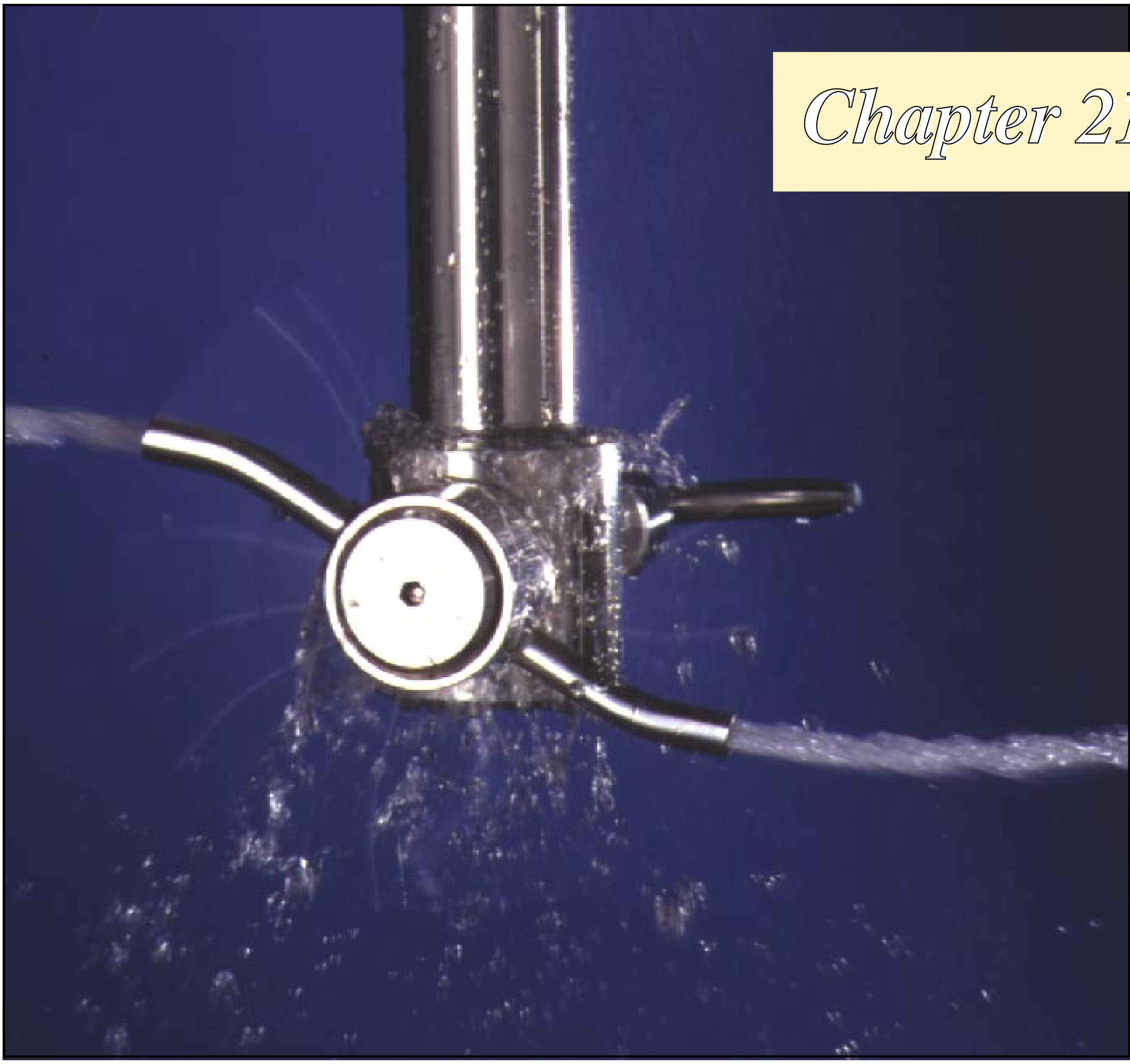


Chapter 21

Cleaning of dairy equipment

Aspects of cleaning

The arrangements for cleaning equipment that comes in contact with products are an essential part of a food processing plant. It must be kept in mind that food manufacturers are always obliged to maintain high hygienic standards; this applies both to the equipment and, naturally, to the staff involved in production. This obligation can be considered under three headings:
1. Trade obligation
2. Moral obligation
3. Legal obligation

Trade obligations

Good, wholesome, clean products that keep well and are free from health hazards are obviously good for trade; customers will buy the same product again. If however a product is contaminated, does not keep well or is the subject of complaints to the authorities, the reverse is true, and the resulting publicity is very damaging.

The potential effects of poor cleaning, poor standards and poor quality must be kept in mind at all times.

Moral obligation

Most of the customers who consume the products never see the factory or how the products are handled. They trust the company, rely on its reputation, and take it for granted that operations are carried out under the cleanest of conditions by well-trained staff who are continually aware and conscious of these factors

Legal obligation

The law attempts to protect the customer and purchaser in respect of health and quality. Failure to meet legal obligations, national or local, can result in very severe action. Prosecution proceedings can be very damaging.

Prevention is better than cure, and companies are obliged to meet legal requirements and maintain high standards. Milk and milk products by their nature are ideal media for the growth of micro-organisms, including many pathogens. As a result of this there is more legislation concerning milk – its production, handling, processing, packaging, storage and distribution – than any other food product. Each country has its own national and perhaps local legislation standards.

Cleaning objectives

As concerns of cleaning results, the following terms are used to define the degree of cleanliness:

- Physical cleanliness – removal of all visible dirt from the surface;
- Chemical cleanliness – removal not only of all visible dirt but also of microscopic residues which can be detected by taste or smell but are not visible to the naked eye;
- Bacteriological cleanliness – attained by disinfection;
- Sterile cleanliness – destruction of all micro-organisms.

It is important to note that equipment can be bacteriologically clean without necessarily being physically or chemically clean. However, it is easier to achieve bacteriological cleanliness as a matter of routine if the surfaces in question are first rendered at least physically clean.

In dairy cleaning operations the objective is nearly always to achieve both chemical and bacteriological cleanliness. The equipment surfaces are therefore first thoroughly cleaned with chemical detergents and then disinfected.

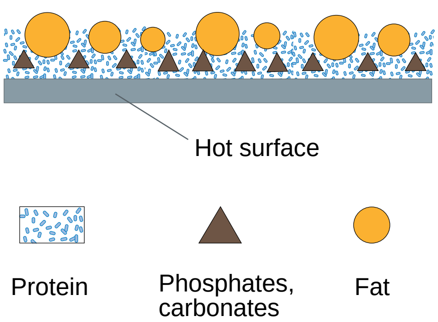


Fig. 21.1 *Deposits on a heated surface.*

Dirt

What kind of dirt is it that is present on the surfaces of dairy equipment and needs to be removed?

It consists of deposits stuck to a surface and its composition, in this particular case, is based on milk components which are utilised by bacteria "hidden" in the dirt.

Heated surfaces

When milk is heated above 60°C, *milk stone* starts to form. This is a deposit of calcium (and magnesium) phosphates, proteins, fat, etc. You can easily see the result on heat exchanger plates after a long production run, in the heating section and the first part of the regenerative section to follow. The deposits stick tight to the surfaces, and after runs of more than eight hours a change of colour from whitish to brownish can also be observed. An attempt to visualise the dirt on a heated surface has been made in figure 21.1.

Table 21.1
Chemical effects and soil characteristics

Component on surface	**Solubility**	**Ease of removal** **Low/medium pasteurisation**	**High pasteurisation/UHT**
Sugar	In water	Easy	*Caramelisation* Difficult
Fat	Not in water	Difficult In alkali	*Polymerisation* Difficult
Protein	Not in water	Very difficult In alkali Slightly in acid	*Denaturation* Very difficult
Mineral salts	Varies in water Most salts in acid	Varies	Varies

It is important to note that equipment can be bacteriologically clean without necessarily being physically or chemically clean.

Cold surfaces

A film of milk adheres to the walls of pipelines, pumps, tanks, etc. ("cold" surfaces). When a system is emptied, cleaning should start as soon as possible, or otherwise this film will dry out and be harder to remove.

Cleaning procedures

Cleaning of dairy equipment was formerly done (and still is in some places) by people armed with brushes and detergent solutions, who had to dismantle equipment and enter tanks to get at the surfaces. This was not only laborious but also ineffective; products were often reinfected from imperfectly cleaned equipment.

Circulatory cleaning-in-place (CIP) systems adapted to the various parts of a processing plant have been developed to achieve good cleaning and sanitation results.

Cleaning operations must be performed strictly according to a carefully worked out procedure in order to attain the required degree of cleanliness . This means that the sequence must be exactly the same every time.

The cleaning cycle in a dairy comprises the following stages:

- Recovery of product residues by scraping, drainage and expulsion with water or compressed air;
- Prerinsing with water to remove loose dirt;
- Cleaning with detergent;
- Rinsing with clean water;
- Disinfection by heating or with chemical agents (optional); if this step is included, the cycle ends with a final rinse, if the water quality is good.

Each stage requires a certain length of time to achieve an acceptable result. In table 21.1 some chemical effects and soil characteristics are listed.

Recovery of product residues

All product residues should be recovered from the production line at the end of the run. This is important for three reasons:

- to minimise product losses,
- to facilitate cleaning,
- to reduce the load on the sewage system, which often means a considerable saving in sewage treatment costs.

Time must be allowed for the product to drain from tank walls and pipes. Surfaces coated with solid residues, e.g. in butter-printing machines, must be scraped clean. Before cleaning starts, the remaining milk is forced out of the production lines with water. Wherever possible, the milk in the piping systems is blown or flushed with water to collecting tanks.

Prerinsing with water

Prerinsing should always be carried out immediately after the production run. Otherwise the milk residues will dry and stick to the surfaces, making them harder to clean. Milk fat residues are more easily flushed out if the prerinsing water is warm, but the temperature should not exceed 55°C to avoid coagulation of proteins.

Prerinsing must continue until the water leaving the system is clear, as any loose dirt left will increase detergent consumption and inactivate chlorine, if used, in the detergent. If there are dried milk residues on the surfaces it may be an advantage to soak the equipment. Soaking softens the dirt and makes cleaning more efficient.

The mixture of water and milk from the initial prerinsing can be collected in a tank for special processing. At least 90% of the unencrusted residues, normally 99% of the total residues, can be removed by efficient prerinsing.

As a rule of thumb, cleaning with alkaline detergent should be done at the same temperature as the product has been exposed to, but at least 70°C.

Cleaning with detergent

The dirt on heated surfaces is normally washed off with alkaline and acid detergents, in that order or the reverse order, with intermediate water flushing, whereas cold surfaces are normally cleaned with alkalis and only occasionally with an acid solution.

To obtain good contact between the *alkaline* detergent solution, typically *caustic soda (NaOH)*, and the film of dirt, it is necessary to add a *wetting agent* (surfactant) which lowers the surface tension of the liquid. Teepol (alkyl aryl sulphonate), an anionic surfactant, is usually used.

The detergent must also be capable of *dispersing* dirt and *encapsulating* the suspended particles to prevent flocculation. Polyphosphates are effective emulsifying and dispersing agents which also soften water. The most commonly used are sodium triphosphate and complex phosphate compounds.

A number of variables must be carefully controlled to ensure satisfactory results with a given detergent solution. These are:

- the concentration of the detergent solution
- the temperature of the detergent solution
- the mechanical effect on the cleaned surfaces (velocity)
- the duration of cleaning (time)

Detergent concentration

The amount of detergent in the solution must be adjusted to the correct concentration before cleaning starts. During cleaning, the solution is diluted with rinsing water and milk residues. Some neutralisation also takes place. It is therefore necessary to check the concentration during cleaning. Failure to do this can seriously affect the result. Checking can be done either manually or automatically. The dosage must always be according to the detergent supplier's instructions, as increasing the concentration does not necessarily improve the cleaning effect – it may indeed have the reverse effect due to foaming, etc. Using too much detergent simply makes cleaning needlessly expensive.

Detergent temperature

Generally speaking, the effectiveness of a detergent solution increases with increasing temperature. A blended detergent always has an optimum temperature which should be used.

As a rule of thumb, cleaning with alkaline detergent should be done at the same temperature as the product has been exposed to, but at least 70°C. Temperatures of 68 – 70°C are recommended for cleaning with acid detergents.

Mechanical cleaning effect

In manual cleaning, scrubbing brushes are used to produce the required mechanical scouring effect, figure 21.2. In mechanised cleaning of pipe systems, tanks and other process equipment, the mechanical effect is supplied by the flow velocity. The detergent feed pumps are dimensioned for higher capacities than the product pumps, with flow velocities of 1.5 – 3.0 m/s in the pipes. At these velocities the liquid flow is very turbulent. This results in a very good scouring effect on the surfaces of the equipment.

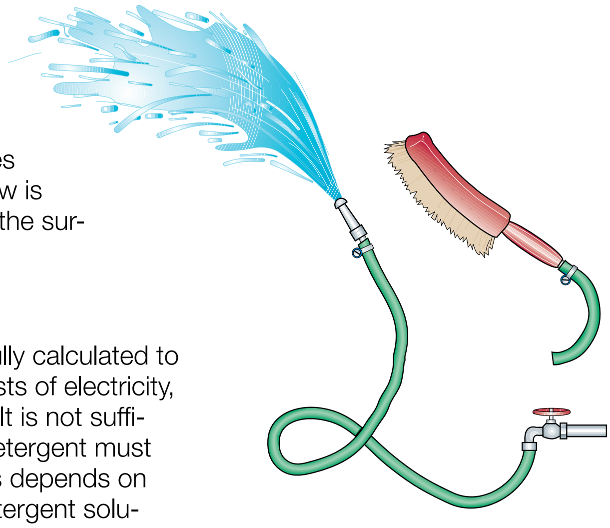


Fig. 21.2 *Examples of mechanical cleaning effects.*
The mechanical effect can be provided either by scrubbing brushes in a manual cleaning system, or by the flow velocity in a mechanised system.

Duration of cleaning

The duration of the detergent cleaning phase must be carefully calculated to obtain the optimum cleaning effect. At the same time the costs of electricity, heating, water and labour must be taken into consideration. It is not sufficient to flush a pipe system with a detergent solution. The detergent must circulate long enough to dissolve the dirt. The time this takes depends on the thickness of the deposits (and the temperature of the detergent solution). Heat exchanger plates encrusted with coagulated protein must be exposed to circulating nitric acid solution for about 20 minutes, whereas 10 minutes' treatment with alkaline solution is enough to dissolve the film on the walls of a milk tank.

Rinsing with clean water

After cleaning with detergent the surfaces must be flushed with water long enough to remove all traces of the detergent. Any detergent left in the system after cleaning can contaminate the milk. All parts of the system must be thoroughly drained after rinsing.

Softened water is preferred for rinsing. This prevents deposition of lime scale on the cleaned surfaces. Hard water with a high content of calcium salts must therefore be softened in ion exchange filters to 2 – 4°dH (German degrees of hardness).

The equipment and pipe systems are practically sterile after the treatment with strong alkaline and acid solutions at a high temperature. It is then necessary to prevent overnight growth of bacteria in the residual rinsing water in the system. This can be done by acidifying the final rinse water to a pH of less than 5 by adding phosphoric or citric acid. This acid environment prevents the growth of most bacteria.

Disinfection

Properly carried out cleaning with acid and alkaline detergents renders the equipment not only physically and chemically but also, to a large extent, bacteriologically clean.

The bacteriological cleaning effect can be further improved by disinfection. This leaves the equipment virtually free from bacteria. For certain products (UHT milk, sterile milk) it is necessary to sterilise the equipment to render the surfaces completely free from bacteria.

Dairy equipment can be disinfected in the following ways:

- Thermal disinfection (boiling water, hot water, steam);
- Chemical disinfection (chlorine, acids, iodophors, hydrogen peroxide, etc.)

Disinfection can be done in the morning, immediately before milk processing begins. The milk can be admitted as soon as all the disinfectant has been drained from the system.

If disinfection takes place at the end of the day, the disinfectant solution should be flushed out with water to avoid leaving any residues that may attack the metal surfaces.

Cleaning-in-place systems

Cleaning-in-place means that rinsing water and detergent solutions are circulated through tanks, pipes and process lines without the equipment having to be dismantled. CIP can be defined as circulation of cleaning liquids through machines and other equipment in a cleaning circuit. The passage of the high-velocity flow of liquids over the equipment surfaces generates a mechanical scouring effect which dislodges dirt deposits. This only applies to the flow in pipes, heat exchangers, pumps, valves, separators, etc.

The normal technique for cleaning large tanks is to spray the detergent on the upper surfaces and then allow it to run down the walls. The mechanical scouring effect is then often insufficient, but the effect can to some extent be improved by the use of specially designed spray devices, one of which is shown in figure 21.3. Tank cleaning requires large volumes of detergent, which must be circulated rapidly.

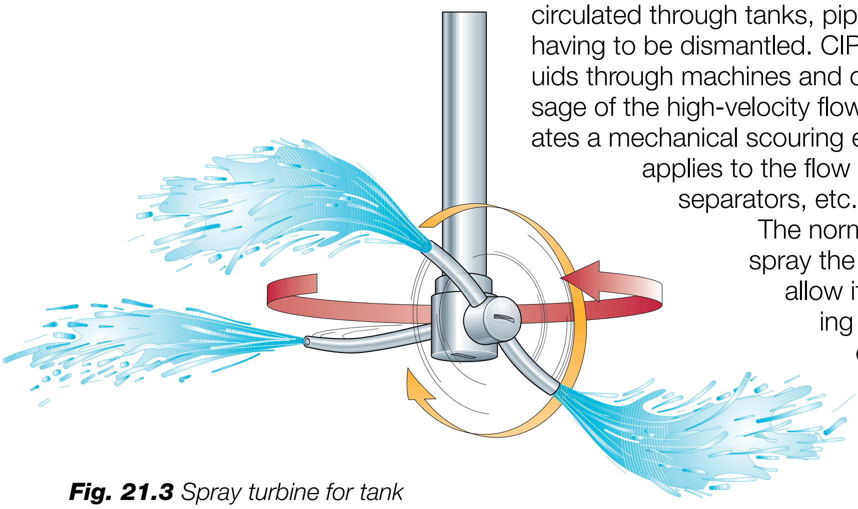


Fig. 21.3 *Spray turbine for tank cleaning.*
The spray turbine consists of two rotating nozzles on the same pipe. One rotates in the horizontal plane and the other in the vertical. Rotation is produced by jet reaction from the backward-curved nozzles.

CIP circuits

The question of the type of equipment that can be cleaned in the same circuit is determined according to the following factors:

- The product residue deposits must be of the same type,so that the same detergents and disinfectants can be used.
- The surfaces of the equipment to be cleaned must be of the same material or, at least of materials compatible with the same detergent and disinfectant.
- All components in the circuit must be available for cleaning at the same time.

Dairy installations are therefore divided for cleaning purposes into a number of circuits which can be cleaned at different times.

Compatible materials and system design

For effective CIP, the equipment must be designed to fit into a cleaning circuit and must also be easy to clean. All surfaces must be accessible to the detergent solution. There must be no dead ends which the detergent cannot reach or through which it cannot flow, see figure 21.4. Machines and pipes must be installed in such a way that they can be efficiently drained. Any pockets or traps from which residual water cannot drain will provide sites for rapid multiplication of bacteria and cause a serious risk of infecting the product.

Materials in process equipment, such as stainless steel, plastics and elastomers, must be of such quality that they do not transmit any odour or taste to the product. They must also be capable of withstanding contact with detergents and disinfectants at the cleaning temperatures.

In some cases the surfaces of pipes and equipment may be chemically attacked and contaminate the product. Copper, brass and tin are sensitive to strong acids and strong alkalis. Even small traces of copper in milk result in an oxidized flavour (oily, train-oil taste). Stainless steel is the universal material for product-wetted surfaces in modern dairies. Metallic contamination is therefore normally no problem. Stainless steel can however be attacked by chlorine solutions.

Electrolytic corrosion is common when components made of copper or brass are built into systems of stainless steel. In such conditions the risk of contamination is great. Electrolytic corrosion may also occur if a system with steels of different grades is cleaned with cation-active agents.

Elastomers (e.g. rubber gaskets) can be attacked by chlorine and oxidising agents, which cause them to blacken or crack and release rubber particles into the milk.

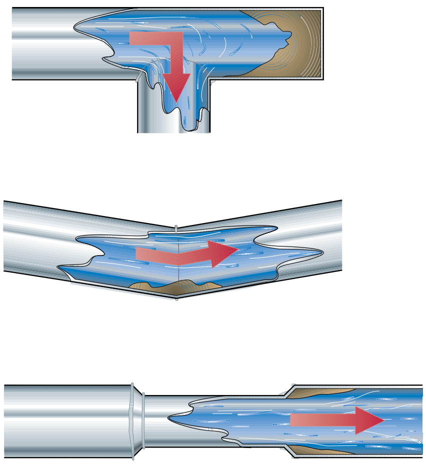


Fig. 21.4 *Examples of positions difficult to clean in a pipe system.*

Various types of plastic in process equipment may present a contamination hazard. Some of the constituents of some types of plastics can be dissolved by the fat in milk. Detergent solutions can have the same effect. Plastic materials for use in dairies must therefore satisfy certain criteria regarding composition and stability.

CIP programs

Dairy CIP programs differ according to whether the circuit to be cleaned contains heated surfaces or not. We distinguish between:

- CIP programs for circuits with pasteurisers and other equipment with heated surfaces (UHT, etc.).
- CIP programs for circuits with pipe systems, tanks and other process equipment with no heated surfaces;

The main difference between the two types is that acid circulation must always be included in the first type to remove encrusted protein and salts from the surfaces of heat-treatment equipment. A CIP program for a pasteuriser, "*hot components*", circuit can consist of the following stages:

1 Rinsing with warm water for about 10 minutes.
2 Circulation of an alkaline detergent solution (0.5 – 1.5%) for about 30 minutes at 75°C.
3 Rinsing out alkaline detergent with warm water for about 5 minutes.
4 Circulation of (nitric) acid solution (0.5 – 1.0 %) for about 20 minutes at 70°C.
5 Post-rinsing with cold water.
6 Gradual cooling with cold water for about 8 minutes.

The pasteuriser is usually disinfected in the morning, before production starts. This is typically done by circulating hot water at 90 – 95°C for 10 – 15 minutes after the returning temperature is at least 85°C.

In some plants, after prerinsing with water, the CIP system is programmed to start with the acid detergent to first remove precipitated salts and thus break up the dirt layer to facilitate dissolving of proteins by the subsequent alkaline detergent. If disinfection is going to be done with chlorinated chemicals, there is an imminent risk of fast corrosion problems if any residues of the acid detergent remain. Therefore, when starting with alkaline cleaning and ending with acid cleaning after an intermediate water rinse, the plant should be flushed with a weak alkaline solution to neutralise the acid before disinfection with a chlorinated chemical can start.

A CIP program for a circuit with pipes, tanks and other *"cold components"* can comprise the following stages:

1 Rinsing with warm water for 3 minutes.
2 Circulation of a 0.5 – 1.5% alkaline detergent at 75°C for about 10 minutes.
3 Rinsing with warm water for about 3 minutes.
4 Disinfection with hot water 90 – 95°C for 5 minutes.
5 Gradual cooling with cold tap water for about 10 minutes (normally no cooling for tanks).

Steps for CIP cleaning of "cold" components:
1 Rinsing with water
2 Circulation of alkaline detergent
3 Rinsing with water
4 Disinfection with hot water
5 Cooling with tap water

Design of CIP systems

In practice there is no limitation to satisfy stringent individual demands as to the size and complexity of CIP plants.

The CIP station in a dairy consists of all necessary equipment for storage, monitoring and distribution of cleaning fluids to the various CIP circuits. The exact design of the station is determined by many factors, such as:

- How many individual CIP circuits are to be served from the station. How many are “hot” and how many are “cold”?
- Are the milk rinses to be collected? Are they to be processed (evaporated)?
- What method of disinfection is to be used? Chemical, steam or hot water?
- Will the detergent solutions be used only once or recovered for reuse?

- What is the estimated steam demand, momentary and total, for cleaning and sterilisation?

Looking back over the history of CIP, we find two schools of thought:

1 Centralised cleaning
2 Decentralised cleaning.

Until the end of the fifties, cleaning was decentralised. The cleaning equipment was located in the dairy, close to the process equipment. Detergents were mixed by hand to the required concentration – an unpleasant and hazardous procedure for the personnel involved. Detergent consumption was high, which made cleaning expensive.

The centralised CIP system was developed during the sixties and seventies. A central CIP station was installed in the dairy. Rinsing water, heated detergent solutions and hot water were supplied from this unit by a network of pipes to all the CIP circuits in the dairy. The used solutions were then pumped back to the central station, and from there to the respective collecting tanks. Detergents recovered in this way could be topped up to the correct concentration and reused until they were too dirty and had to be discarded.

Centralised CIP works well in many dairies, but in large dairies the communication lines between the central CIP station and the peripheral CIP circuits have grown excessively long. The CIP pipe systems contain large volumes of liquids, even when they are "drained". The water remaining in the pipes after prerinsing dilutes the detergent solution, which means that large amounts of concentrated detergent must be added to maintain the correct concentration. The greater the distance, the greater the cleaning cost. A move back towards decentralised CIP stations therefore began in large dairies at the end of the seventies. Each department had its own CIP station. Examples of the two systems are shown below.

Centralised CIP

Centralised systems are used mainly in small dairy plants with relatively short communication lines, an example is shown in figure 21.5.

Water and detergent solutions are pumped from the storage tanks in the central station to the various CIP circuits.

The detergent solutions and hot water are kept hot in insulated tanks. The required temperatures are maintained by heat exchangers. The final rinse water is collected in the rinse-water tank and used as prerinsing water in the next cleaning program. The milk/water mixture from the first rinsing water is collected in the rinse-milk tank.

The detergent solutions must be discharged when they have become dirty after repeated use. The storage tank must then be cleaned and refilled with fresh solutions. It is also important to empty and clean the water tanks,

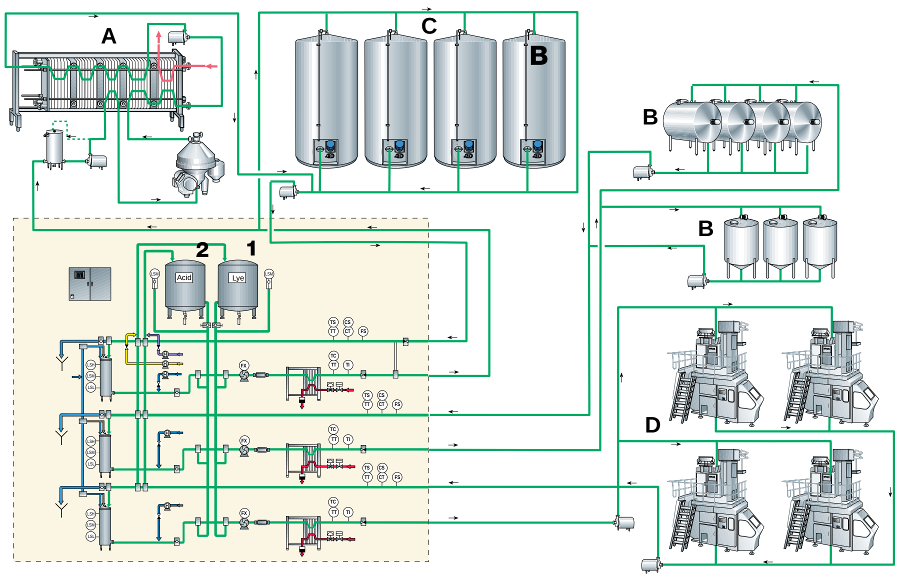


__Fig. 21.5__ Principle of the centralised CIP system.

Cleaning unit (within the broken line)
1 Tank for alkaline detergent
2 Tank for acid detergent

Object to be cleaned:
A Milk treatment
B Tank garden
C Silo tanks
D Filling machines

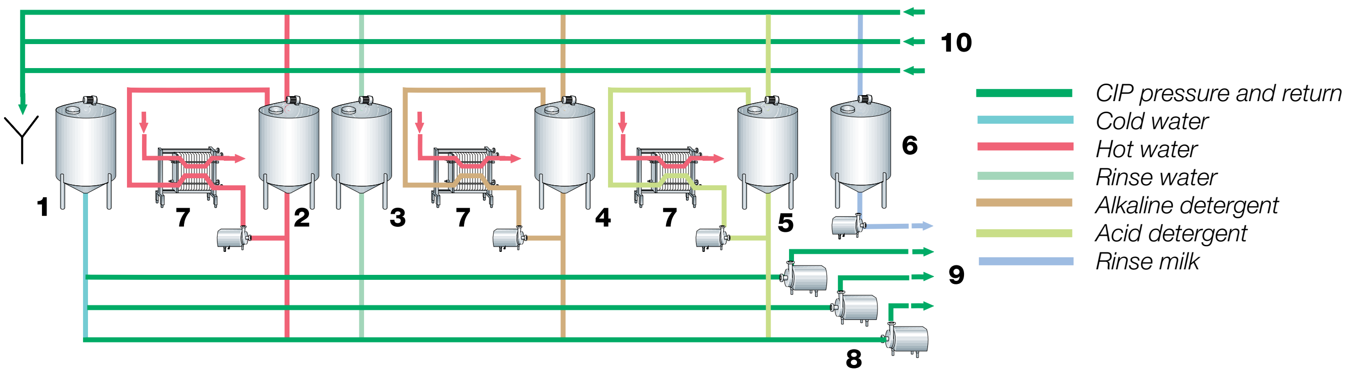
especially the rinse-water tank, at regular intervals to avoid the risk of infecting an otherwise clean process line.

An example of the design of a central CIP station is illustrated in figure 21.6.

A station of this type is usually highly automated. The tanks have electrodes for high and low level monitoring. Returning of the cleaning solutions is controlled by conductivity transmitters. The conductivity is proportional to the concentrations normally used at dairy cleaning. At the phase of flushing with water the concentration of detergent solution becomes lower and lower. At a preset value a change over valve routes the liquid into the drain instead of the relevant detergent tank. CIP programs are controlled from a computerised sequence controller. Large CIP stations can be equipped with multiple tanks to provide the necessary capacity.

Fig. 21.6 *General design of a central CIP station.*

1 Cold water tank
2 Hot water tank
3 Rinse water tank
4 Alkaline detergent tank
5 Acid detergent tank
6 Rinse milk tank
7 Plate heat exchanger for heating
8 CIP pressure pumps
9 CIP pressure lines
10 CIP return lines



Decentralised CIP

Decentralised CIP is an attractive alternative for large dairies where the distance between a centrally located CIP station and peripheral CIP circuits would be extremely long. The large CIP station is replaced by a number of smaller units located close to the various groups of process equipment in the dairy.

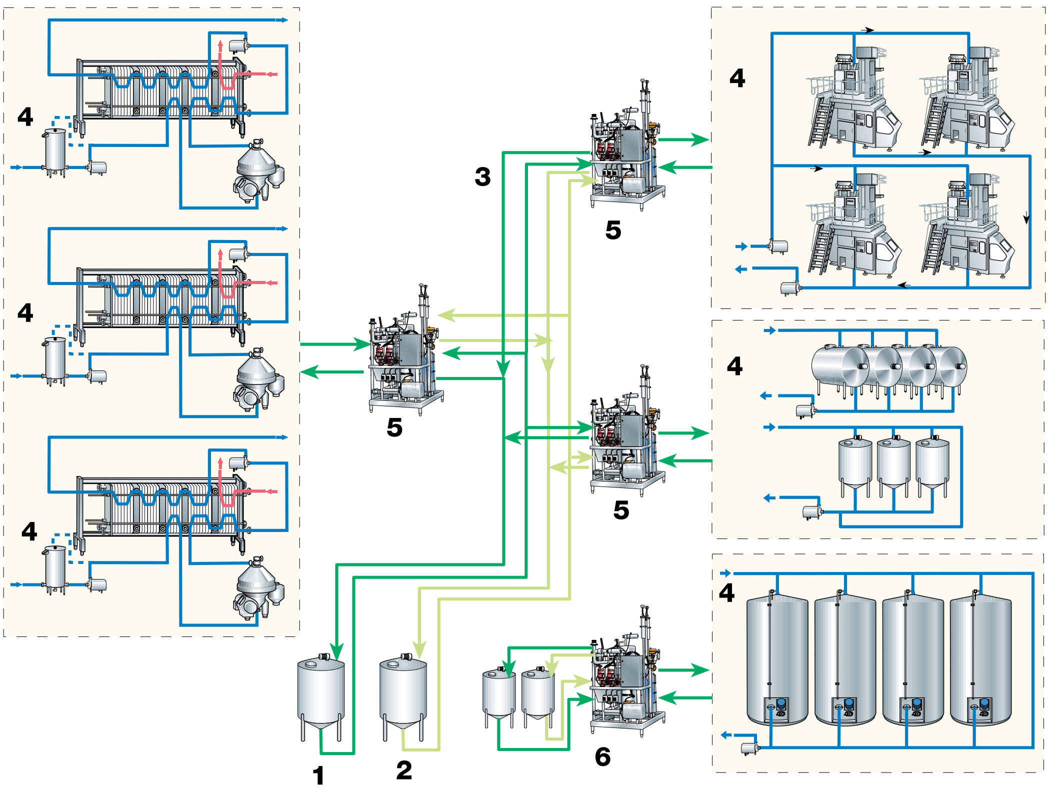


Fig. 21.7 *Satellite CIP system*
1 Storage tank for alkaline detergent
2 Storage tank for acid detergent
3 Ring lines for detergents
4 Objects to be cleaned
5 Satellite CIP unit
6 Decentralised CIP system with its own detergent tanks

Figure 21.7 illustrates the principle of a decentralised CIP system, also called satellite CIP system. This still has a central station for storage of the alkaline and acid detergents, which are individually distributed to the individual CIP units in main lines. Supply and heating of rinsing water (and acid detergent when required) are arranged locally at the satellite stations, one of which is shown in figure 22.8.

These stations operate on the principle that the various stages of the cleaning program are carried out with a carefully measured minimum volume of liquid – just enough to fill the circuit to be cleaned. A powerful circulation pump is used to force the detergent through the circuit at a high flow rate.

The principle of circulating small batches of cleaning solutions has many advantages. Water and steam consumption, both momentary and total, can be greatly reduced. Milk residues from the first rinse are obtained in a more concentrated form and are therefore easier to handle and cheaper to evaporate. Decentralised CIP reduces the load on sewage systems as compared to centralised CIP, which uses large volumes of liquid.

The concept of single use detergents has been introduced in conjunction with decentralised CIP, as opposed to the standard practice of detergent recycling in centralised systems. The one-time concept is based on the assumption that the composition of the detergent solution can be optimised for a certain circuit. The solution is considered spent after having been used once. In some cases it may however be used for prerinsing in a subsequent program.

Verifying the cleaning effect

Verification of the effect of cleaning must be regarded as an essential part of cleaning operations. It can take two forms: visual and bacteriological inspection. Because of the advance of automation, process lines today are

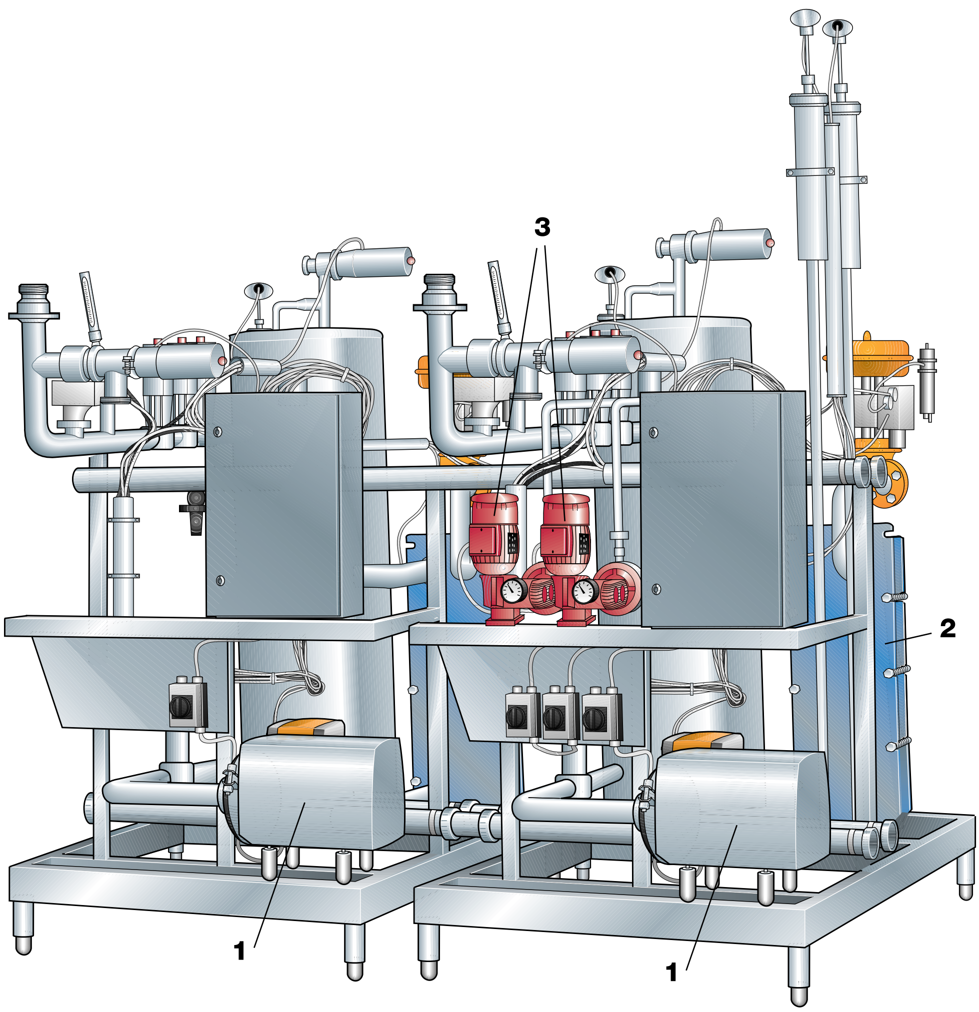


Fig. 21.8 *CIP unit for a decentralised system with two cleaning lines and equipped with two circulation tanks and two dosing pumps for concentrated detergents connected to the detergent and rinse water recovery tanks.*

1 Pressure pumps
2 Heat exchanger
3 Dosing pumps

seldom accessible for visual inspection. This must be replaced by bacteriological monitoring, concentrated to a number of strategic points in the line. CIP results are usually checked by cultivating coliform bacteria. When a swab test of a surface is made, the criterion is less than *one coli bacterium per 100* cm^2 of the checked surface. The result is unacceptable if the count is higher. These tests can be made on the surfaces of the equipment after completion of the CIP program. This applies to tanks and pipe systems, especially when excessively high bacteria counts have been detected in the products. Samples are often taken from the final rinse water or from the first product that passes through the line after cleaning.

All products must be checked for bacteriological quality in their packages to obtain full quality control of the manufacturing process. The complete quality control program, in addition to the coliform test, also includes determination of the total count of micro-organisms and organoleptic control (tasting).