions
- The ability to avoid heat shock from wide temperature differentials between rinse and wash solutions.
- Multiple operating temperatures Lower initial capital cost

The disadvantages of single-use systems include:
- Higher water use Higher detergent use
- Time delay to reach operating temperature

5.2.2 RE-USE CIP SYSTEMS (Multiple-Use of Water, Chemicals & Solutions)
Re-use systems are used where cross-contamination concerns in terms of allergen controls are not critical and concern over microbiological cross contamination measure is in place and provided by other means of sterilization or sanitization. The dairy industries that are governed under the PMO recommend but do not require re-use systems built separately to segregate post-pasteurization from pre-pasteurization areas of the processing plant. Re-use systems are ideal for process operations requiring frequent cleaning. The recovery of heat, rinse water, caustic, and acid provide economic advantages over single-use systems. All or some of the cleaning solutions are saved for reuse on the next cleaning cycle.

There should be sufficient time to drain piping circuits and equipment between acid washes, caustic washes, sanitizing, etc. Adequate draining of the preceding chemical will minimize the time and amount of rinse water required for removal.

The potential advantages of a reuse system include:
- Cleaning solutions and rinse water are recovered
- Lower water, heat, and chemical usage
- Faster overall wash cycle time due to less heating especially in winter months
- Recovered cleaning solution are heated and charged with chemical

The disadvantages of a reuse system include:
- Allergen and micro contamination risk Single concentration for all cleaning circuits
- Common cleaning solutions will be used for all product soils
- Larger floor space required (multiple tanks require significant space) Higher initial capital cost
- Rinse water recovery tank may harbor micro-organism
- Intermittent cleaning of the caustic, acid and recovery tank required

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6 VALIDATION VERIFICATION MONITORING

OVERVIEW

To ensure efficient, effective, and repeatable sanitation procedures are being executed the following should be addressed in a facility's written sanitation program.

1. Success criteria should be highlighted as critical before design to prevent over or under design of a system.

Purpose of cleaning

EXAMPLE: removal of previous product and soils (cross-contact, allergen and sensory), reduction of microorganism contamination load to an acceptable level (analytical).

Success criteria defined

EXAMPLE: visually clean food contact surfaces, acceptable thresholds for indicator microorganisms such as APC <10 CFU/swab, temperature range for wash step, minimum time for sanitizing step, minimum flow rate for pre-rinse.

Roles and responsibilities

EXAMPLE: Engineering – design, documentation and programing of the system and circuit; Maintenance – repair, calibration, and maintenance; Quality – Validation, Verification & Monitoring (VV & M), coordination and training; Manufacturing – operation of the system and records.

Required activities

EXAMPLE: see Validation, Verification & Monitoring below.

Documentation

EXAMPLE: a comprehensive “Validation” or “initial Verification” report summarizing the protocol followed and the results collected for each specific line or system to properly manage the hazards of concern.

6.1 VALIDATION

The validation report should reference appropriate documentation to address the effectiveness of the chemistry and/or cleaning method, for example, the product label directions for cleaning and sanitizing process by the chemical supplier to address soils. See FARRP for allergen cleaning and testing farp.unl.edu/ and OpX Leadership Network’s Allergen Cleaning Validation Checklist.

6.2 VERIFICATION

The facility’s CIP cleaning program should identify the processes to ensure the continued proper execution of sanitation such as visual inspection, assessment of employee execution of the SSOP(s), e.g. measuring chemical concentrations, ATP swabs, microbial swabbing, chemical (including allergens) final rinse water testing and record review.

Testing to acceptable analytical results should be repeated multiple times as part of initial verification of a new or modified system under worst-case scenario for soil difficulty.

6.3 MONITORING

The facility’s sanitation program should include procedures for measuring and recording analytical results and procedural adherence to ensure that control measures are operating as intended. Critical elements of sanitation include time, temperature, flow, pressure, concentration/conductivity.
7 GLOSSARY

7.1 ASSISTED CIRCULATION SYSTEM (ACS)
A closed system for circulation cleaning, typically used when the processing equipment is circulated within itself and is "single use".

Common terms:
Pot-n-Pump: in place cleaning using existing processing equipment (i.e. no CIP skid).
Flush system: Pot-n-Pump cleaning in place without recirculation (i.e. one pass cleaning).

7.2 BIOFILM
A microbial consortium adhering to a surface.
NOTE: Biofilms are frequently but not in every case embedded in extra-cellular polymeric substances. (Source: EHEDG Glossary 2013/12/12.GO3)

7.3 CLEAN IN PLACE (CIP)
(SOURCE EN ISO 14159:2008)
3.3 cleaning in place (CIP) cleaning (3.4) of equipment by impingement or circulation of flowing chemical solutions, cleaning liquids and water rinses into, onto and over surfaces in equipment or systems without dismantling and designed for the purpose (Source 3-A 00-00-2014)

C3.1 Clean-in-Place (CIP) Cleaning: The removal of soil from product contact surfaces in their process position by circulating, spraying, or flowing chemical solutions and water rinses onto and over the surfaces to be cleaned.
NOTE: Components of the equipment, which are not designed to be cleaned-in-place, are removed from the equipment to be cleaned-out-of-place (COP) or manually cleaned.

7.4 CLEAN OUT OF PLACE (COP)
(SOURCE ANSI/3-A 00-00-2014)
C3.2 Clean-Out-of-Place (COP) Cleaning: Removal of soil when the equipment is partially or totally disassembled. Soil removal is affected by circulating chemical solutions and water rinses in a wash tank, which may be fitted with a circulating pump(s).

7.5 DENATURE
To cause the tertiary structure of a protein to unfold, as with heat, alkali, or acid, so that some of its original properties, specially its biological activity, are diminished or eliminated.
(Source: Dictionary.com denature in science)

7.6 DRY CLEAN
Dry clean - applies to areas where no aqueous cleaning liquids are used, and cleaning is by but not limited to vacuum cleaners, dusting cloths, brooms, and brushes. (Source: OpX One Voice for Hygienic Equipment Design for Low-Moisture Foods)

7.7 EUROPEAN HYGIENIC ENGINEERING AND DESIGN GROUP (EHEDG)
www.ehedg.org

7.8 FDA - U.S. FOOD AND DRUG ADMINISTRATION
www.fda.gov/Food/default.htm

7.9 FOREIGN MATERIAL
A material substance of a particular kind or for a particular purpose that is foreign to the product.

7.10 FOULING
Fouled: Being encrusted, clogged, or choked with a foreign substance.

7.11 FOOD SAFETY MODERNIZATION ACT (FSMA)
www.fda.gov/Food/GuidanceRegulation/FSMA/default.htm

7.12 GOOD MANUFACTURING PRACTICE (GMP)
CURRENT GOOD MANUFACTURING PRACTICE (CGMP)
Current good manufacturing Processes (CGMP), also known as good manufacturing Processes (GMP), provide guidelines for manufacturing, testing, and quality assurance to ensure that a product is safe for human or animal consumption or use.
7 GLOSSARY

7.13 HAZARD ANALYSIS
CRITICAL CONTROL POINT (HACCP)
HACCP is a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product. www.fda.gov/Food/GuidanceRegulation/HACCP

7.14 UNITED STATES DEPARTMENT OF AGRICULTURE USDA - FOOD SAFETY AND INSPECTION SERVICE (FSIS) www.fsis.usda.gov/wps/portal/fsis/topics/regulatory-compliance/haccp

7.15 MANUAL CLEANING
cleaning by manual means when the machinery is open, or partially or totally disassembled. (Source EN ISO 14159:2008 definition 3.14)

7.16 POTABLE WATER
Water that is safe and satisfactory for drinking and cooking. www.epa.gov/ground-water-and-drinking-water

7.17 PRODUCT CONTACT SURFACE
machinery surfaces which are exposed to the product and from which the product or other materials can drain, drip, diffuse or be drawn into (self-returned) the product or product container. (Source EN ISO 14159:2008 (3.23))

7.18 PROTEINACEOUS SOIL
oil that is high in protein material.

7.19 SANITIZE
(A) To adequately treat cleaned surfaces by a process that is effective in destroying vegetative cells of pathogens, and in substantially reducing numbers of other undesirable microorganisms, but without adversely affecting the product or its safety for the consumer. (Source FSMA, Final Rules Fed Reg: 80, Sept 17, 2015 - Section 3.0)

(B) A process to adequately treat a clean product contact surface that is effective in destroying vegetative cells of microorganisms of public health significance, and in substantially reducing numbers of other undesirable microorganisms, but without adversely affecting the product or its safety for the consumer. (Source - ANSI/3-A 00-00-2014)

7.20 SANITATION
all actions dealing with cleaning or maintaining hygienic conditions in an establishment, ranging from cleaning and/or sanitizing of specific equipment to periodic cleaning activities throughout the establishment (including building, structural, and grounds cleaning activities). (Source ISO/TS 22002-1:2009(en), 3.13 Prerequisite programs on food safety — Part 1: Food manufacturing)

7.21 SANITIZER CHEMISTRY
Using chemicals to adequately treat cleaned food-contact surfaces by a process that is effective in destroying vegetative cells of microorganisms of public health significance, and in substantially reducing numbers of other undesirable microorganisms, but without adversely affecting the product or its safety for the consumer. (Source SANITATION LEXICON, GMA Sanitary Design Workgroup, 2013 (21CFR111.3))

7.22 SOIL
any unwanted matter. (Source EN ISO 14159:2008)
7 GLOSSARY

7.23 TRANSFER PANEL (DIVERTER PANEL, FLOW DIVERT PANEL, FLOW TRANSFER PANEL, FLOW-VERTER PANEL)
A panel with process connections to which process lines are piped. The panel contains one or more removable jumper spool connections that allows for varying line connections to be made. The use of transfer panels allows for a needed physical separation between process, cleaning and/or utility lines.

7.24 TUB
A wide round vessel or oblong container in which a product is held.
www.merriam-webster.com/dictionary

7.25 TURBIDITY
Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample.
https://water.usgs.gov/edu/turbidity.html

7.26 VALIDATION
Validation means obtaining and evaluating scientific and technical evidence that a control measure, combination of control measures, or the food safety plan as a whole, when properly implemented, is capable of effectively controlling the identified hazards.
(Source FSMA, Final Rules FR: 80, Sept 17, 2015 (Part 117.3)).

7.27 VERIFICATION
Verification means the application of methods, procedures, tests and other evaluations, in addition to monitoring, to determine whether a control measure or combination of control measures is or has been operating as intended and to establish the validity of the food safety plan.
(Source FSMA, Final Rules FR: 80, Sept 17, 2015 (Part 117.3)).

7.28 VISCOSITY
The thickness of a liquid which determines pourability. The resistance to flow is measured in relationship to water in centipoises (cp). Water has a viscosity of 1 cp.
(Source SANITATION LEXICON, GMA Sanitary Design Workgroup, 2013 (ISSA Terms))

7.29 WASH TUNNEL (CONVEYORIZED WASHER, CONTINUOUS BATCH WASHER, PALLET WASHER, TUNNEL WASHER)
A type of Clean-Out-of-Place (COP) washer that is designed for continuous part cleaning operations. Parts are taken out of normal operation and typically loaded into the washer on one side, conveyed through the tunnel washer and cleaned within a cabinet enclosure, and unloaded on the opposing end. Cleaning occurs by the flow / pressure of the cleaning solution applied to the part in one or more cleaning zones.
(Source FSMA, Final Rules FR: 80, Sept 17, 2015 (Part 117.3)).
8 CIP TOOLS AND RESOURCES

8.1 CHECKLIST FOR CIP

This checklist is designed to provide assistance to small to mid-sized companies that are developing or revising their Clean-In-Place (CIP) of processing equipment.

Available only as a stand alone document. DOWNLOAD NOW

8.2 EXAMPLES OF CIP SYSTEMS

1 TANK CIP SYSTEM

*Elements depicted in drawings, with two-letter designation inside a circle, represent instruments used for the measure of critical CIP criteria.

PE – Pressure Element, FE – Flow Element, CE – Conductivity or Chemical Concentration Element, LE – Level Element, TE – Temperature Element

(diagrams courtesy of Sani-Matic)
8 CIP TOOLS AND RESOURCES

2 TANK CIP SYSTEM

MULTI-TANK CIP SYSTEM
DUAL OPERATING/MULTI-CIRCUIT CIP SYSTEM


8 CIP TOOLS AND RESOURCES

8.3 GUIDELINES FOR COMMON DESIGN CONSIDERATIONS

These are general guidelines – specific applications may require more detailed design.

8.3.1 DON’T FORGET ABOUT YOUR FLOOR DRAINS!
Floor or hub drains need to be able to handle the flowrates that your CIP System will be delivering. This can range from low flows of 40 GPM to as high as 250+ GPM for 4”+ line circuits.

8.3.2 SIZING TANK OUTLET AND RETURN VALVES & HEADERS
For tank outlet valves & headers, it’s always best to consider “over-sizing” to minimize pressure drop via gravity to the CIP Supply Pump.

- 40- 100 GPM, 2.5” outlet valves/manifolds
- 100 – 180 GPM, 3” outlet valves/manifolds
- 180 – 300 GPM, 4” outlet valves/manifolds

For CIP Return Headers/Valves;

- 40 – 100 GPM – 2”
- 100 – 180 GPM - 2.5”
- 180 – 250 GPM – 3.0”

Success criteria should be highlighted as critical before design to prevent over or under design of a system.

8.3.3 SIZING AND SELECTION OF CIP SOLUTION HEAT EXCHANGERS;
Type of Heat Exchanger: Shell and tube heat exchangers are typically applied for CIP system, though many plate heat exchangers will work also. If you have large sized particulates in your process, a shell and tube heat exchanger is preferred to avoid particles lodging in the plate pack.

Temperature Rise: Most CIP Systems are designed with a 30°F rise per pass. This helps prevent thermal shocking to the piping and equipment, as well as minimizing the steam load.

For example, a 100 gpm Flow rate from 90-120°F would require approximately 1500 pounds of steam per hour. A quick calculation is Steam flow (lbs/hr) = Solution flowrate (gpm) x 0.5 x ΔT (°F)
8 CIP TOOLS AND RESOURCES

8.3.4 SIZING TANKS IN A CIP SYSTEM:

**Wash Tank:** The sizing of the wash tank is based upon the sum total of the working volume of the wash tank and the retention volume of the longest CIP circuit. The working fluid level is determined by the level required to ensure that proper Net Positive Suction Head (NPSH) is provided to the CIP supply pump. For line circuits, the retention volume should be calculated from the line sizes and linear footage of pipe for the longest circuit. For tank circuits, a retention volume should include the volume of CIP Solution will be cascading down sidewalls of tanks and volume at the tank outlet to provide proper NPSH to the CIP return pump.

**Pre-Rinse Tanks:** Historically, this tank has been sized to be the same as the wash tank. With the focus on water reduction, the pre-rinse tank can be oversized to be able to recover increased volumes of post rinse water and reduce total water utilization.

**Post-Rinse Tanks:** Sizing of these tanks is based upon surge volume of fresh rinse water required by the rinse cycle flow rate and rinse time. At minimum, these tanks would be the same size as the wash tank.

8.3.5 BURST RINSE & AIR BLOWS

A burst rinse is the process of sending a short (4-5 Seconds) bursts of water of fresh water thru the system. This process assists with “phase segregation” meaning when moving from a wash step to a sanitize step, it’s safer to flush the previous cycle out of the piping/tank circuit prior to initializing the next step. It also aids in removing foam from the bottom of tanks should that problem persist. Often, the burst rinse it is followed with an air-blow step. This high volume, lower pressure air purge helps evacuate the lines between wash steps and further aids in the phase separation.
8 CIP TOOLS AND RESOURCES

8.3.6 PIPING & VALVE CONSIDERATIONS

1. Product must be protected from CIP chemicals
   a. Clear break with jumper connection, or
   b. Mix-proof valves

2. Avoid dead legs. Close couple valve and piping arrangements so that the length of the branch tees does not exceed three pipe diameters from the center of the pipe.
   a. Minimize number and length of tank nozzles. Increase diameter of tank nozzles for easier cleaning.

3. In branch tees and split flows, use isolation valves to avoid compromise in cleaning velocity to the path of least resistance and starving the flow in a restricted path

4. Plastics and rubber elastomer materials must be compatible with cleaning chemicals.

5. Minimize the distance to return pumps and locate transfer pumps close to the tank

6. Mount blind caps horizontally
   a. Blind caps mounted vertically pointed up can trap air pockets
   b. Blind caps mounted vertically pointed down can trap debris

7. Design piping with slope for free drainage (See ANSI/3-A 00-00-2014 – General Requirements)
   a. Pitch all lines to drain points
   b. Pitch CIP return connections to pump inlet.

8. Ensure that the turbulent flow in piping is at least 1.5 m/s (5 ft/sec)

9. For circuits that cannot be fully drained, it is preferable to leave it with a sanitized solution and follow with flush prior to production

10. Use only eccentric reducers in the proper orientation in horizontal piping to facilitate line draining.

11. A separate inline recirculating booster pump is often required to achieve adequate velocity cleaning in plate heaters.

12. Design plate heater cleaning with recommended velocity/flow by the manufacturer.

13. Valves are used to control the direction of flow and for isolation.
    When using, selecting, or installing valves, consider the following:
    a. Install valves to close against the flow to avoid water hammer
    b. Close couple valves to avoid dead legs with respect to valve arrangements
    c. Ensure that valve stems with an O-ring seal design pulse during the cleaning cycle to remove soil in between the recessed cavity areas of the O-ring and its groove

14. Water hammer and hydraulic shock should be avoided. When valves and pumps are not sequenced together properly, the instantaneous stoppage of flow causes a water hammer or hydraulic shock. It can result in equipment and piping systems damage.
## 8 CIP TOOLS AND RESOURCES

### 8.3.7 SOME POTENTIAL PROBLEMS AND SOLUTIONS REGARDING CIP SYSTEMS

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>SOLUTION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DIFFICULTY MAINTAINING FLUID TEMPERATURE</strong>&lt;br&gt;The cleaning of tanks often results in a large drop in the CIP fluid temperature that makes it difficult to maintain the proper temperature in downstream lines.</td>
<td>Clean tanks and lines in separate CIP circuits</td>
<td>Often it is unavoidable to clean small sections of lines with tanks (e.g. outlet line). When doing so take care that adequate temperatures are maintained.</td>
</tr>
<tr>
<td><strong>CIP PUMP NOT PROVIDING ENOUGH FLOW FOR PUMPING</strong>&lt;br&gt;It is important that CIP return pumps on the outlet of tanks are sized that they can keep any CIP solution from building up or “pooling” in the bottom of the tank. In many cases the pump required to meet the needs of evacuating the tank cannot also meet the pressure requirements for cleaning subsequent line circuits.</td>
<td>Clean tanks and lines in separate CIP circuits</td>
<td>Although there are pumps that can perform both duties, for the other reasons stated above, it is still best to avoid cleaning both tanks and lines in the same CIP circuit.</td>
</tr>
<tr>
<td><strong>TANK IS NOT GETTING CLEAN</strong>&lt;br&gt;Improper number or design of spray balls/devices in a tank.</td>
<td>The correct number depends on a variety of variables, however, it is best to rely on your tank fabricator or qualified spray device manufacturer to recommend/decide on the quantity, nozzle or hole diameter, type and position of the spray balls/other devices.</td>
<td>A riboflavin or similar type of test can be used to ensure proper coverage and cleaning of the tank.</td>
</tr>
<tr>
<td><strong>SPRAY NOZZELS ARE PLUGGED WITH PARTICULATES.</strong></td>
<td>In-line filters can eliminate particulate that can cause nozzels to plug</td>
<td>Periodic inspections of nozzels is a good practice</td>
</tr>
<tr>
<td><strong>SPRAY DEVICE NOT AT CORRECT PRESSURE</strong>&lt;br&gt;Tank spray devices require a specific flow and pressure to operate as designed. Often these flows and pressures are much different than the requirements or capacities of the process lines.</td>
<td>If tank and line cleaning requirements are not compatible, clean tanks and lines in separate CIP circuits.</td>
<td>In cases where the spray device(s) requirements and process line requirements are compatible, it is acceptable to combine the tank and incoming lines into a common CIP circuit, so long as the cleaning requirements for all are met.</td>
</tr>
</tbody>
</table>
## 8 CIP TOOLS AND RESOURCES

<table>
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<th>PROBLEM</th>
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</tr>
</thead>
<tbody>
<tr>
<td>EXCEEDING SPECIFIED FLOW RATES AND PRESSURES FOR TANK CLEANING DEVICES</td>
<td>Maintain manufactures recommended flow rates and pressures</td>
<td>More is not always better.</td>
</tr>
<tr>
<td>Exceeding specified flow rates and pressures for Tank Cleaning Devices (i.e. spray balls, nozzles, etc.) will often times result in less effective sprays and can produce misting/atomizing of the CIP Solution, adversely affecting the end result.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PORTS AND NOZZLES IN PROCESS TANKS NOT CLEANING PROPERLY.</td>
<td>Do not designing process tanks with excessive number of nozzles, particularly in the top head. Length of ports and nozzles should be minimized. When possible, it is a good idea to use flush-mounted devices and ports.</td>
<td>Ports and nozzles should always be self-draining. When flush-mounted ports are not suitable port lengths should be less than or equal to the diameter of the port. If cleaning is a problem, consider custom-drilled spray balls or rotary spray devices.</td>
</tr>
<tr>
<td>Excessive numbers or lengths of ports complicate the ability of the spray balls to properly reach all of the recessed areas associated with multiple inlets.</td>
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<td></td>
</tr>
<tr>
<td>TANK OUTLET AND/OR ELEVATION IS INAPPROPRIATELY SIZED FOR CLEANING AND PROCESS DUTY.</td>
<td>When designing process tanks, keep in mind that the tank outlet sizing and elevation are critical to both process objectives as well as Cleaning objectives. The outlet elevation is also critical to both Process &amp; CIP.</td>
<td>Keeping in mind that elevated temperature often associated with CIP can affect pump performance. A recommended guideline for tank outlet elevations is a minimum of 30°.</td>
</tr>
<tr>
<td>CIP SOLUTION IN TANK IS BUILDING</td>
<td>Adding the air eliminator at the CIP return pump suction and then capped off after CIP (If this same pump is used for product supply.) A dedicated CIP return pump with (liquid ring pump) can eliminate air cavitation.</td>
<td>During CIP, the process of emptying tank level and maintaining minimum ideal level for continuous recirculation can cause pump to airlock.</td>
</tr>
</tbody>
</table>
8 CIP TOOLS AND RESOURCES

8.4 TEN COMMANDMENTS FOR CIP DESIGN

Ten Commandments for CIP Design

1. Always remember that water runs downhill ...

2. ... and that it is easier to pump water into a tank, than to pump it out.

3. Pitch tank “CIP Return” Manifold/Connections continuously to pump inlet.

4. Keep tank head nozzles few in number, short in length, and large in diameter, for they are not easy to clean.

5. Avoid 3-port divert valves like the common plague.

6. Design to close all valves against flow.

7. Locate CIP systems in (near) and (when possible) beneath the center of CIP loads

8. Eliminate all “Dead Ends” (branches of more than 1-1/2 pipe diameters) for they will trouble you forever.

9. Pitch all lines to easily opened drain points.

10. Design and install supports to eliminate “friendly” piping that waves when starting pumps and opening and closing valves, for friendly systems are short-lived.

reprinted courtesy of Dale Seiberling
8 CIP TOOLS AND RESOURCES

8.5 OPX LEADERSHIP NETWORK TOOL BOX

- Validating the Reduction of Salmonella and Other Pathogens in Heat Processed Low-Moisture Foods
- One Voice for Hygienic Equipment Design for Low-Moisture Foods
- Allergen Cleaning Validation Checklist
- Spotlight on Baking
- One Voice, Factory Acceptance Tests; Protocols for Capital Equipment in the CPG Industry
- Factory Acceptance Tests Checklist
- Total Cost of Ownership Playbook
- Total Cost of Ownership Checklist

8.6 REFERENCES

