A Guide to Clean In Place (CIP)

Clean-in-place (CIP) technology offers significant advantages to manufacturing facilities, from efficient and reliable cleaning of process equipment and piping at lower cost to improved product quality. This summary highlights the important factors in CIP technology, identifying several designs of CIP systems and discussing the basic operation of the units. The controls incorporated into CIP systems are critically important, being required to provide a variety of cycle times, temperatures, composition and concentration of cleaning solutions. The clean-in-place systems may include current recycling and regeneration technologies, in order to reduce operating costs and control the cost of waste disposal.

A&B Process Systems has over 30 years of experience in the design, fabrication, installation and start-up of CIP systems for the chemical, pharmaceutical, bio-pharmaceutical, dairy, food and other processing industries. The company offers a seminar that focuses upon many aspects of this technology. Through the seminar A&B Process Systems is able to provide practical knowledge that is of immediate use, knowledge that has been gained from those years of experience working with the clean-in-place technology.

Introduction

The development of clean-in-place (CIP) technology, i.e., the automatic, reproducible and reliable delivery of cleaning solutions, rinse and wash water to and through process equipment and process piping, has improved both product quality and plant hygiene. Furthermore, the ability to clean a processing system, incorporating tanks, pumps, valves, filters, heat exchange units and process piping, without the need to disassemble all or part of that system, significantly reduces cleaning costs and minimizes the handling of chemicals to provide a safer environment for plant personnel. These systems may be integrated into existing processing systems, but more importantly, clean-in-place technology should be included in the design of any new process system, to be simultaneously incorporated with the design of the process flows, the controls and automation.

Clean-in-place technology may be applied to any equipment in which contact by a liquid can be achieved by way of spraying or recirculation of water and aqueous cleaning solutions under pressures ranging from 25 to 80 psig. Prior to cleaning a process system, it is economically beneficial to many processing industries to recover the residual product. Several approaches may be used, e.g., evacuation, "water flush," "airblow" or "pipe pigging." This latter term describes the propelling of a flexible, elastomer projectile through the piping system. The pig is usually driven by air, nitrogen, water or a cleaning solution. This technique reduces downtime between product runs or when formulations are changed and recovery of the product is economically significant.

Designs of CIP systems

There are several designs of CIP systems. The "single-pass" and the "recirculating" configurations are often utilized in the processing industries, since both require minimal capital investment, typically have a small footprint and are flexible, in that the unit can readily adjust to a range of cleaning protocols. However, the cost for the chemicals, water and steam and for disposal of the wastewater are higher than for other designs.

The dairy and food industries have consistently favored a "re-use design," which provides for the recycling of the water and possible regeneration of the cleaning chemicals. These CIP systems have a larger footprint than "single pass" systems and there is a greater risk of cross-contamination during operation. The "re-use" systems also lack flexibility, in that a single temperature and a single concentration of cleaning solution is used for whole process system, unless additional vessels are included in the CIP unit.

The pharmaceutical and bio-pharmaceutical industries prefer to use a multi-tank configuration, with independent, stainless steel tanks being used to hold water of different quality, e.g., deionized water (DI), hot or cold water for injection (WFI) and water from reverse osmosis units (RO). These multi-tank systems are operated as if they were single-use systems, the tanks being drained between subsequent programs to minimize cross-contamination.

A single-use, eductor assisted CIP unit, which reduces the consumption of water and chemicals, was developed primarily for use in the dairy and food processing industries, but has recently found application for selected pharmaceutical processes. This system is capable of circulating small volumes of water at relatively high rates.

How does a CIP system operate?

The operation of the CIP system requires the control of several conditions, i.e., the fluid flow rates and velocities, temperatures, cleaning times and the concentrations of the cleaning chemicals (detergents, caustic soda). Fluid velocities in the process piping are typically approximately 5 feet per second, although some systems in the pharmaceutical and bio-pharmaceutical industries use higher velocities. In the case of tanks, the rates of flow of either water or cleaning solution are largely determined by the size of the tank, as well as the number and the properties of the spray devices. These flow rates usually range from 10 to 160 gallons per minute.

Spray devices come in a variety of designs. The traditional spray ball is commonly used and provides directional streams of water or cleaning solution from small, static nozzles. Rotational devices provide spherical spray patterns and direct impingement spray devices introduce high pressure streams at low flows, rotating through 360˚ The impingement spray devices represent an alternative to the removal of soils or deposits by cascading water or cleaning solution that cascade down the sidewalls of the tanks or vessels.

The temperature of the CIP process may vary from 135 to 175˚F and control is usually critical. The necessary heat transfer demands are met either by incorporating heat exchangers (plate-and-frame or shell-and-tube) into the CIP system, or by direct injection of steam. Chemicals may be added using peristaltic, pneumatic diaphragm and or more precise metering pumps. Concentrations of the cleaning solutions are monitored and controlled by the measurement of the pH or electrical conductivity of the solution.

The CIP process involves a sequence of cycles that includes an initial and final drain step, a pre-rinse, wash and post-rinse. The duration of the rinse and wash cycles vary from 5 minutes to 1 hour. In the pharmaceutical, bio-pharmaceutical, dairy and food industries, the CIP process may include a "sanitize" cycle to reduce the levels of bacterial contamination. This cycle necessarily uses aqueous solutions of strong oxidants such as hydrogen peroxide, ozone, chlorine dioxide and other chlorine-containing compounds.

When a "sanitize" cycle is included, thorough final rinse cycles are required to avoid corrosion of the stainless steel tanks, vessels and process piping, due to the presence of traces of the strong oxidant, particularly the chlorine containing compounds or chloride ions. In order to efficiently drain process equipment and process piping, the system should be designed and installed to either allow the fluids to flow out under gravity or be pitched to drain points. It is also very important to avoid sections of the piping and equipment in which fluid flow is restricted. Split flow designs also adversely affect the flow of solution through a piping system. Any problem areas should be identified and the piping modified or an appropriate cleaning method developed. The pre-rinse uses recycled water to flush out loosely adhering particulates and soil. This water is often flows directly to the drains as it leaves the CIP system. The wash cycle may use more than one chemical, depending upon the degree of fouling and nature of the deposits in the process equipment and piping. The post-rinse cycle provides the final flush for the system. The effluent from this final cycle may be discharged to the drains, directed to a solution recovery tank or to a pre-rinse tank, as has been described earlier. The effluent may flow to the drain or recovery points under gravity, but some CIP systems include return pumps or eductor devices.

How important is the control system to the operation of the CIP unit?

The importance of the controls incorporated into the CIP system cannot be overstated. It is necessary to include a variety of instruments and devices, i.e., resistors that are dependent upon temperature, pH probes, conductivity meters, flowmeters, timers, level sensors and alarms. Fully automated control must provide for variable times for rinse and drain cycles and for recirculation of the various solutions. The system must also have the capability to change the temperature, flowrates, composition and concentration of the cleaning solutions. The main control unit is usually based upon PLC equipment, often as multiple panels to service operator stations and for valve and I/O termination. The process control system is critical to controlling or minimizing hydraulic shock, a common problem in CIP units. The proper sequencing or "pulsing" is required to clean the valves, lip seals, o-rings and valve seats. A correctly designed and installed control system may eliminate the problem of hydraulic shock, leading to lower maintenance costs and longer component life. A&B Process Systems has recognized the importance of providing user-friendly controls and instrumentation with any CIP system. The Automation and Controls group at A&B works with the design engineers and the customer to ensure that this objective is realized and that the proper level of operator training is provided.

What is meant by "process validation?"

Process validation is an important aspect of a properly managed CIP system. Three questions should be asked of the operating CIP unit;

Is the CIP system working as intended?
Has the CIP process cleaned/ sterilized to the level required?
Have residual chemicals been removed from the process equipment and process piping?

The answer to question (a) is provided by the array of instruments in the CIP system. The probes, devices and meters monitor fluid flows, times, temperatures and concentrations of the cleaning solutions and the data obtained establishes that the system is, or is not, working as intended. The answers to questions (b) and (c) are obtained from analysis of the effluents, using such techniques as TOC (total organic carbon) analyses, atomic absorption, HPLC (High Pressure Liquid Chromatography) and GC (Gas Chromatography). Efficient cleaning of the tanks in the process system requires that the interior surfaces be totally covered by the sprays introduced through the spray devices. The surface coverage is determined by the "Riboflavin Validation" process, a visual analysis based upon the response of the organic compound to ultra-violet light.

Are other factors or components significant to CIP processes?

An important component of the CIP system is the transfer panel. This is actually a "routing station," which controls the distribution of the various fluid streams. Today's transfer panels are the result of continued modification and development of the "flow-verters" or "cleaning hook-up stations" used for solution distribution in early CIP systems. There are several geometric configurations used for the ports in the design of the transfer panel, the simplest and most common arrays being triangular or radial. The incorporation of "proximity sensors" into these designs has become an industry standard, the sensors interfacing with the process control system, as well as providing verification of the connections to the transfer panel for product and operator safety.

The utilization of chemicals, water and energy is an important consideration in CIP systems. Manufacturing facilities are concerned with controlling consumption of the chemicals and water to reduce the cost of operation and waste disposal and to maintain compliance with respect to the environmental regulations. In CIP processes large volumes of the solutions are brought into contact with the contaminated surfaces and economic operation often requires recycling and re-use of the rinse water, wash water and chemicals in the cleaning solutions.

In the design, fabrication and installation of clean-in-place systems, the engineers at A&B Process Systems emphasize the advantages of incorporating current recycling and regeneration technologies, particularly those approved by the USDA and FDA. The company offers a tutorial that focuses upon the critical aspects of water management. A&B will also complete a water audit at a customer's plant to identify opportunities for recycling and re-use of chemicals and water.

How can one learn more about this technology?

A&B Process Systems has over 30 years of experience in the design, fabrication and installation of process equipment, including CIP systems. The company is renowned for its' expertise in the fabrication and installation of stainless steel equipment and the stainless steels are the materials of choice for CIP systems. A&B offers a technical seminar that focuses upon many aspects of the CIP technology and draws upon the years of experience to present practical and immediately useful information. The seminar provides details of system design, system operation, system components – the tanks, valves, pumps, spray devices, heat exchangers, transfer panels – and the interconnecting piping. In addition topics such as electropolishing and welding methodology are discussed.