CIP process efficiency

Index

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People for Process Automation

Automated cleaning-in-place systems reduce the need to dismantle and clean food processing equipment to maintain food safety. The implementation of accurate process measurement in the CIP process enables food and beverage organisations to reduce waste and save energy, while minimising the production downtime needed for cleaning.

In the food and beverage industry, the cleaning of process equipment is critical to ensure the health and safety of the consumer, as well as maintain the quality of the product.

Proper cleaning is essential for the production of high quality food products especially those with extended shelf life.

processed food, beverage plants and breweries replacing manual strip down and cleaning of process equipment. The primary commercial advantage is a substantial reduction in the time that the plant is out of production and the ability to utilise more aggressive cleaning chemicals in a contained environment, which cannot be safely handled with manual cleaning.

What is CIP?

Cleaning of complete items of plant or pipeline circuits without dismantling or opening of the equipment, and with little or no manual involvement on the part of the operator. The process involves the jetting or spraying of surfaces or circulation of cleaning solutions through the plant under conditions of increased turbulence and flow velocity.

A CIP system typically consist of vessels for preparation and storage of cleaning chemicals, pumps and valves for circulation of the CIP chemicals throughtout the plant, instrumentation to monitor the cleaning process, and vessels to recover the chemicals.

It should be made clear that CIP is a methodology for removing product residues from a process plant, and is not a means of eliminating micro-organisms from the system (sanitisation or sterilisation).

Fouling of process plant

A side effect of processing of any food product is the build-up of debris (soiling) on surfaces and in pipes, resulting in fouling of process equipment - especially those elements of equipment in which the product is heated.

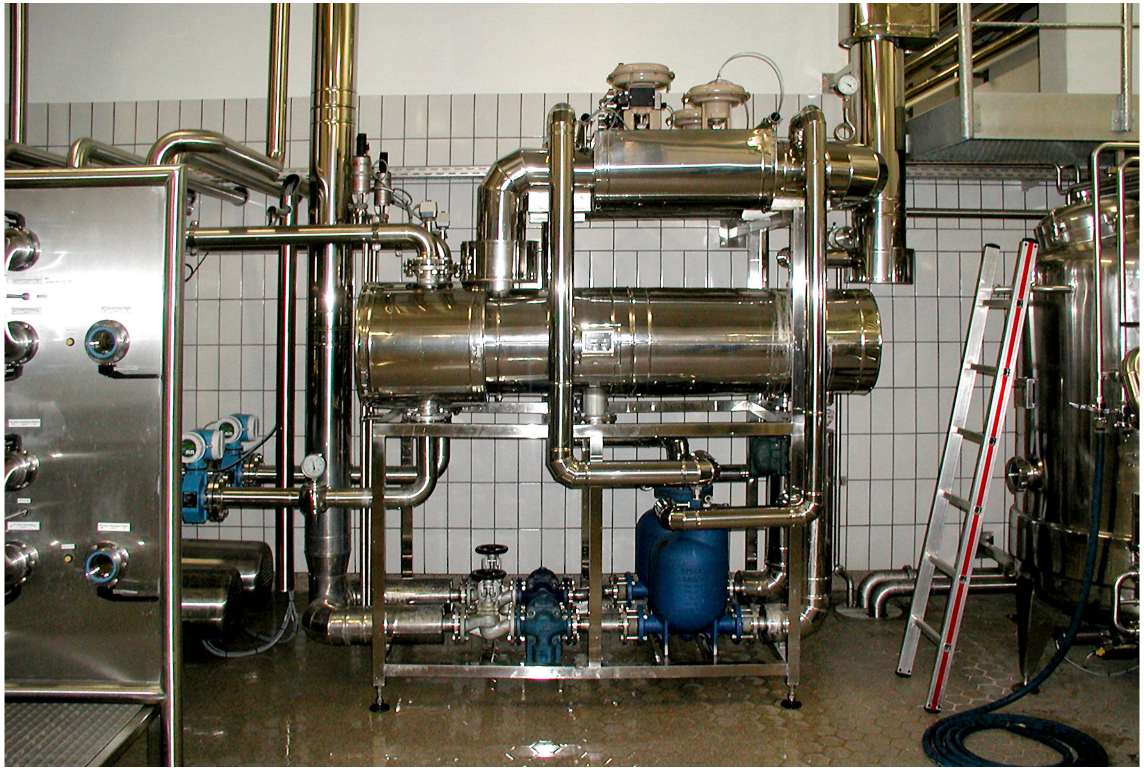
When designing a CIP system, knowledge about the type and amount of soil as well as its condition, is necessary. The main soil types are fats, proteins, carbohydrates (including various types of sugars) and minerals salts. Many of these types of soils are not water soluble, and therefore require the use of a cleaning solution.

Table 1: Solubility of food debris

Water Soluble	Alkali Soluble	Acid Soluble
Sugars	Fats	Mineral Salts
Some Salts	Proteins	Mineral Oils

Soils resulting from food processing can be complex mixtures, depending on the food being processed and heat treatment can make them more difficult to remove. How long a plant should wait between cleaning cycles depends on the plant and experience, but generally waiting too long between cleans can mean having to dismantle the plant.

A good example of soil complexity is the type of soils found in a dairy plant: milk remaining in a pipeline; air-dried films of milk; heat-precipitated milk constituents (protein and milk-stone); fat; and hard water salts. In the case of UHT milk mineral deposits are common at higher temperatures. Each type of soil will need a specific regime for removal.



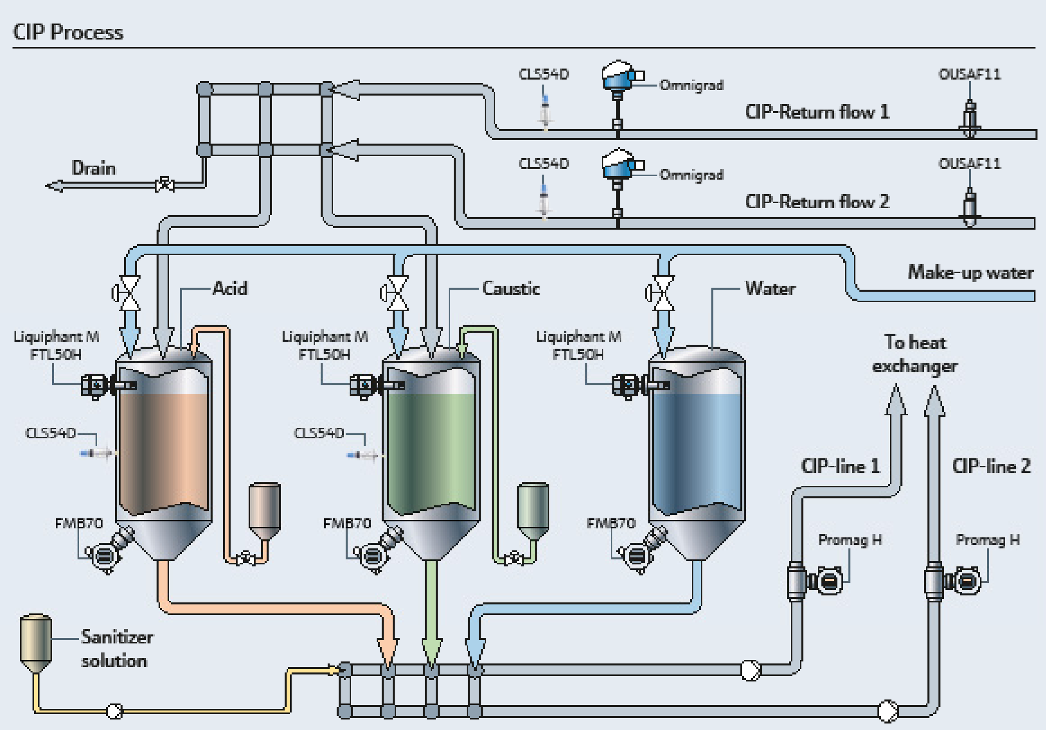
CIP challenges for food and beverage processors

The challenge for an organisation producing food and beverage products is in finding the balance between maintaining clean equipment for food safety and product quality, and not losing excessive production time by over-cleaning. Then, when cleaning occurs, the process needs to be optimised to minimise the use of energy and resources (water and chemicals). It is therefore necessary to monitor the CIP process in real time - an inability to do so leads to over-caution and results in wastage, not only in cleaning resources, but also in production time.

Another aspect of the CIP process is the elimination of waste and the recycling of chemicals and water. Smaller plants often use a single-use system, in which chemicals and soil residues are disposed of, but in larger plants, such waste can be very costly. Larger multi-use CIP systems recycle and filter the waste to return at least some of the water and chemical back to the CIP storage for reuse.

It is also now common for large processing plants to process their own wastewater in order to meet environmental regulations, so efficient CIP processes and recycling are also important to reduce the cost of waste processing.

The CIP cleaning process



The CIP Process

Adhesive forces that hold the soil on a surface need to be broken to make the impurities leave the surface. To acheive this there are four parameters involved in the cleaning process:

- **Mechanical force**
- **Thermal force**
- **Chemical force**
- **Contact time**

These processes all require energy (thermal, kinetic and chemical) applied over sufficient time in order to acheive the removal of the soil and carry it away. They are not independent and changing any one parameter can affect the other three. For example, lowering the cleaning temperature may increase the contact time required, and therefore also the quantity of water and chemicals, which results in greater energy consumption overall.

Mechanical action

The shear forces created by the water or cleaning solution flow are the mechanical forces that help remove the soil. Nozzles increase the effective pressure and shear forces by concentrating the flow and effectively impacting the surface to be cleaned 'harder'. Making effective use of spray nozzles means setting the flow rate such that the nozzles work most effectively.

In cleaning pipes, turbulent flow is necessary to create shear forces inside the pipe. Typically a flow velocity of greater than 1.5 m/s is necessary to cause turbulent flow. The use of a high velocity and turbulence also improves cleaning efficiency in small dead legs, for example at instrumentation points or sample valves. Research has also shown that flow velocities that are too high (greater than 2.1 m/s) are not beneficial, so pumping the solution to a higher pressure simply wastes energy for no greater effect. The volume flow rate necessary to acheive a flow velocity between 1.5 and 2.1 m/s will depend on plant design - in particular, pipe diameters and choice of nozzles.

Table 2: Typical flow and volume for different pipe diameters at turbulent flow

Pipe Diameter	Flow (l/h)	Volume (l/100m pipe)
25.0 mm	~ 2,070	~ 40
38.0 mm	~ 5,100	~ 99
51.0 mm	~ 9,600	~ 184
63.5 mm	~ 15,400	~ 287
76.0 mm	~ 22,500	~ 408
101.6 mm	~ 40,200	~ 748

Instruments for monitoring flow rate

Accurately measuring flow rate with a flow meter makes it possible to ensure that optimal pressure is maintained at spray nozzles, and that turbulent flow in pipes is sustained without over-pumping and wasting energy. For this reason, depending on the design of the CIP system, flow meters may be required at multiple points in the system.

Measuring process liquid flow can be accomplished by any number of flow measurement technologies. In a CIP application, flow measurement should ideally be acheived by an instrument that is minimally intrusive in the CIP flow, is not affected by cleaning chemicals and does not lose accuracy when there is turbulent flow.

The requirements of flow measurement in the CIP system (sanitary, accurate over a wide range of flow rates, unobstrusive and robust) can be fulfilled with the use of a magnetic flow meter. Flow rates of cleaning chemicals are generally twice the velocity of the product, so a sensor with a full bore design will ensue that no added pressure drop occurs in the system, meaning that energy costs associatd with increasing flows and pressures are kept to a minimum.

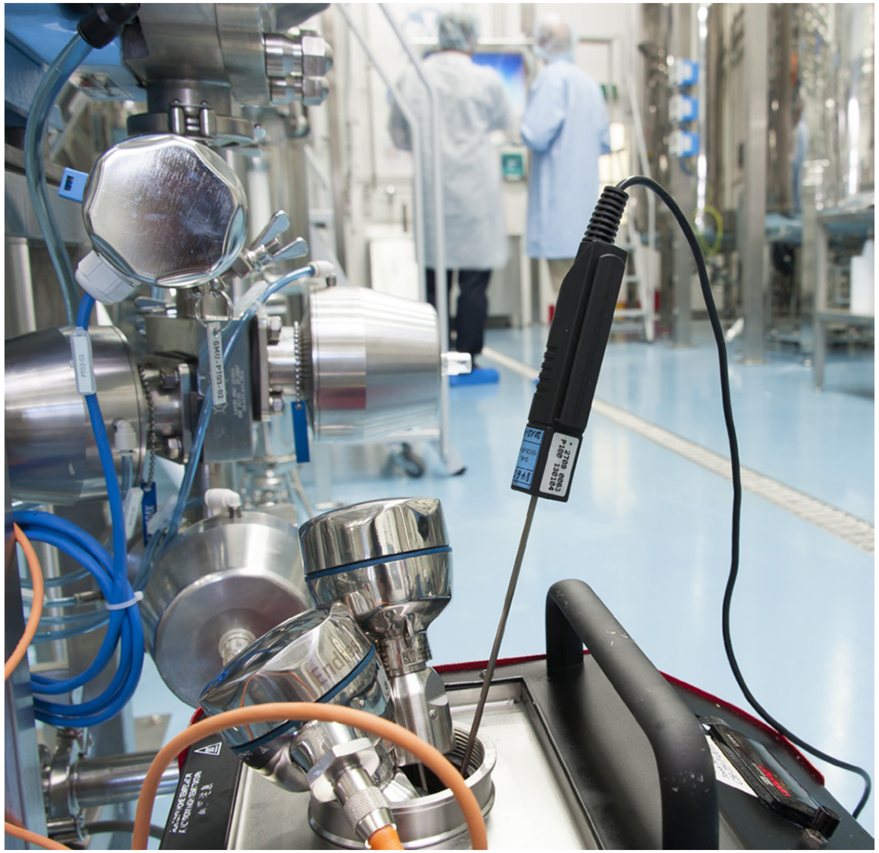
For more detailed information on Proline Promag H 100, please visit http://bit.ly/2kJQC28

The accuracy of a typical magnetic flow instrument used for CIP is unaffected by large flow variations and the accuracy of the instrument should be guaranteed over a turndown of 1000 (0.01 to 10 m/s). Since the magnetic measurement principle is virtually independent of pressure, density, viscosity and temperature. It is ideal for monitoring in the extreme conditions found in CIP (cold. low viscosity water up to high temperature chemicals and high density/viscosity products).

Magenticflowmetersarereadilyavailable that meet all guidelines for sanitary applications, such as 3-A and EHEDG.

Proline Promag H 100

Watch the Electromagnetic flow measuring principle video via below link https://www.youtube.com/watch?v=f949gpKdCI4



Temperature

Molecules move faster at an elevated temperature and therefore the effectiveness of a cleaning point is increased with increased temperature, due to higher molecular energy. As a general rule a plant should be cleaned at the same temperature as it has been processing the food. Contrary to what might seem intuitive however, ever higher temperatures are not necessarily effective. If a higher cleaning temperature is used, then reactions in the soil layers - such as denaturation of proteins - may occur, making soil harder to remove. Table 3 shows cleaning temperature ranges for some dairy processing equipment. Rinsing will also occur at different temperatures, with an initial flush being in the 40-60°C range, the post-alkaline rinse being a hot rinse, and the final rinse being cold.

Table 3: Cleaning temperatures for dairy processing equipment

Type of Chemical	Temperature Range	Equipment to be Cleaned
NaOH	60-80°C	Milk collection tankers, tanks and pipes
	70-90°C	Milk pasteurisers
	90-140°C	UHT plants
HNO_3	60-65°C	Tanks, pipes, milk pasteurisers
	80-85°C	UHT plants

Instruments for monitoring temperature

Temperature sensing should occur at two places in the CIP system: at the initial water heating point, to manage feedback for the water heating process and in the CIP return to confirm the temperature of the wash and rinse are correct.

The real-time temperature of the wash solutions will also be necessary to compensate for correct calculation of chemical concentration from conductivity data.

Temperature sensors that come in contact with CIP cleaning solutions should be of a hygienic compatible design: 3-A or EHEDG to ensure cleanability is met. They are generally constructed with 316L stainless steel wetted parts. A compact thermometer that utilises a Pt100 (Class A) sensor element for measurement is the most appropriate. Additionally a device with a Pt100 4-wire connection eliminates errors caused by the resistance of the sensor feed cables. A built-in transmitter in the device converts the Pt100 input signal into the 4-20 mA signal. Modern temperature sensors use a new kind of thin film sensor element that is soldered directly into the sensor tip. The film design improves upon previous generation sensors, as its performance is not affected by vibration that is commonly found on CIP systems. Soldering the thin film sensor directly onto the tip also results in extremely fast temperature response as it ensures ideal heat transfer from the process to the sensor element.

A side benefit of fast temperature response is that it can be used to compensate for the change in conductivity based on temperature by taking the 4-20 mA value directly into the onductivity transmitter. This ensures fast determi-nation of the conductivity and concentration values derived from the conductivity instrument, saving both time and money.

iTHERM TM 411

For detailed information on iTHERM TM411, please vist http://bit.ly/2koB7jT

Concentration

Mechanical forces at the right temperature are not sufficient for many soils – the soils also need to be chemically attacked to help them leave the production surfaces.

Typically there will be at least two cycles of chemical wash – usually an alkaline wash, and an acid wash. Each wash is followed by a rinse cycle to clear out the remaining residue and chemicals.

Normally the alkaline wash takes place first – the alkaline chemicals help to break down the organic soil, such as proteins, fats and sugars. The most commonly used chemical is caustic soda ($NaOH$), or a formulated mixture with $NaOH$ and other additives to make it more effective or lower the sodium concentration in the waste. Sodium in wastewater poses an environmental problem because it is typically difficult or impossible for wastewater plants to remove. Potassium hydroxide (KOH) is sometimes used instead, but it requires a greater concentration and is significantly more costly than $NaOH$. The caustic solution is usually used at a concentration of between 0.5 wt% and 2 wt%, although some foods may require a higher concentration. In most cases, however, a concentration that is too high can be counter-productive because it can induce crosslinking of proteins, making them harder to remove. In dairy applications for example, 0.5 wt% has been found to be the most effective – dairy protein fouling is caused by protein crosslinking, and the right concentration of $NaOH$ will break down the crosslinks, while too much can induce more crosslinking.

The acid wash step is used to dissolve minerals, although it has some effect on organic soil as well. Typically nitric acid (HNO_3) or phosphoric acid (H_3PO_4) is used. As for the alkaline solution, there are also mixed formulas available. Nitric acid is typically used at a concentration of 0.5 wt% to 1 wt%. Having a solution that is too strong can attack some polymer materials and stainless steel.

Similarly for breweries, the alkaline wash cycle breaks down the hop oils, tannis and resins that acid washing cannot. Mineral-based soils however, as commonly found in milk or brewing such as calcium oxalate, that lead to build-up of beerstone or milkstone, require an acid wash cycle to remove them.

The acid wash step is used to dissolve minerals, such as beerstone, water scale, calcium and magnesium carbonates, although it has some effect on organic soil as well. It is more effective against bacteria than alkaline solutions.

Instruments for monitoring concentration and completion

Without a way of measuring the concentration of cleaning chemicals in a CIP system, a purely timing-based method tends to be used - assuming the whole system is up to the correct concentration and then running the wash through for a set period of time. To ensure cleaning occurs effectively, the set time for the wash normally includes a safety margin.

By installing conductivity sensors in the CIP return line, it is possible to know when the wash fluid is up to the correct concentration, and that ideal cleaning concentration has been reached - as well as when a rinse cycle has flushed the chemicals.

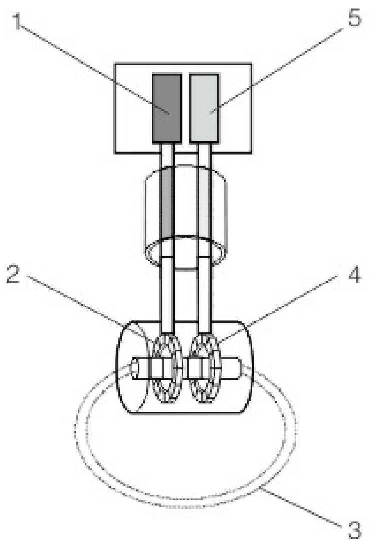
Conductivity sensors in the chemical storage vessels also confirm the correct concentration of the alkaline and acid cleaning solutions in storage and whether the concentration needs adjustment after recycling.

Digital conductivity sensor Indumax CLS54D

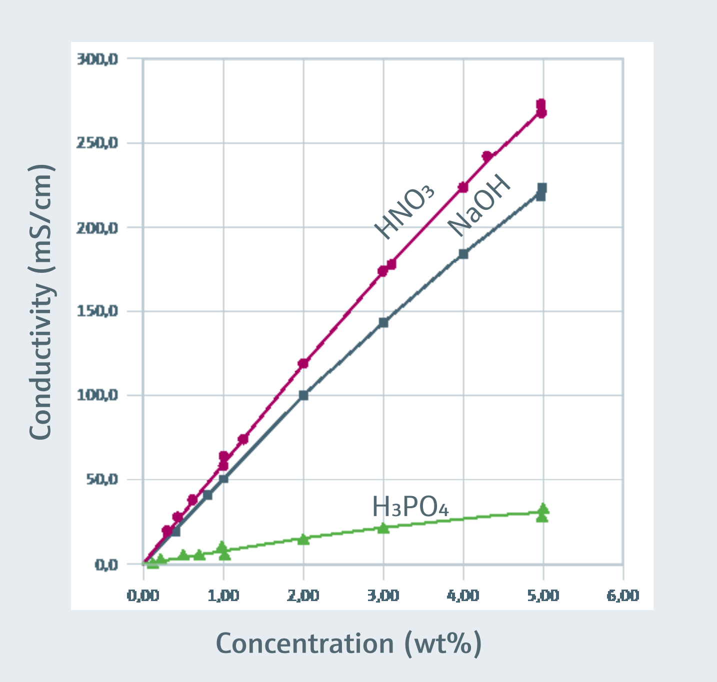
Watch our principle of measuring conductivity video via below link
https://www.youtube.com watch?v=5qxenj3NpE0

For more information on Analog conductivity sensor Indumax CLS54D, please visit
http://bit.ly/2jszemt

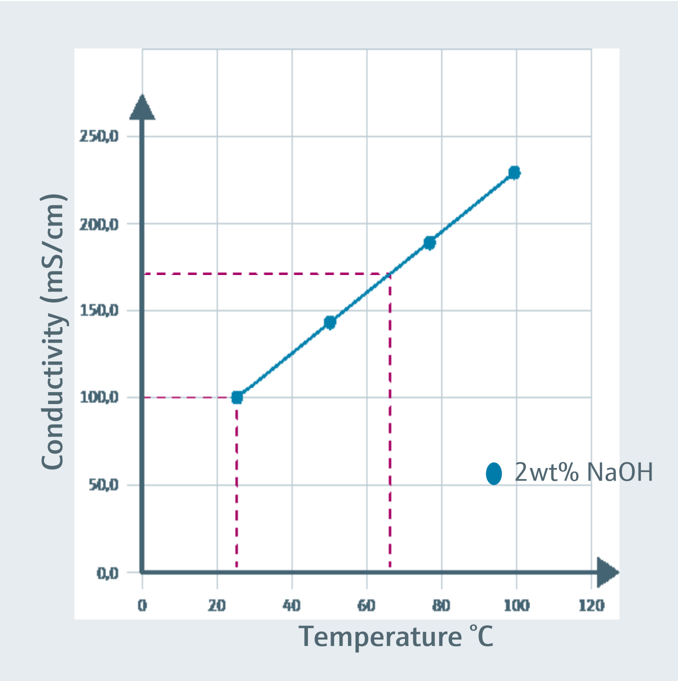
The measurement principle of such a conductivity sensor (Figure 5) is based on an inductive signal, whereby a generator (1) generates an alternating magnetic field in the primary coil (2) which induces a curent in the medium (3). The strength of the induced current depends on the conductivity and thus the ion concentration of the medium. The current flow in the medium generates another magnetic field in the secondary coil (4). The resulting current induced in the coil is measured by the receiver (5) and processed to determine the conductivity.



Inductive conductivity measurement



Graph 1: Conductivity versus concentration at 25°C.[2]



Graph 2: Temperature dependence of NaOH concentration

It should be pointed out however, that conductivity is related to chemical concentration via a calibration curve (Graph 1), and such calibration curves relate to a specific temperature. As temperature increases, conductivity increases for the same concentration. Given that different cycles of a CIP process may occur at different temperatures, it is necessary to compensate the conductivity measurement with real time temperature measurement collected by a temperature sensor. Temperature compensation coefficients are also required for the chemical cleaning agent being used (see Graph 2).

Optical sensors can also be used to detect suspended solids in the wash return and to detect when soil is no longer present.

Conductivity and optical instruments can be used to:

- Detect when the alkaline or acid wash solution has achieved ideal concentration (conductivity)
- Detect and adjust for fluctuations in the concentration of the wash solution due to soiling (conductivity)
- Confirm the flow of soil in the waste return (optical)
- Confirm the end of the wash cycle by detecting no further soil (optical) and normal chemical concentration (conductivity)
- Confirm the end of a rinse cycle when all chemicals have been flushed (conductivity)
- Monitor the correct concentration of wash chemicals in storage (conductivity)

Knowing when a cycle has fully begun (correct concentration), optimising the concentration throughout the wash and knowing as soon as cleaning has completed, all serve to minimise the wastage of energy, chemicals, water and time, by using only of much of each as in necessary.

For interface detection and measurement of chemical concentration at the elevated temperatures present in a CIP process, a sensor that is sanitary, robust and reliable is required. For this application, toroidal or inductive conductivity sensors are ideal. In addition, when connected to an appropriate smart transmitter, it is possible to convert and display the chemical concentration locally.
The benefits of inductive conductivity measurement are:

- There are no electrodes, and therefore no polarisation
- They offer accurate measurement in media or solutions with a high degree of soiling and tendency to deposition
- There is complete galvanic separation of measurement from the medium

Conductivity and optical sensors that come in contact with CIP cleaning solutions should be designed according to 3-A sanitary standards or EHEDG guidelines. They also need to be able to withstand contact with acid and alkaline cleaning chemicals without damage.

PEEK (polyetheretherketone) is a common material used in the contact elements of instruments, being chemically, thermally and mehanically resistant to the cleaning chemicals. The inductive conductivity sensor is therefore considered to be a non-contact sensor, since the measurement coils are encased in the injection moulded PEEK body. PEEK allows for a smooth surface finish (Ra <0.8um) and guarantees biological safety, as pathogens are unable to stick to the surface.

OUSAF 11.

For more information on absorption sensor OUSAF11, Please visit
http://bit.ly/2kOdUon

Contact time

The period of circulation depends on the degree of fouling and the types of equipment being cleaned. Typically 20 minutes of caustic circulation is required for pipework and vessels.

In dairy processing, pasteurisers and UHT plants that suffer from higher level of fouling may require up to 40 minutes of caustic circulation. Acid circulation is normally 10 minutes.

Of course the longer the contact time in each cycle of the CIP process (flush, alkaline wash, rinse, acid wash, rinse), the more pumping energy is used, the more heating energy is used, and the more water and chemicals are used and needs to be recycled. It is therefore essential that each stage of the CIP process is shortened to only as much time as is necessary to get the job done.

The contact time is dependent on correct temperature and flow rate, and on the right chemical balance during the wash cycles. Minimising the necessary contact time for effective cleaning therefore depends solely on optimising the flow rate, temperature and chemical concentrations - as well as detecting when cleaning has completed - as described in the above sections.

Other required measurements

CIP chemicals such as NaOH and HNO_3 are of course toxic and need to be stored carefully, and at the correct concentrations ready to use. In modern multi-use CIP systems, the recycling of filtered chemicals for re-use also does not result in all chemicals being returned and so the storage vessels will need to be replenished from time to time.

Maintaining an accurate inventory, as well as automating the filling and low level detection for chemical storage vessels are therefore also important aspects of managing a CIP system. Instrumentation that can be used to assist in the management of chemical inventory include:

- Conductivity and temperature sensors to detect concentration
- Level limit switches to detect high and low level

The Choice of instruments will need to take into consideration their chemical compatibility with the chemicals they contact, as described previously.

Vibrating fork level switches designed for hygienic applications and with a protection class of IP69K are simple to commission (no calibration, specific know-how or tools are required for its set up) and work with all types of liquid media found in the CIP process. Such sensors can be used in areas where other measuring principles are not suitable due to conductivity, buildup, turbulence, flow conditions or air bubbles - all of which are found in the CIP process.

In vibrating fork level switches, a piezoelectric drive causes the tuning fork to vibrate at its resonant frequency. When the tuning fork is immersed in a liquid, its intrinsic frequency changes due to the change in density of the surrounding medium. The electronics system in the poinr level switch monitors the frequency and indicates whether the tuning fork is vibrating in air or is covered by liquids.

Level limit switches provide high levels of safety for the CIP process by ensuring reliable over-fill protection as well as avoiding pump damage by preventing dry running.

Liquiphant FTL33.

Watch liquiphant FTL33 video via below link
https://www.youtube.com watch?v=fKvTyu5a6r0

For more information on Liquiphant FTL33, please visit
http://bit.ly/2kJUbFQ

Conclusion

Cleaning process equipment is a necessary and important part of food and beverage processing - for food safety and to maintain product quality. CIP systems, designed and operated correctly, can eliminate the need to dismantle euipment and manually clean it.

Operating CIP systems in the most cost-effective and efficient way requires accurate cleaning data at all steps of the process. The correct choices and application of process instruments can assist food and beverage operators to optimise their cleaning process, reducing chemical use and minimising energy consumption.

References

1. Romey A (ed,) 1990, CIP: cleaning in place, Society of Dairy Technology.
2. Tetra pak, Cleaning in place: A guide to cleaning technology in the food industry.
3. op cit.