Qualifications

Diploma in Beverage Packaging (Beer)
Unit 2.1 Quality

Cleaning in Place (CIP)

DIPLOMA IN PACKAGING (BEER) - MODULE 2

UNIT 2.1: Quality

ELEMENT 2.1.4: Cleaning in Place (CIP)

ABSTRACT: This section describes the factors to be taken into account in the design of plant cleaning systems, including the types of material that contaminate plant surfaces. The action of detergents and sterilants and their formulations are also considered, plus descriptions of CIP processes and factors affecting the optimization of cleaning systems.

LEARNING OUTCOMES: On completion of this unit you will be able to:

1. Define the key principles applied in the design of process plant cleaning systems.
2. Identify the key factors in the design of effective cleaning techniques.
3. Understand how detergents and sterilants act and the basis of their formulations.
4. Understand the factors influencing the optimization of CIP and other cleaning processes.

SYLLABUS.

2.1.4.1 CIP principles:

- Factors affecting the performance of cleaning systems:
- Composition of soil, scale and biofilm
- Microbiology of cleaning
- Safety requirements

2.1.4.2 Detergents and sterilizing agents:

- Detergent and sterilant chemistry
- Ingredients of caustic or alkali detergents
- Ingredients of acid detergents
- Ingredients of sterilants

2.1.4.3 Design and operation of CIP systems:

- Design principles
- CIP of vessels
- CIP of pipework systems and hoses
- Types of CIP systems
- Optimization of cleaning systems

Element 2.1.4 Cleaning in Place (CIP)

2.1.4.1 – CIP PRINCIPLES

The underlying principles that determine the need for a cleaning system are as follows:

- define the factors affecting performance of cleaning systems;
- determine the composition of the soils, scale or biofilm accumulating on the surfaces of the plant;
- identify the microbiology and chemistry of cleaning.

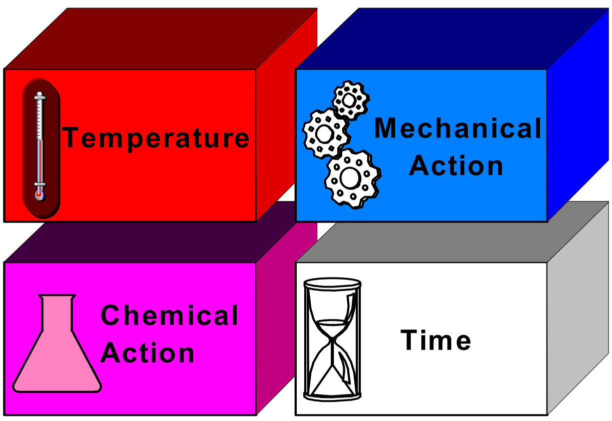
A. Factors Affecting Performance of Cleaning Systems

The underlying principles of a balanced cleaning system are based on the following:

- the mechanical force for a determined time period;
- the chemical composition at a determined temperature;
- the synergistic effect of the above factors.

The balanced application of these factors will determine both the design and effectiveness of the cleaning system. As each of the factors influence cost of the initial plant (vessels, pumps, piping, heat exchangers, instrumentation and the area occupied by the cleaning station with upgraded building finishes), as well as the running costs (chemicals, water, heat, effluent, power, spares), the optimum balance must be achieved to obtain the required levels of hygiene.

There are four factors that have to be optimized during the operation of the cleaning system, as inefficiencies will become evident as soon as one or two of them falls below their effectiveness level.



These four factors are inter-related and inter-dependent to ensure an effective cleaning of surfaces.

These four factors impacting on the cleaning efficiency are influenced by conditions that are also important to consider.

Mechanical Factor:
- quantity of the soil to be removed from the surface
- flow rates
- turbulence
- shear stress
- pressures and pressure drops
- water hammer prevention (lifts seats on valves allowing CIP into product line)
- efficiency of flow and pressure measuring instruments.

Chemical Factor:
- quantity and quality of the soil to be removed from the surface
- initial concentration as measured and efficiency of conductivity meter
- topping up in the circuit
- presence of solids in solution
- dilution in circuit
- neutralisation e.g. CO2 by caustic
- return of CIP liquid to holding vessel or drain in multi-use system.

Temperature:
- initial temperature as measured
- controlling in the circuit
- cooling in the circuit e.g. pass over cold surface of process plant
- return of CIP liquid to holding vessel or drain in multi-use system
- efficiency of temperature control.

Time:
- time for complete process
- time to wash out or rinse the previous chemical or product
- time for chemical to react on surface soil
- time to drain the detergent in the bottom of the vessel
- time to sequence CIP and CIR pumps
- time to sequence opening and closing of automated valves
- efficiency of time control.

In the selection of the correct equipment to be included in the cleaning system, the following principles must be considered:

- A ‘multi use CIP system’ requires that the capacity of the vessels in the CIP plant must be sized to hold the required quantity of the chemicals and water for reuse and recirculation.

- The number of vessels is determined by the type of chemicals to be used *e.g.* caustic hot and or cold, acid, sterilant.

- The level of instrumentation is defined by what parameters are required to be monitored *e.g.* temperature, flow, pressure, level and conductivity.

- The flow characteristics of the CIP for vessel and piping systems is determined by the principles of fluid dynamics as follows:

  - flow rates required to clean surfaces of vessels range from 1000 to 3510 litres per hour per meter of vessel circumference for spray balls;

  - the force from the spray ball or rotating spray cleaners on the vessel surface is only totally effective at the point of contact; point of impingement. The fluid then runs down the side of the vessel wall by gravity to clean the rest of the surface. There are two schools of thought on whether flooding of all the surface with fluid from low pressure spray balls is more or less effective than rotating high pressure jets that work on the principle of maximum impingement of fluid directed at the targeted surface as it completes a rotation every 6 to 12 times a CIP cycle. There is no conclusive evidence that one system is superior to the other given all the factors that contribute to an effective cleaning system;

  - the force of the fluid through pipelines determines the effectiveness of the cleaning of the surface. Turbulent flows, defined in Reynolds Number (Re), have a direct relation to the shear stress on the side of the pipe and this determines the mechanical force on the surface that helps to remove the soil or scale;

  - other factors that will influence the flow-cleaning effectiveness are the pressure drop across the pipe lengths, the number of bends, fittings, roughness of the internal surface of the pipe and the pipe diameter. To optimize all these factors, a detailed hydraulics study is required of the entire piping system. The Table below shows the recommended flow rates for CIP through pipe sizes normally encountered in a beverage plant.

Pipe Dimensions for Detergent Flows in a Beverage Plant				
Product	50 mm ID m/s	80 mm ID m/s	100 mm ID m/s	125 mm ID m/s
Detergent	2.5 – 3.0	2.5	2.0 – 2.5	1.0 – 2.0

B. Composition of the Soils, Scale and Biofilm Accumulating on the Surfaces of the Plant

There are two types of soil in a brewery or beverage plant:

- organic which include organic polymers like carbohydrates, proteins, organic acids, tannins, hop oils, *etc.*

- inorganic which includes metal ions like magnesium, calcium, potassium, sodium, *etc*., anions like sulphates, phosphates, silicates, carbonates, oxalates, *etc.*

It is very important to know the soil composition in order to be able to determine what type of detergent will be most appropriate to remove it.

When scale is formed in a vessel or pipe, it will reflect the composition ratio of material used in production *i.e.* if the ratio of organic to inorganic is X in materials used in production, this ratio should only change if there is conversion in the processing, biological or chemical. If a conversion is taking place in different areas of the plant, these ratios should be known.

For scale to build up there should be some movement of molecules, polymers and particles. This movement should be slow enough to allow adherence to the surface of a vessel or pipe. The movement can be provided by mechanical means like stirring or by heating. Molecules, polymers or particles are sometimes charged which will result into polar or ionic interaction. Soils tend to build on a surface in layers. It has been observed especially in thick scales where layers are observed to be in different colours.

Biofilms

Microbes have the propensity to form their own niches or micro-environments by creating biofilms. Biofilms can be defined as organized microbial systems consisting of layers of microbial cells associated with surfaces. These biofilms can be simple up to complex ecosystems with each different type of organism providing for the needs of the others in a co-dependent fashion.

From a cleaning and sanitising point these biofilms are detrimental to the cleaning process in that they harvest and protect the inner layers of cells from the cleaning and sanitising agents.

Biofilms tend to adhere tightly to surfaces via the co-development of organic and inorganic scales that are bound and held together by materials such as gums and polysaccharides secreted by the microbial members of the biofilm. Once biofilms become established they can be extremely difficult to remove.

Typical sites for biofilm formation are inside pipe lines where there is low turbulence, shadow areas of tanks and any surface that remains in contact with a source of nutrients for an extended time period. Thus once a biofilm has established itself it tends to become self-perpetuating in that the initial inadequate cleaning process that allowed for the film to develop becomes even less efficient at removing it and the film becomes deeper and larger and more firmly anchored to the production surface. Surface roughness is critical in allowing these films to have an initial binding surface. The smoother the surface the more difficult it becomes for organisms to attach.

Dental plaque is an excellent example of a biofilm.

In industrial situations, biofilms can reduce the flow in pipes, be responsible for sensor failures and valve failures. In addition they can harbour microbes that are responsible for corrosion and as such can become the sites of pinhole corrosion of metal surfaces leading to pipe and vessel failures. Thus biofilm control has become big business.

C. Microbiology of Cleaning

Why Microbiology Impacts on Levels of Hygiene

The required degree of cleanliness required for a processing plant is defined by the potential impact of the soil (soil and/or microbes) on the resultant product. This is largely determined by the type of product being produced in that particular plant.

Products that are sensitive to spoilage require higher degrees of cleanliness (hygiene) than those that are not as susceptible; therefore knowledge of the products propensity to spoil is essential in determining an appropriate cleaning solution. This may or may not include a sanitising/sterilisation step.

- Sterilization is defined as the elimination of all forms of life including microbial spores; typically this is most effectively achieved with live steam at a minimum temperature of 120°C for a contact time of at least 20 minutes and typically is found in the pharmaceutical manufacturing environment.

- Hygienic conditions are defined as a degree of cleanliness that eliminates all vegetative forms of life, typically found to be suitable for most aspects of beer brewing and other beverage plants.

- Clean conditions are defined as those suitable for the removal of all soils but not all vegetative cells. Thus the higher the required degree of cleanliness the more robust the cleaning process has to be and the more important it becomes to ensure that the plant is designed for efficient cleaning.

Control of microbiological growth thus becomes the objective of any cleaning and sanitising programme. Growth control can be affected by:

- limiting microbial growth *via* the removal of nutrients (cleaning);

- the removal of protective materials and films in the forms of scales and biofilms;

- The removal of all viable microbes *via* either total removal (sterilisation) or removal of vegetative cells only (application of bactericidal agents to kill microbes or *via* the application of agents that prevent growth – bacteriostatic).

Typically control measures follow the cycles of:

- decontamination (or cleaning);

- disinfection (*via* chemical and/or physical agents) to prevent growth or eliminate viable microbes;

- sterilization to prevent the growth of any surviving organism in product, thus eliminating spoilage.

What Kills Micro-organisms

Heat sterilization for all micro-organisms: there is a maximum permissible temperature for growth and survival and exceeding this will result in death (macro-molecules lose their structure and cease to function). This is a combination of time and temperature.

Steam sterilization is used for kegs.

Hot water at between 80-50^{o}C is used to sterilize small pack filling plants that produce beer which will not be tunnel pasteurized. It is important to understand that the micro-organisms are killed by the energy released from the latent heat of vaporization when steam condenses to water.

Thus in order to effectively steam sterilize, wet steam must be used rather than superheated steam.

Radiation sterilization: all forms of electro-magnetic radiation are effective in controlling microbial growth as each act through a specific mechanism *e.g.* UV leads to denaturation of genetic material.

Ionizing radiation produces electrons, hydroxyl radicals and hydride radicals –these high energy unstable compounds react with cellular material leading to its ionisation and resultant loss of function (X-rays are the most common form of ionising radiation).

Water used for blending will often be sterilized in this way. This method cannot be used for beer as the flavour and aroma will be affected, a condition known as 'light-struck'.

Which Micro-organisms are Detrimental to Hygiene

Those that have the potential to grow in the product being processed at that stage of the process.

D. Safety Requirements

Cleaning of tanks and pipe lines require the use of harsh chemicals which are strong acids and strong bases. Sometimes, oxidizing compounds are used. Safety precautions, as required by Occupational Health and Safety legislations (ISO 18000), have to be considered when using these chemicals. Components of these chemicals may have short or long-term affect on the health of the employees. Some components can affect the health of the consumer at parts per million levels. The safety of environment has to be considered as well, which means that the products used have to comply with environmental legislation with respect to handling of spillage.

Every material used must be accompanied by Material Safety Data Sheet (MSDS). A MSDS should disclose the following:

- manufacturer's details
- product identification
- composition information on ingredient
- hazards identification
- safety first measures
- fire fighting measures
- accidental release measures
- handling and storage
- exposure control and personal protection
- physical and chemical properties
- stability and reactivity
- toxicological information
- ecological information.

The MSDS is meant to give enough data about the product that assist the user to make an informed technical decision. A user will only know about this safety information if the information provided is read and the supplier is questioned to get clarity. There is still a culture of not going through the MSDS document before the product is used.

In the UK this is law and comes under the COSHH (Control of Substances Hazardous to Health) legislation.

2.1.4.2 Detergents and Sterilizing Agents

A detergent is a blend of chemicals, which is put together to solubilise soil and remove it from the surface and ensure that it does not re-deposit itself back on the cleaned surface. Sterilizing agents (sterilants) are formulated to kill microbes and bring micro-organism load to an acceptable level. It is normal for chemicals to be purchased from a chemical supplier who will formulate them to suit the cleaning surface.

A. Detergent and Sterilant Chemical Properties

Detergents are formulated from either acids or alkalis; therefore the chemical properties are acidic or basic.

The sterilants, especially those for traditional non-rinse application, are acidic when peracetic acid or hydrogen peroxide is used; when halogens like chlorine, are used, the base material is made of alkali for stability.

Alkaline detergents tend to work better for two reasons:

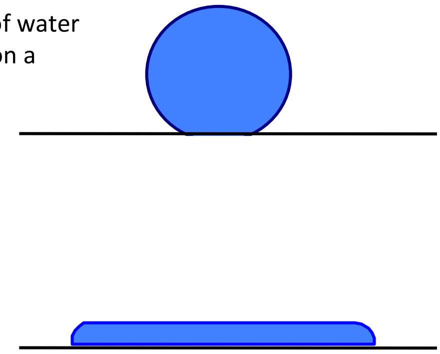
- organic soil tends to be 'acidic' in nature, organic acids, polyphenols, *etc.;*
- basic detergents can hydrolyse organic polymer chains, which add to the easy removal of soil as smaller molecules.

Detergent Ingredients

Formulated detergents usually contain surface active agents to "wet" the surface to be cleaned; dissolving agents (either alkali or acid); dispersal agents to maintain insoluble solids in suspension; and rinsing agents to aid drainage.

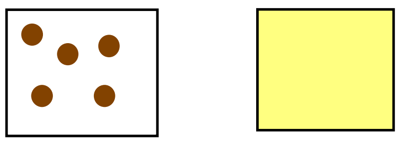
Wetting Power.
Water is always used as the medium for carrying the detergents used in cleaning brewing plant and water has a relatively high surface tension. That is, it forms 'beads' on a surface rather than wetting it.

Most detergents contain a substance that reduces surface tension and so increases the detergent's wetting power.



Wetting agents have a tendency to foam so they may be supplemented with some form of antifoam.

Dissolving.
When a substance is dissolved, it becomes chemically bound into the liquid and the liquid is usually clear. If **soil** can be dissolved in the detergent liquid, not only can it be removed from the plant surface, it can also be carried away easily.



There are two main types of soil that need to be removed from the surface of brewing and packaging plant:-

- Organic soil which includes yeast, protein, fat and sugar.

  Plant which has a lot of organic soil that needs to be removed should be cleaned with a detergent that contains compounds that can dissolve it.
  Alkalis like caustic soda dissolve organic soil and caustic solutions are often used to clean fermenting vessels and brewhouse plant.

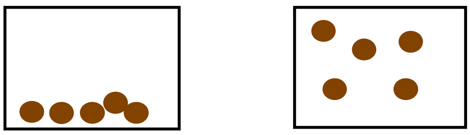
- Inorganic soil which includes scale or 'beerstone'.

  Plant in some breweries becomes scaled up quite quickly especially in hard water areas. This plant needs to be cleaned regularly with a detergent that dissolves scale. Acids like nitric acid or phosphoric acid are good at dissolving inorganic soil. Sequestering agents which can be added to alkaline detergents are also capable of dissolving scale.

Dispersion.
Not all the soil on brewing and packaging plant is soluble though insoluble soil can be removed if it is 'dispersed' so that it can be carried away in the liquid.

Soil on the plant surface

The same soil dispersed in a liquid



Detergents contain substances that help to disperse the soil and to hold it in suspension so that it can be rinsed away.

Rinsing.
It is important that at the completion of a cleaning cycle, no detergent and accompanying soil remains on the plant surface. In other words, the detergent must be 'rinsable'.

Thus to be effective, a detergent must be capable of adhering to the plant surface being cleaned; when the job is done, however it must be rinsed away.

Rinsing agents are added to the detergent to enable these two incompatible actions to take place.

Formulated detergents used in the beverage industry comprise:

- base material, which is either alkali or acidic
- surface active molecules as wetting agents
- chelating agents or sequestrants
- flocculating agents (sometimes).

The sequesterants or chelating agents are added in order to soften water by grabbing metal ions like calcium and magnesium. The chelating agents hold the calcium and magnesium salts in solution preventing scale formation and blockages. The presence of these metal ions tends to bond dirt together by providing multiple charges for multi-site attachment. The surface-active molecules act as wetting agents that assist with penetration of dirt otherwise water clings to itself due to the bipolar nature of the water molecule. During cleaning of organic soil, like proteins, surface-active molecules are created out of hydrolysed proteins hence foaming is observed during cleaning.

Ingredients of Caustic or Alkali Detergents

Caustic detergents are made of caustic soda (sodium hydroxide) as the main ingredient with sodium gluconate/heptonate or amino tris (methylenephosphonic acid) as chelating agents. Other agents like EDTA, NTA, sodium polyphosphates, zeolites are sometimes used. Caustic or alkali detergent can be chlorinated. The choice of chelating agents or sequestrants depends on the pH of the working solution. Their effectiveness is pH dependant.

Caustic detergents are not suited for the cleaning of aluminium tanks as it reacts with the aluminium. To clean surfaces where caustic is not allowed, alkali detergents are often used. The detergents use sodium metasilicates as a base. Sometimes soda ash or phosphates salts are used as alkali source with builder (sequestering) properties. Nitric acid can also be used as it does not react with aluminium. For aluminium kegs a neutral detergent is often selected.

Dealing with stubborn dirt found in paraflows (heat exchangers), chlorinated caustics or chlorinated alkalis are sometimes used. The amount of available chlorine of the working solution should not exceed 200ppm to protect stainless steel from pitting.

The addition of chlorine enhances the cleaning ability of caustic. As a quick guide:

0.25% Caustic + 60-80ppm Chlorine is equiv. to 1% Caustic
0.5% Caustic + 60-80ppm Chlorine is equiv to 2% Caustic

Wetting agents are added to caustic or alkali detergent to improve penetration and rinsability of caustic.

Ingredients of Acid Detergents

In the beverage industry, acid detergents are used for descaling and for cleaning bright beer tanks under CO_2 pressure. The scale is made of metal salts of oxalates, phosphates, carbonates, silicates, *etc*. The acid detergent should be able to penetrate for which a strong acid component is required. To facilitate the peeling of scale molecules, a component of acid is required that will attach itself to metal ions and act as a sequestrant. Acid detergents are predominantly made of a blend of phosphoric acid and nitric acid to a 1.2:1 ratio. For cleaning Bright Beer Tanks phosphoric acid is used on its own as the tank does not become heavily scaled.

Nitric acid is a strong acid, which is good for penetrating the scale and phosphoric acid has sequestering properties for easy removal of scale. Acids with a higher level of nitric acid than phosphoric acid are recommended for passivation of stainless steel.

Adding wetting agents and sequesterants in an acid detergent improves penetration and removal of scale especially when the scale is not only inorganic soil.

In the bright beer area it is normal to us phosphoric acid at about 1.0-2.0% strength under CO_2 pressure and with a mechanical washing head in order to give good scrubbing (impingement) action. It is recommended that Bright Beer Tanks are specially cleaned with caustic every six months. When this is done the manway door is opened and that BBT is inspected – door rubbers, vessel internally and cleaning head. Care is taken to follow the permit procedure to ensure that the vessel is safe before inspection.

Ingredients of Sterilants

There are different types of sterilants for use in different areas of the plant and they are formulated differently to minimise the negative effects that they might have on the finished product.

- **Sterilants Recommended for Non-Rinse Application**
  These are peracetic and hydrogen peroxide based sterilants. They are made from the blending of acetic acid and hydrogen peroxide in the presence of a stabilizing agent such as 1-hydroxyethylidene–1, 1–diphosphonic acid (Dequest 2010). When used, the breakdown products will be oxygen and water for hydrogen peroxide and acetic acid and oxygen for peracetic acid.

  These types of sterilants break down in the presence of metal ions. Because peracetic acid based sterilants are oxidizing, they tend to affect flavour stability of beer if not rinsed. Apart from being used in vessel sanitation, they are also used in sterilant baths and in environmental sterilant formulations.

- **Sterilants Recommended for Soak Baths**
  Iodophors are used in soak baths, because their presence can be easily be detected with brownish red colour. Iodophors combine elemental iodine with surface-active compound. Acid is added to ensure that the usage concentration is at lower pH.

  Iodophors can taint the product when not handled properly. Where a fear of tainting exists, peroxide or peracetic acid based sterilants are used in soak baths.

- **Environmental Sterilants**
  Environmental sterilants are used on floors, walls, external surfaces of tanks and pipes and cleaning of drains. For these to work effectively on surfaces, they must be able to cling to the surface to allow for extended contact time. When rinsed off the walls, they must be easily removed. Because the risk of contact with the product is low, there is a wider choice of ingredients that can be used.

  Quaternary ammonium compound (QAC) sterilants work by surface action. The QAC formulations contain non-ionic surfactants like ethoxylated fatty alcohols to boost foaming properties of the product. In order that micro-organisms do not develop a resistance to sterilants, different types should be used over specific periods of time.

  Gluteraldehydes are commercially available as acidic solutions and they are activated before use by making them alkaline. They have a wide spectrum activity against different micro-organisms. Recommended strength is usually 2% solution.

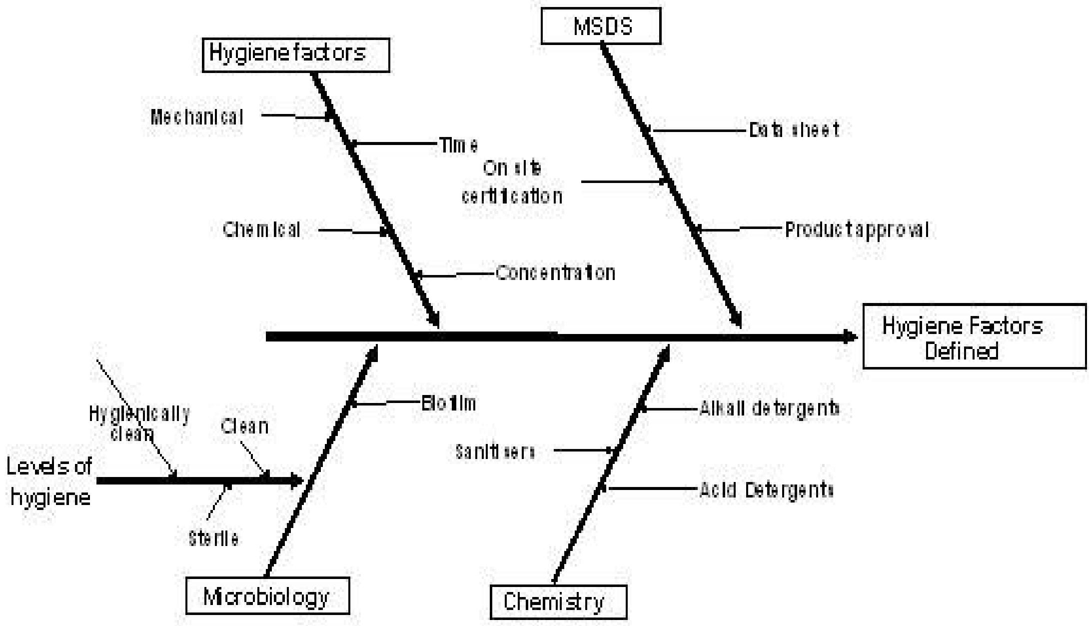
  Biguanides and Chlorhexidines have widespread bactericidal properties. For the product to foam, non-ionic surfactants are added. Because of their cationic nature, anionic compounds deactivate these materials. They are also not compatible with phosphate, borate, chloride, carbonates ions because they form salts, which are insoluble. This will make active ingredients unavailable.

- **Sterilants for Drains**
  The most popular sterilant for drains is sodium hypochlorite solution that has been diluted to release about 5% available chlorine during use. These must be kept separate from stainless steel equipment, as the free chlorine settles on the moist surface causing pitting corrosion.

- **Sterilants used in Different Areas of Processing**
  Chlorine dioxide has gained popularity as an effective safe to use sterilant. It is effective at low concentration (0.5 to 2ppm) and it is not affected by pH. Chlorine dioxide is effective against a wide spectrum of micro-organisms. It is effective in removing biofilms. Chlorine dioxide does not chlorinate, therefore there is no risk of forming trihalomethanes (THM) when coming across organics. Chlorine dioxide works by free radical electrophilic abstraction rather than oxidative substitution or addition like chlorine. The breakdown products are chlorite and chloride.

  Chlorine dioxide is used for disinfection in many areas, water disinfection, post or final rinse sterilant, biocide for cooling tower and pasteurizers.

Summary



Hygiene factors summary

2.1.4.3 DESIGN AND OPERATION OF CIP SYSTEMS

A. Design principles

For cleaning to be satisfactory there needs to be a balance between temperature, chemical concentration, mechanical action and time. The following relates these points to the cleaning process.

Temperature
If the chemical temperature is increased by 10°C this will increase the rate of reaction or detergency by up to 2 times (Law of Arrenhius). It is advised not to use a temperature in excess of 85°C as at this temperature dirt will start to emulsify. Temperature is important when cleaning complex equipment like fillers when it is not always possible to have adequate mechanical and chemical action reaching every part of every component.

Chemical
Soil (dirt) removal mechanisms are assisted by the use of chemicals which work by:

- Having close contact with the soil using wetting and penetrating properties.
- Displacing soil through emulsifying, wetting, soaking and breaking down proteins. Also dissolving mineral salts.
- Dispersing soil by de-flocculation and/or emulsifying
- Preventing the re-deposition of soil by providing good dispersing, emulsifying and rinsing properties.

Increasing the strength will increase effectiveness up to a sensible level. For caustic 2% is sensible. Lower caustic concentrations are possible if fast rinsing surfactants are used within the detergent.

Mechanical
Mechanical activity refers to the 'scrubbing' action that takes place during cleaning. A rotary jet head cleaner will give a more aggressive clean than a spray ball. In fact the types of cleaning are quite different and are known as:

Impingement (Rotary Jet Cleaners) – cleaning action that strikes the surface of the vessel with sufficient force to lift off dirt. Rotary Jet Cleaners will clean through a cycle. This means that it could take six minutes before the full surface of the vessel is covered.

Irrigation (Spray Balls) – cleaning action that wets the complete surface of the vessel. It is therefore much more reliant on chemical action. This can be improved by using burst rinsing for more effective soil removal.

When pipes are cleaned it is also important that a turbulent flow is achieved, again, to achieve a 'scrubbing' action. This is well described under 'Hygiene.

Time

Unfortunately a good scrubbing action cannot always be achieved and so contact time becomes an important factor. An example would be the bowl or annular tank of a can or bottle filler. It is not possible to achieve turbulent flow, so extra time is allowed for the chemicals to work.

B. Cleaning In Place (CIP)

Cleaning-in-place (CIP) systems allow vessels, piping, valves and other equipment to be cleaned without dismantling all or part of the items. Surfaces are exposed to controlled conditions where detergents act on the surfaces to eliminate soil and to sanitise.
(Note: To supplement internal cleaning EXTERNAL cleaning may also be necessary. For fillers this procedure may be carried out during a full CIP due to the build up of beer residue on the outside of the filler. For sterile filling this procedure is essential.)

Spray Systems

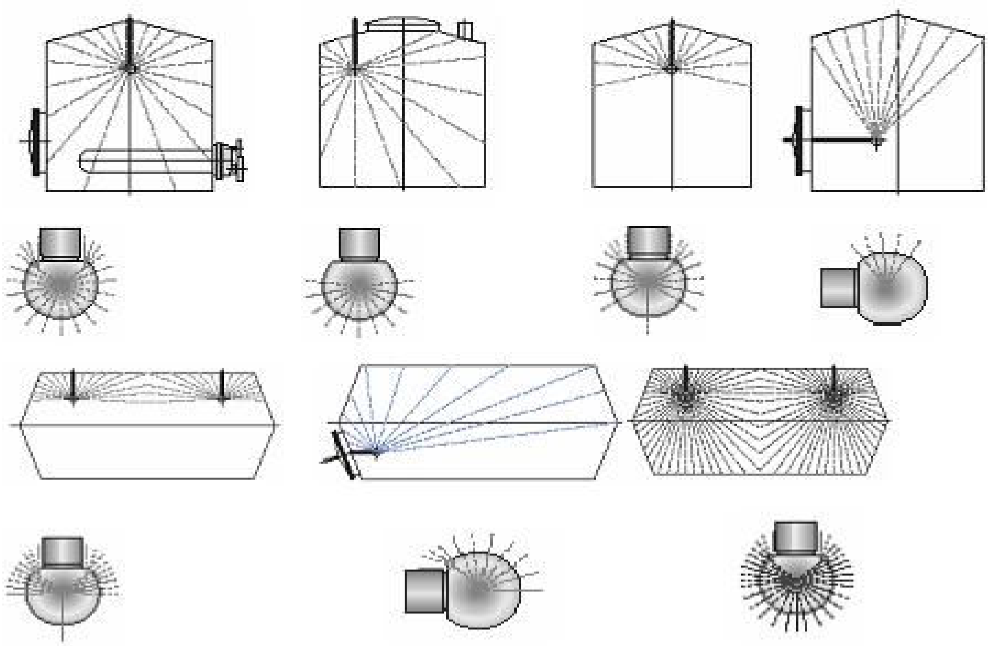
The choice of spray balls or rotating spray cleaners is a key factor in the effective design and operation of a CIP system. There are a number of reputed manufacturers of this equipment but the chosen data is from GEA Tuchenhagen and Alfa Laval Tank Equipment A/S as they represent typical designs that could be selected to achieve the required outcomes.

The dimension of the vessel dictates the type of spray device required for an effective covering of the entire surface during the CIP cycle. Spray balls showers the entire surface all the time the pump is operational by directing the impact flow of the fluid on the area where most of the soil is located, *e.g.* at the yeast ring in the fermenting vessel example above. The fluid runs down the side of the walls of the vessel in a continuous curtain contributing to the effect of the chemical, timing and temperature to assure a clean surface.

Spray Balls

The following shapes of vessels can be fitted with the fixed spray balls with multiple holes or for two, three or four jets. To cover the entire surface of the vessel, either one or multiple spray balls can be installed in one vessel to ensure that the spray diameter of each spray ball gives total cover of the vessel surface. The spray angle can be chosen to give from 90° to 360° cover.

Selection of spray balls should be done in consultation with the manufacturers.



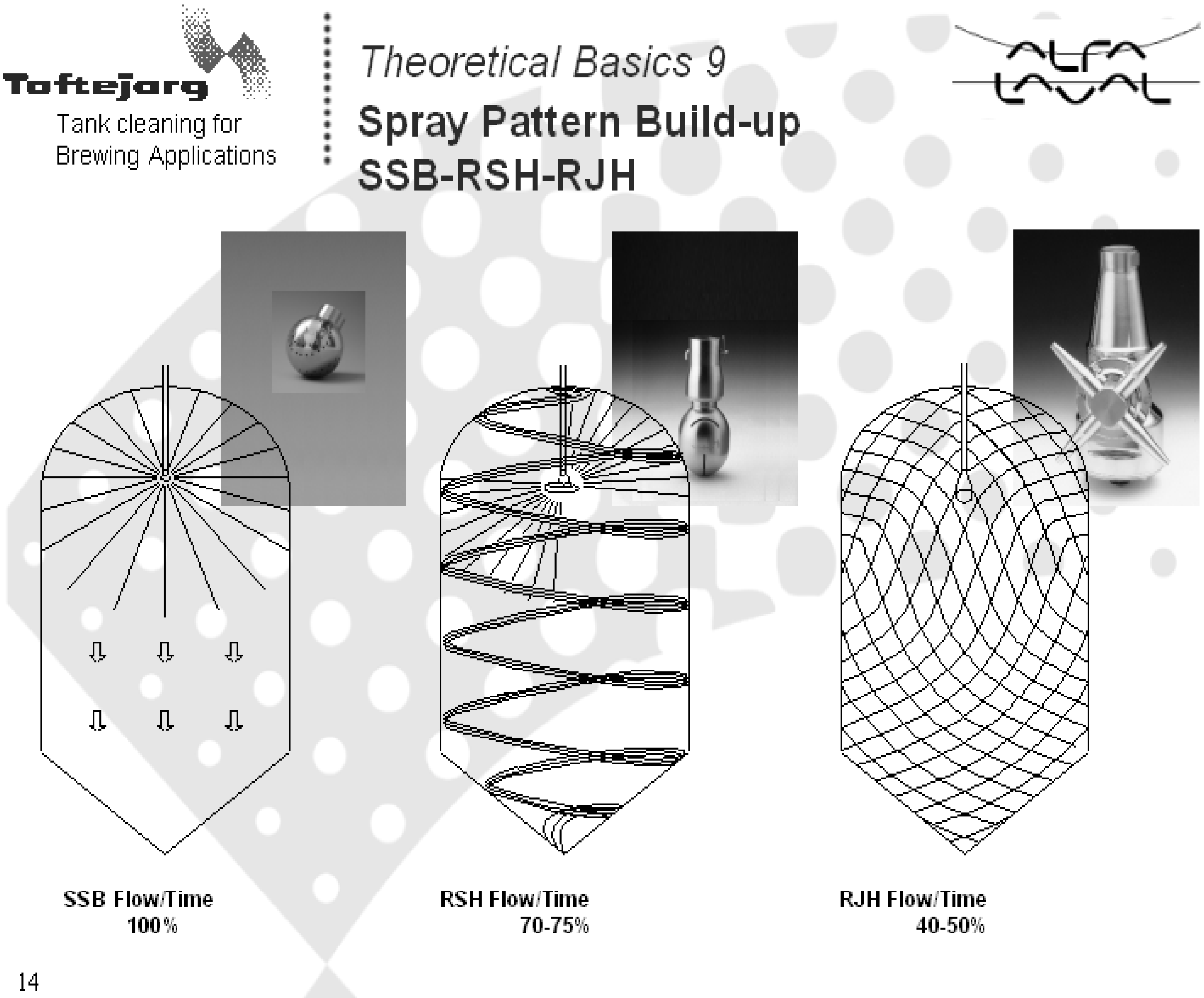
Rotating Spray Cleaners

Rotating spray cleaners require a high pressure to direct the fluid onto the surface of the vessel that has an impact effect at the point of contact. The fluid flows down the rest of the surface cleaning on its way.

Rotating spray cleaners from two suppliers show the different applications when they are positioned on the floor of the vessel and when they are fixed at the top of the vessel. The rotating jets have a higher impact force on the surface exerting greater mechanical effect on the soil or scale, than the flooding low pressure system applied on fixed spray balls.

The jets on a rotating mechanism direct the fluid at one point a specified number of times for a complete cycle, at the end of which the entire surface will be covered.

The selection of rotating spray cleaners should be done in consultation with the manufacturers.



Alfa Laval/Toftejorg Rotating Jet Heads. This shows examples of how different types of spray devices distribute liquid over the surface of vessels.

Maintenance of Spray Cleaning Devices

The blockage of holes in the spray balls and rotating spray jet cleaners must be avoided at all times as this seriously impairs their effectiveness. The devices must be inspected on a routine basis to ensure that they are clear of the debris and function correctly.

Rotating jet cleaners are sometimes fitted with a sensor to check that the system is rotating. If the rotating jet cleaner is not functioning, the sensor will identify the condition and send a signal to the CIP control system to close down the plant

C. CIP of Vessels

The effectiveness of CIP over the entire surface of a vessel is determined by the flow of the fluid at its impingent area and as it flows down the walls of the vessel. However, the factors that assure an effective cleaning process are mechanical, chemical, time and temperature and these have to be optimised to ensure effective cleaning.

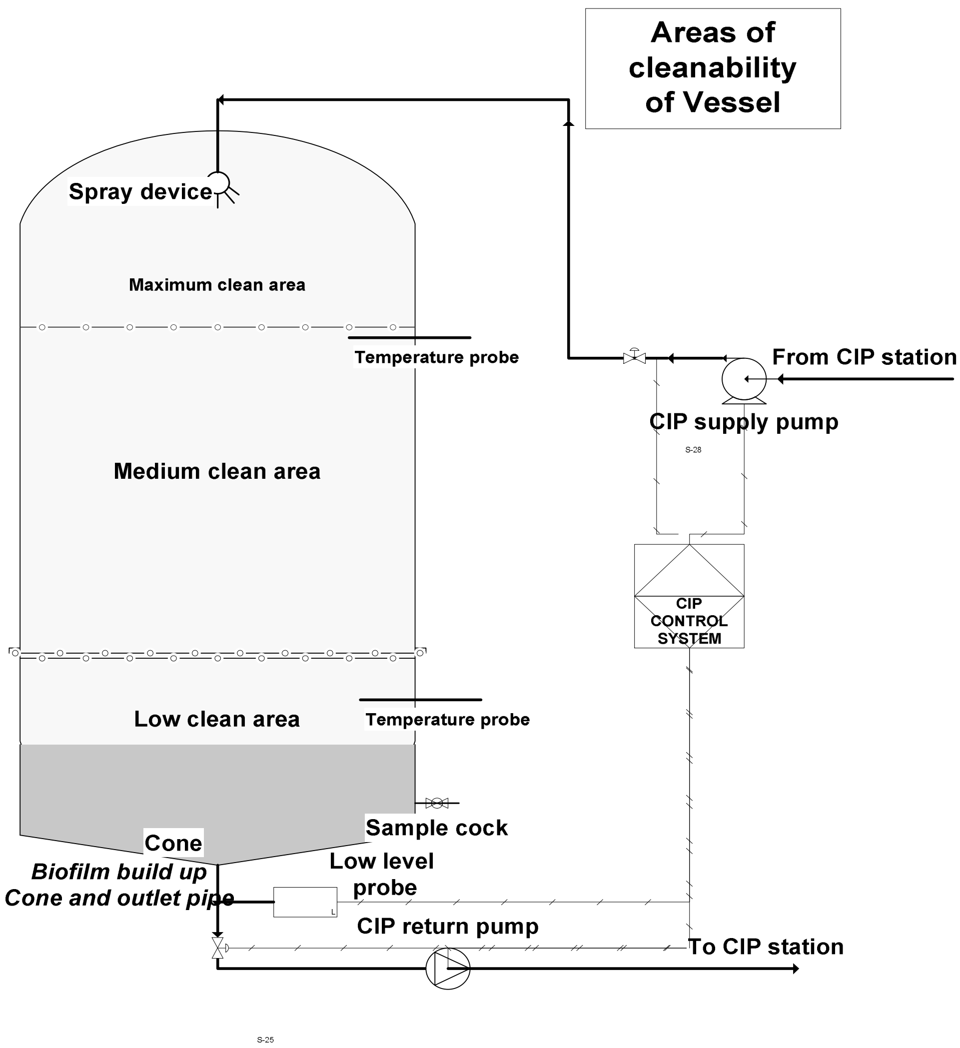
The spray systems are most effective on those areas where the fluid impinges on the surface. Experience and research has shown that vessels have three zones with different levels of cleanability, i.e. absence of soil, biofilm and scale. This is shown diagrammatically on the next page.

The top area surface, where there is greatest impingement, is always clean provided that the spray device holes are not blocked. The middle of the vessel tends to be less clean as the fluid flows down the side walls from the spray ball and the rotating jets are at their longest trajectory. In this area temperature probes are normally located.

At the bottom of the vessel, whether conical or domed shape, there is clear evidence of biofilm and scale formation when using both types of cleaning device. In this area chemical effectiveness is at its lowest and the temperature may have been reduced by the cooling medium remaining in the cooling jackets that would cool the detergent as it flows down the wall. If the CO_2 has not been removed completely, caustic will be neutralised.

Evidence has been seen of this in vessels that have completed the CIP cycle with caustic, demonstrated by a zero reading on the conductivity meter on the return line and by a distinct odour of CO_2 inside the tank.

Low level indicators at the bottom of the vessels have to be totally reliable at all times. This will allow for effective sequencing of the CIP return pump and the supply pump to ensure that the bursts of detergents do not accumulate at the bottom of the vessel making the chemical effect on the biofilm even less effective. These low level indicators also indicate that the CIP cycle has terminated and the vessel is empty of detergent ready for filling with product. Failures in these low level indicators have caused numerous incidents of vessels being filled with product on top of detergent chemicals.



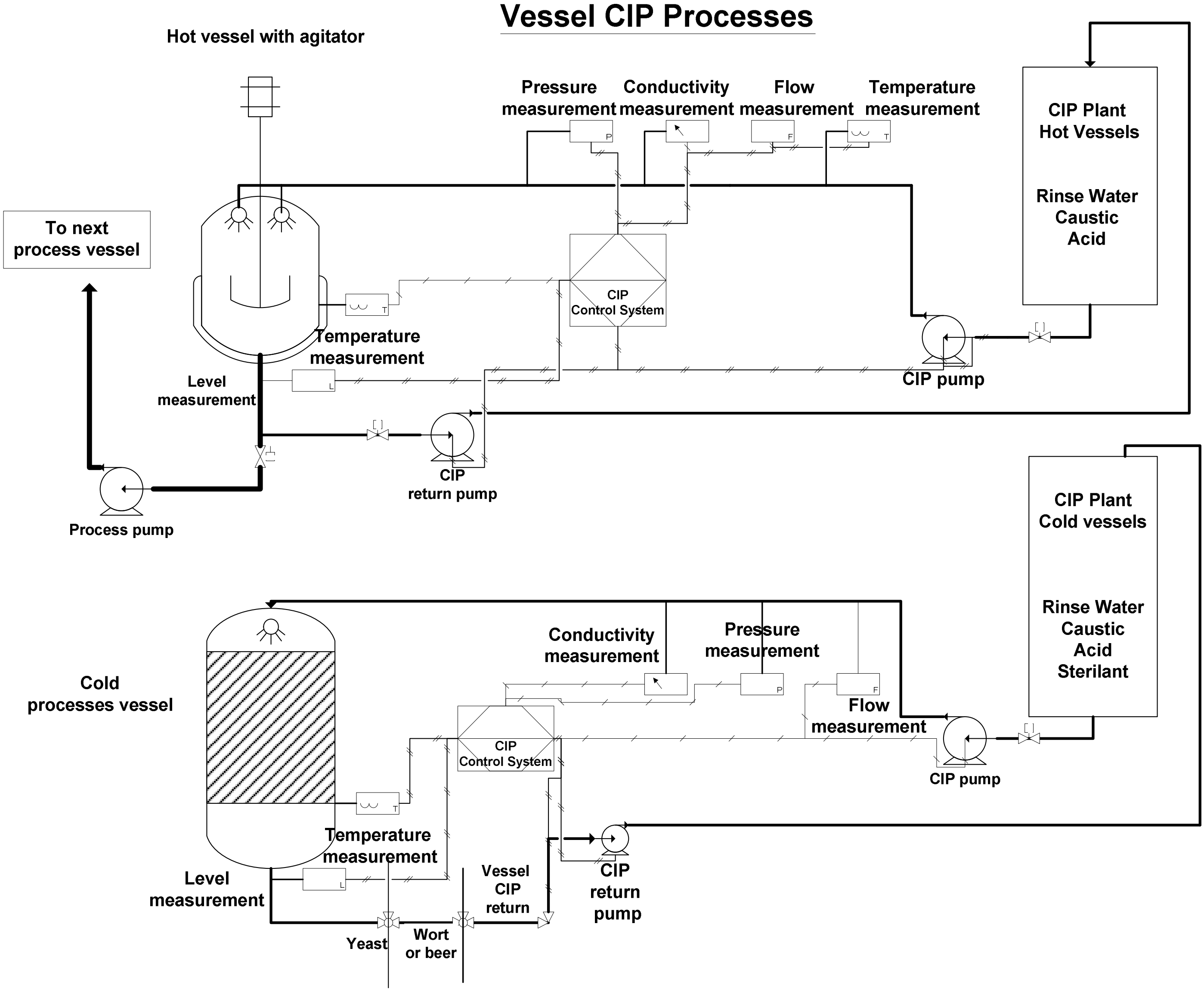
The figure on the next page shows the layout for CIP of hot and cold vessels.

To optimize fluid flows for the CIP of vessels, the following factors must be considered:

- spray devices define the volume and pressure required for effective cleaning depending on its spray circle for the vessel in which it has been installed;
- supply CIP pumps will deliver the following flows:
  - spray balls example: 360 angle in a 5 meter diameter vessel: 350hl/h at 1.5 bar pressure. Burst of fluid shower the entire surface, normally recommended: with specific bursts of defined minutes on and off;
  - rotating jet cleaner example: 360 angle in a 5 meter diameter vessel; 240hl/h at 6 bar pressure. Continuous flow of fluid to get the rotating cycles to obtain 100% coverage over the total time for CIP;
- return CIP pump service:
  - low level probe senses flow and the pump starts;
  - low level probe senses no flow and the pump stops.

There are some important considerations that need to be taken into account in the sequencing of the supply and return in CIP pumps.

Vessel CIP Processes



- Avoid excessive back-up of fluid over the required level to cover the low level probe in the outlet pipe of the vessel.

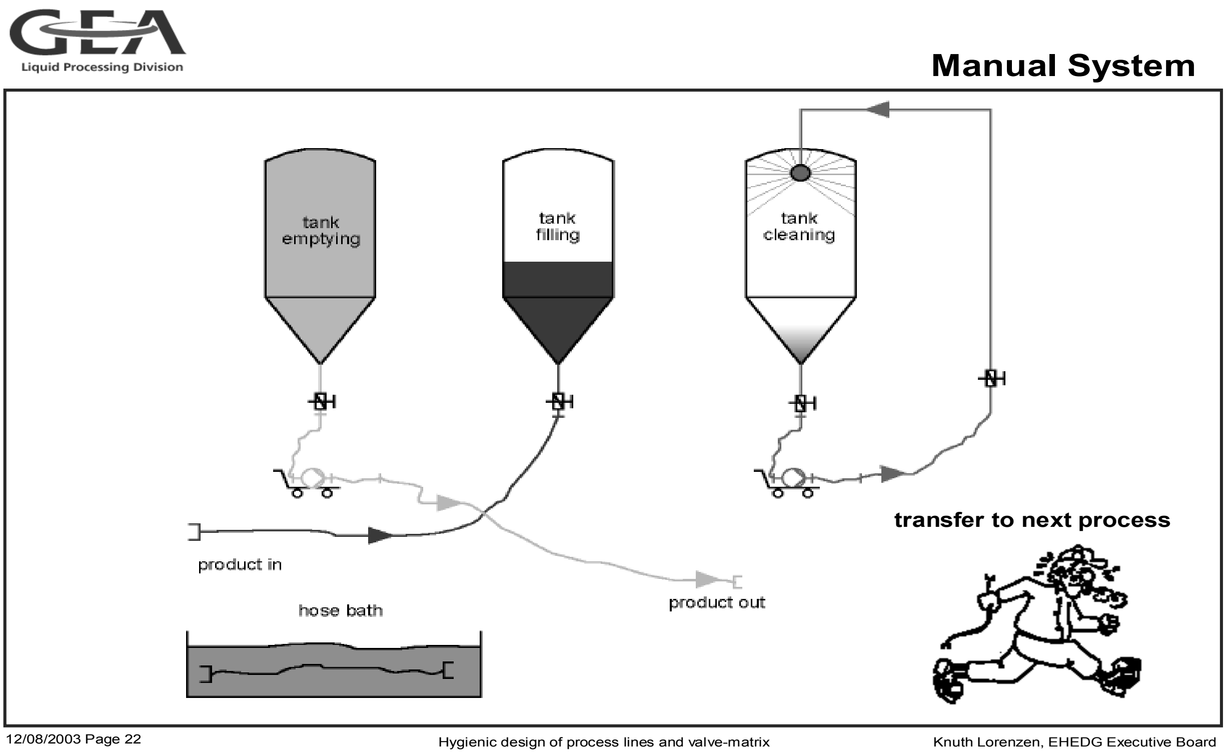
- Ensure that the pipe has enough fluid to supply the required suction pressure on the return pump.

- Avoid vortexing of the pump when it has no suction pressure as it will cause cavitation of the pump and result in mechanical damage to the impeller and seal.

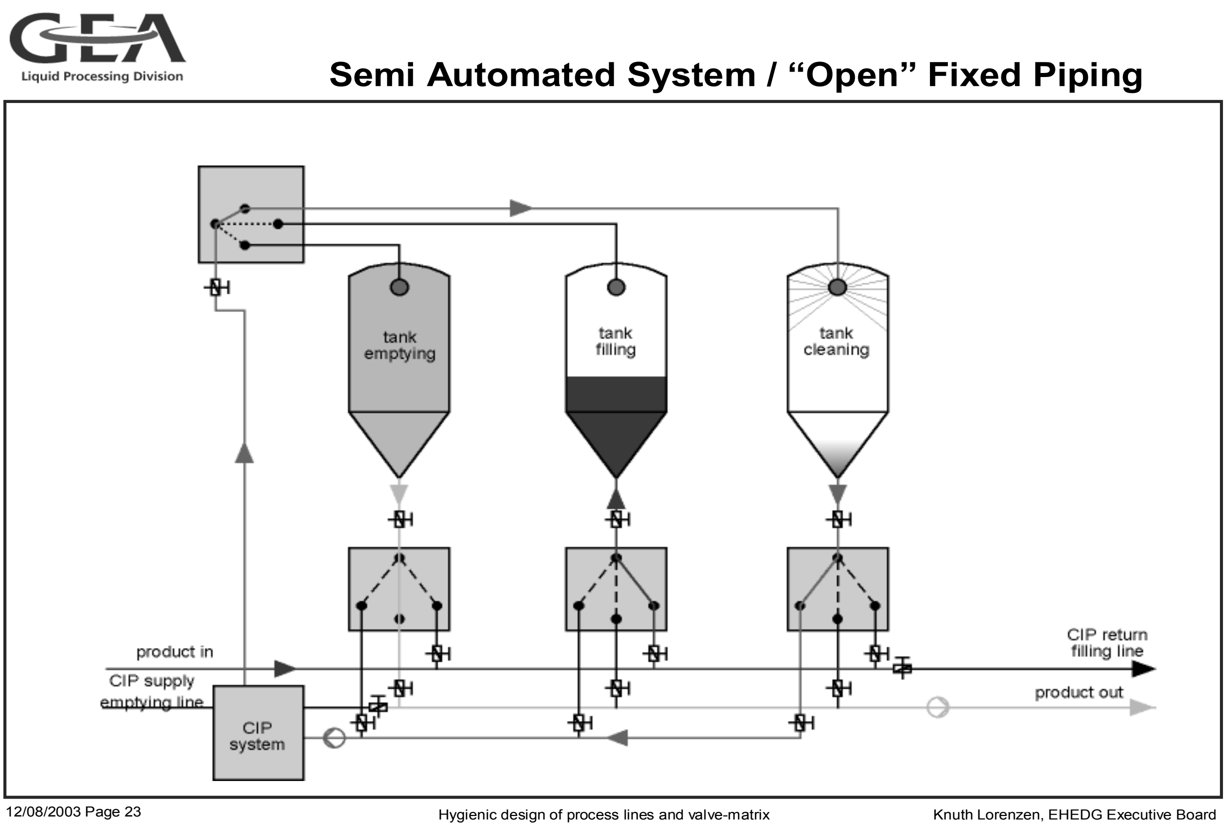
In a domed bottom vessel vortexing is often a problem. A vortex breaker has to be fitted manually at the vessel outlet, most often positioned next to the manway, before CIP starts. Once CIP is complete, the vortex breaker is removed. If the vessel is a fermenter or a storage tank where a thimble is fitted in the vessel outlet to hold back yeast or tank bottom, this can be done at the same time, once the vortex breaker is removed.

The following represents three levels of CIP:

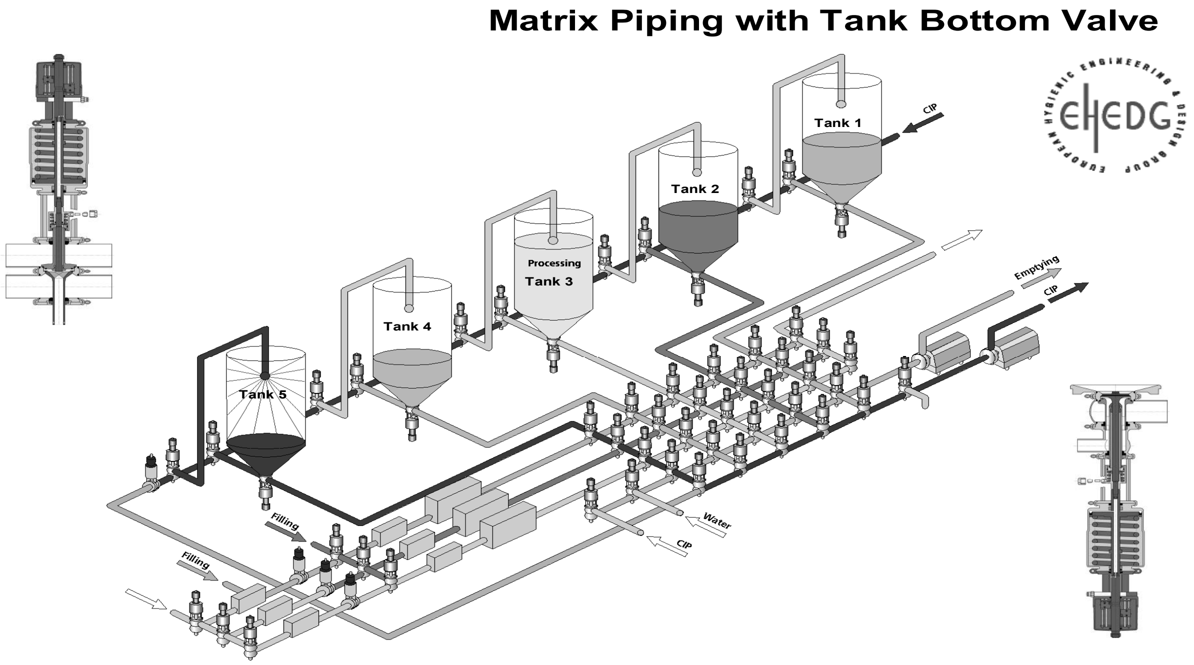
(a) manual process;
(b) semi-manual using pipe panels;
(c) a fully automated system.



(a) Manual CIP system - the CIP of the vessel is done by connecting the vessel to a mobile unit



(b) Semi automatic CIP system - the CIP of the vessel is done through the panels



(b) Fully automated CIP system

The CIP of the vessel is done through a fully automated system. The CIP flows in the pipe behind the vessel and up to the spray device. The CIP return flows from the bottom of the vessel to the return pump. The CIP flows through the pipe directly under the vessel to ensure that the entire piping system is cleaned. The process piping is cleaned through a separate line with hot detergent.

D. CIP of Pipework

In the case of cleaning vessels with flow rates specified for spray devices, care must be taken that those flow rates are also effective for cleaning the outlet pipes of the vessel, especially as those detergents are cold and often low in concentration. Flow rates for vessel CIP are frequently not sufficiently high to achieve an effective cleaning of the outlet pipes. In the case of fully piped up and automated systems where inspection of the pipes and vessel is rarely practised, this problem requires careful consideration. Product pipes must be cleaned with hot detergents, separately from vessel cleaning.

To ensure an effective cleaning of piping, all four factors must be optimized to ensure optimum hygienic conditions. The importance of flow characteristics has been discussed above under **Underlying Principles**.

Hoses

- Hoses should withstand cleaning by steaming and by hot alkaline and acid solutions without imparting any off flavour to the product or causing other problems. The hose should be unaffected by continuous immersion in 1% chloramine solution.
- As rubber hoses are used in connection with CIP systems, the risk of bursting has to be considered. New hoses must not be subjected to high internal pressure over $5kg/cm^2$. If detergent is circulating at 3m/s a pressure of $5kg/cm^2$ may be assumed.
- Two hose fastenings per end must be placed on the hoses to ensure that the coupling is secured on the hose and they are safe to use.
- Microbiological tests are done on the hoses by holding the two ends up and pouring 100ml of sterile water into one end of the hose. A person then 'dances' on the hose to release any biofilm from the internal surface. The water is then collected and plated as for any other micro sample. Each hose must be numbered and registered to record its life and the cleaning done.

E. Types of CIP systems - Multi Use CIP vs. Single Use CIP

In the design of the CIP system, there is a choice of incorporating either a multi-use or single use system. In determining the choice of either of these two systems, the following factors need to be considered.

Multi Use System:

- high initial capital cost of the vessels, instrumentation, pumps, valves, piping and control system;
- relative inflexibility of the CIP chemicals;
- relative independence from the chemical suppliers;
- complex control system and instrumentation;

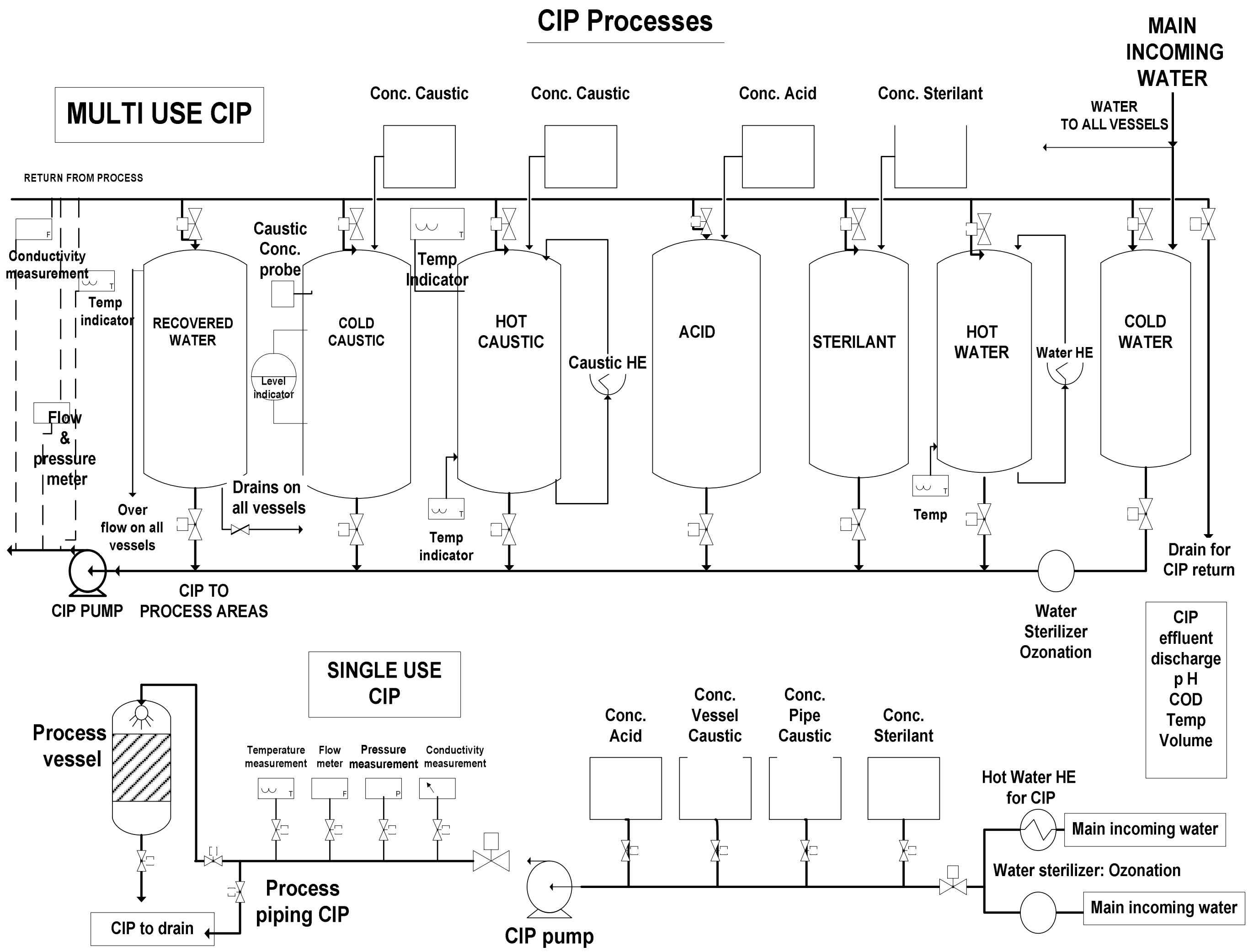
- high maintenance;
- control of chemicals requires complex instrumentation;
- high and variable effluent loads when discharging entire vessels with caustic, acid or sterilants;
- central location with high grade building finishes that are chemical resistant;
- recovery of detergent for re-use.

Single Use System:

- low initial capital costs: few to no vessels, short piping routes, simpler valving and instrumentation;
- relative dependence on chemical supplier;
- mobile unit;
- simple controls;
- medium maintenance;
- simple detergent controls;
- control of effluent discharges and smaller volumes;
- reduced area for CIP station;
- no recovery of detergent so not cost efficient or environmentally acceptable

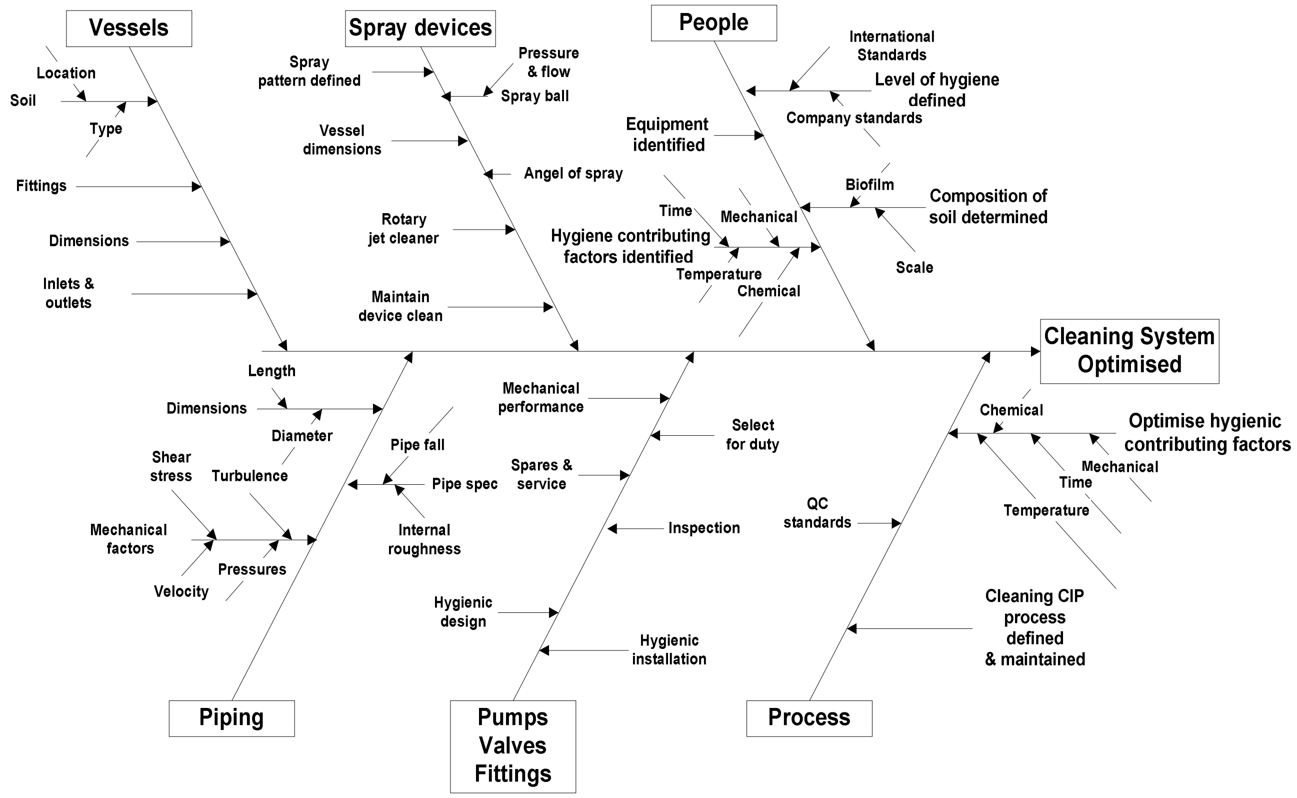
When deciding which of the two systems is most suitable, the economic, logistical and environmental factors need to be considered side by side.

To compare the two systems, the two process flow diagrams are shown below:



F. Optimization of cleaning systems

The figure below summarizes the key aspects of optimizing a cleaning system.



Effective cleaning is the result of a combination of four factors:-

- **Time**. How long is the cleaning agent/detergent in contact with the plant?
- **Temperature**. How hot is the cleaning agent/detergent?
- **Chemical activity**. How strong/effective is the cleaning agent/detergent?
- **Physical activity**. How vigorously is the cleaning agent/detergent applied to the plant?

If one of these factors is reduced, for example if the plant has to be cleaned quickly, then another factor must be increased to compensate, for example hot instead of cold detergent could be used.

Plant design needs to take this concept into consideration in the following ways:-

- The plant capacity needs to be large enough to allow time for cleaning.
- The parts of the plant where very high standards of hygiene and sterility are required should be capable of being cleaned hot.
- The materials of construction should be capable of withstanding strong detergents like caustic soda.
- The plant design should either allow access for manual cleaning or more commonly, ensure that detergent can flow over the surface at the speed required to give a vigorous clean.

Hot Cleaning.

Some plant is designed to be cleaned at high temperatures because of the importance of hygiene and sterility; an example could be a yeast culture vessel.
Plant design features that allow high temperature cleaning are:-

- Strong construction, for example thick walls to a vessel.
- The presence of a pressure relief valve, which must be regularly tested.
- Vacuum relief system, to prevent the collapse of the vessel due to the very low pressures that will occur if the vessel cools quickly.

Construction materials.

The choice of material that the plant is made from needs to allow for the detergents and sterilants that are going to be used.

Most modern plant is constructed of a suitable quality of stainless steel; however, pump glands, sensing equipment like thermometers, hoses and valves must also be compatible with what might be very corrosive substances. Some of the more obvious problems are listed below:-

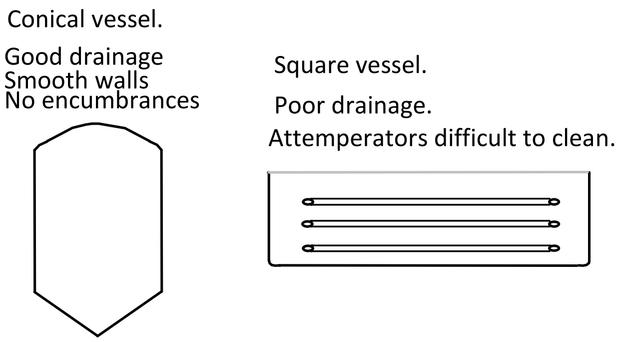
- Caustic soda will dissolve aluminium.
- Chlorine is a very strong oxidising agent and will corrode most metals.
- Acids will seriously damage concrete.
- Dilute sulphuric acid corrodes many grades of stainless steel.
- Hoses and rubber seals, for example plate heat exchanger gaskets can pick up taints from sterilising agents.

Plant design.

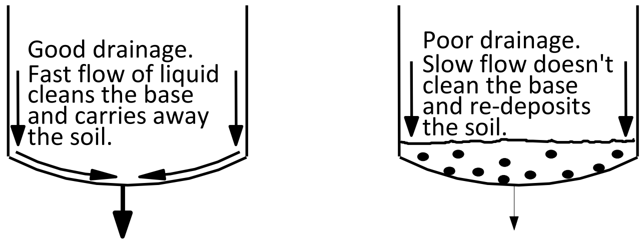
When taking the need for effective cleaning into consideration during the design of the plant the main areas are:-

- As few encumbrances in vessels as possible.
- Vessels must drain well.
- There must be no ‘dead legs’ in the pipework.
- Pipes must be designed for fast flow of detergent during cleaning.
- Spray heads must be sited in the correct position.
- Where necessary, the plant must be accessible for cleaning or maintenance.

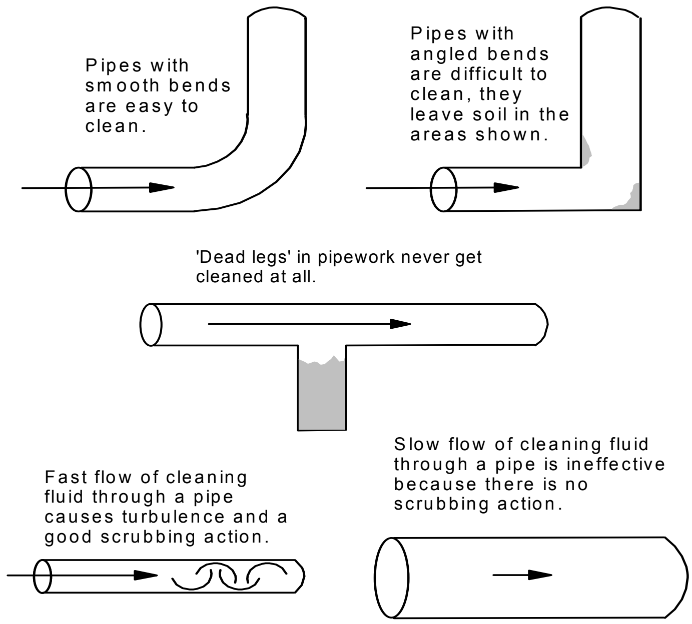
(a) Vessel design.
Vessels in modern breweries are designed for being cleaned in place, hat is by spray head rather than manually by personnel having to enter and clean. They drain well and have very few internal encumbrances.



(b) Vessel drainage:-

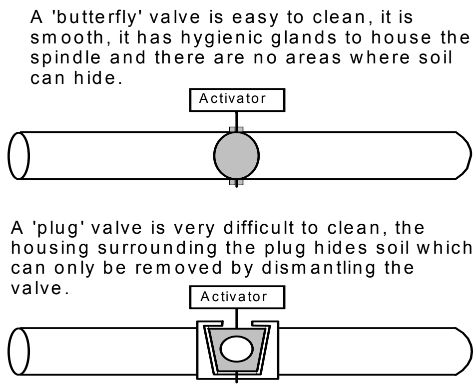


(c) Pipework design.
Pipes and mains in modern breweries are designed to be cleaned in place; they have smooth bends and no ‘dead legs’. Flow of cleaning fluids is fast through all the pipework, an ideal is 2 meters per second.

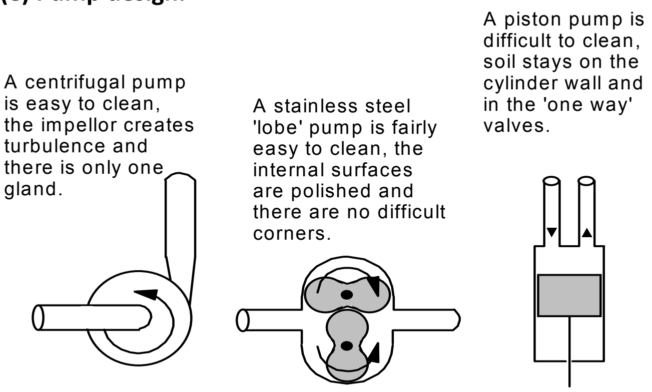


A pipe circuit for CIP should consist of pipes of the same diameter, otherwise the flow in the larger diameter pipework will be too slow.

(d) Valve design.
Valves in modern breweries are designed so that they can be cleaned in place as part of the pipework cleaning cycle.



(e) Pump design.



Sometimes pumps are fitted with pressure relief by-pass systems. This by-pass must be opened during the cleaning programme.

(f) Room and building finishes.
The buildings that house brewing and packaging plant should be designed so that:-

- The floors can be cleaned easily. This means good drainage and well finished floors possibly tiled.
- The walls can be cleaned easily. Possibly tiled walls.
- The plant can be accessed for maintenance, ideally without the need for scaffolding.
- There is adequate lighting with access for maintenance.
- There is good ventilation.

Hygiene of plant environment assured.

- All floors must be constructed from cement, tiles or suitable material that is durable and has a flat surface that will allow for regular cleaning and sanitation.
- Skirting of the wall to floor joints must be 100mm high and of the same material as the floor finish.
- Floors must have a 1 to 1,5% fall towards the drains to prevent ponding of water after hosing down.
- Floors of the process and packaging areas must be made from materials that resist acid and caustic at the concentrations found in the operational areas. Where areas are earmarked for storage of the concentrated forms of detergents and other materials, the floors and walls should be able to resist those materials.
- All drains in the process areas and packaging areas should have appropriate airlocks.
- Drain covers in the packaging areas should be constructed with baskets to retain glass.
- Walls in the process areas should be tiled to the ceiling or coated with a durable and washable coating. Ceilings should be painted with durable and washable coating. Where possible, anti-mould coatings should be used.
- Walkways and hand rails should be made of corrosive resistant material or coated with a suitable corrosion resistant material.
- Walls of the storage areas should be painted with a suitable durable coating.
- Natural ventilation or air-conditioning should supply sufficient air movement to prevent mould growth and eliminate odours.
- No protrusions should be allowed on walls and windows should have sills facing the outside. Any internal protrusion or beams should have a 30° fall to prevent dust from accumulating and to facilitate cleaning.
- All holes to the exterior should be covered by plastic mosquito netting.
- All process areas should be protected against entry of insects, vermin, dirt and dust.
- Hot and cold water points should be positioned strategically around the plant for hand cleaning and cleaning of equipment, walls and floors.
- All factory drainage systems should be dimensioned (size and falls) to allow for effective discharge of effluent with solids without having any blockages.
- Ablutions must be positioned away from the process area and be fitted with suitable lockers, showers, washbasins and other required sanitary fittings.

Materials Used for General Cleaning

- Suitable bins to hold all waste material should be positioned around the plant;
- brooms and brushes to sweep and clean the floor;
- squeegees to push excess water from the floors;
- drain pumps and pull through to clear blocked drains;
- sufficient hoses and hose points to clean all surfaces (walls, floors and equipment);
- special brushes for cleaning surfaces of the plant: care must be taken not to scratch inside and outside surfaces of stainless steel plant;

- personnel performing cleaning duties should be suitably clothed and protected.

Cleaning Agents

- Sufficient 70°C water must be available on tap to facilitate cleaning in all process areas.
- A suitable detergent should be used for general cleaning of all surfaces: choices of the detergents need to take account of the fact that chlorine based chemicals are corrosive on stainless steel equipment. MSDS certificates must be available for all materials on site.

Control of Environment

- Physical inspection of all plant and buildings to assess the level of hygiene must be done on a routine basis.
- Microbiological surveys of the environment (walls, floors, equipment and the air) will indicate the effectiveness of the plant hygiene programme.