

REVIEW OF PRACTICES FOR CLEANING AND SANITATION OF MILKING MACHINES

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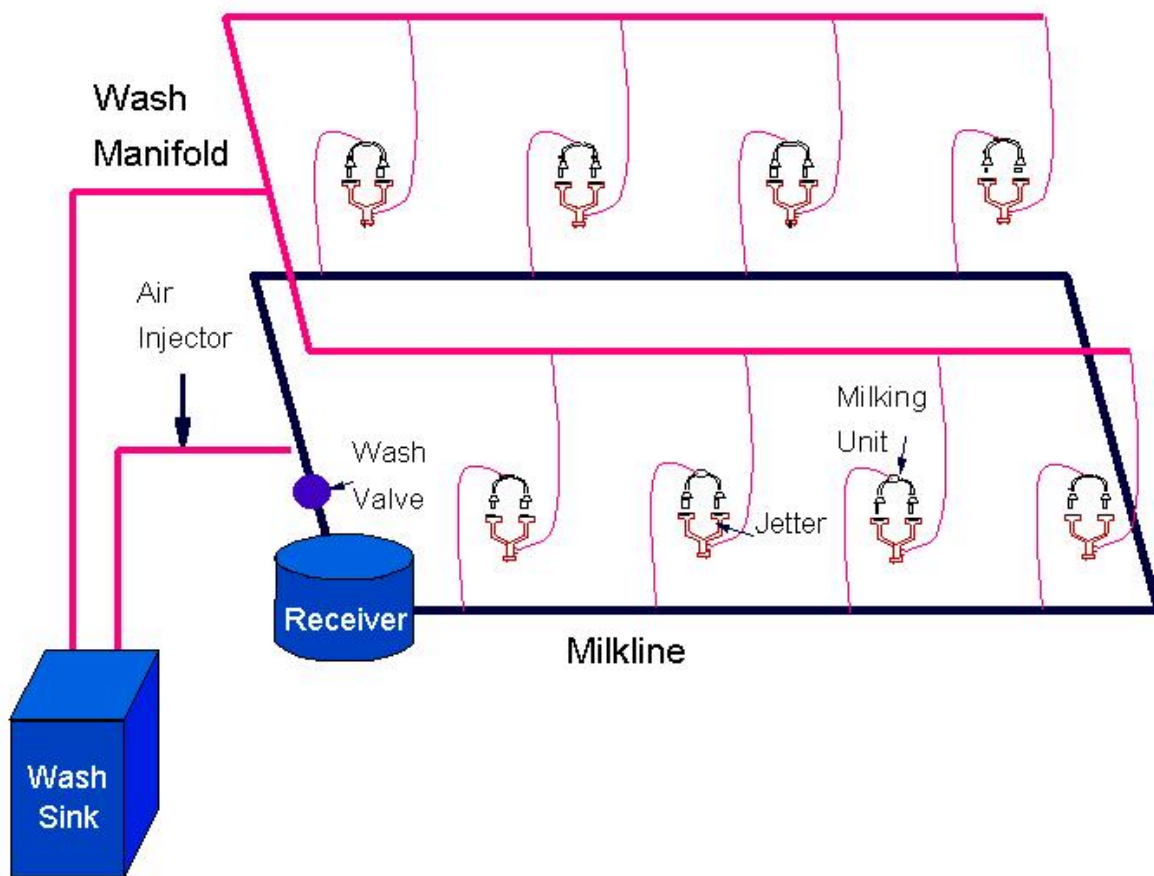
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Cleaning of milk handling equipment is accomplished by a combination of chemical, thermal and physical processes. Recommended cleaning and sanitizing practices are a balance between the cleaning temperatures, cleaning chemical concentration, contact time and mechanical action. A cleaning failure can result from a failure in any one of these processes. Any one of these factors can be intensified to make up for lack in another, up to a point. For example, a cleaning failure will result if cleaning solutions are not adequately distributed to all parts of the milking system. If little or no cleaning solution contacts a surface, the chemical and thermal actions cannot take place.

Assuring that the mechanical cleaning action is adequate typically requires very little added cost but relies on the skill of the equipment installer. As milking machines become more complex the task of assuring adequate mechanical cleaning action in all parts of the milking machine becomes increasingly complex. This has been an area of study in recent years. This paper will give an overview of cleaning and sanitation practices for milking machines with an update of recent research.

Although system designs vary considerably, typical features of milking parlor CIP systems are shown in Figure 1. Cleaning solutions are transported from the wash vat through the sanitary parts of the system and back to the wash vat during the CIP process. Two-phase flow patterns are determined by the diameter of system components and water and air flow rates. Internal diameters range from 10 mm in short milk tubes to 98 mm or more in milklines and in excess of 150 mm in milk meters and recorder jars. Flow velocities and flow patterns therefore vary greatly in the different parts of the system. Air-injection is normally used to produce slug flow in milklines. The objectives and optimal control strategies for air and water admission to milking units and other components differ from those for the pipeline. Milking units are either flooded or alternately flooded and emptied. Large components such as some milk meters and recorder jars are generally cleaned with a spray or sheet of water over the interior surfaces.

In milking parlors, milking units are commonly attached to wash assemblies (jettors) fed from a wash manifold. This water-draw pipe network and jettors make up the wash manifold. Cycled air-injection may enter through the wash manifold (A1 in Figure 1), the milkline (A2 in Figure 1) or both. When air is injected only through the wash manifold (A1) it is common to include a hose or pipe from the water draw line directly to the milkline (the dashed line in Figure 1). Air and water are separated at the receiver jar. The air travels to the distribution tank and is removed from the system by the vacuum pump. Water is returned to the wash vat by the milk pump through the milk transfer line.



Milklines must be sloped between 1 and 2 percent toward the receiver jar to prevent slugging in milklines during milking. All pipelines, hoses and components must also be installed so that they will drain by gravity between cleaning cycles. Drainage is an important aspect of cleaning, because any standing water in the system increases the risk of bacterial growth between milkings and mixing of different cleaning chemicals during cleaning.

MECHANICAL PROCESSES

Manual cleaning: Simple milking machines such as bucket milkers are typically disassembled and cleaned by hand. Even in the most complex machines using circulation cleaning, however, there are still components that must be disassembled and cleaned by hand. The source of the mechanical cleaning action is typically a brush used to remove milk soil deposits. The use of extended contact times (soaking parts in a sink) is also widely practiced for small components.

Flooded flow: The milk transfer line (from the milk pump to the wash sink) is cleaned in a flooded condition with the milk pump providing the fluid velocity. Milking machines with milking line diameter less than 48 mm have used flooded flow to circulate cleaning solutions through milking lines. Flooded flow is also encountered in components such as hoses milking units in which internal diameters are small. The desired flow velocity for flooded components is about 3 m/s.

Great variation in water flow between milking units can occur in milking parlors when no attempt is made to adjust the flow. The system vacuum, line diameter and length, and the lift from the wash sink determine the flow capacity of the wash manifold. Excessive flow through the first several units can drain the wash manifold resulting in little or no flow through units at the end of the line.

Milk pump capacity is often the limiting factor in CIP systems. The distribution of water flow between units should be as uniform as possible to make the most efficient use of water and air when cleaning milking equipment and to avoid exceeding the capacity of the milk pump. Adding flow restrictors is an effective way of optimizing water flow rates for cleaning and balancing the flow between units. Field studies have indicated that 3 L/min is sufficient to clean most milking units. While many units will clean at flow rates below this value, the risk of cleaning failure appears to be increased. Systems with milk meters or weigh jars require 4.5 to 6 L/min for effective cleaning.

Steady air admission: The amount of water required to fully flood a milking system with very long and/or large diameter milklines becomes impractical. The power available to achieve adequate flow velocity is also limited with the equipment available as part of the milking machine. Air admission has been used to produce two-phase (air/water) flow and overcome these limitations. Steady air admission is practiced on some small diameter milklines (< 48 mm) to reduce the required water volume and increase flow velocities. Some milking units and milk meters are also designed to introduce steady air admission during cleaning. This steady air admission will improve mechanical cleaning action slightly but makes balancing water flow through units more difficult and increases the vacuum pump capacity required for cleaning.

Cycled Air Admission And Slug Flow: Cycled air admission is commonly practiced on milking machines with milkline diameter 48 mm or greater. The objective in air-injected flow is to form a 'slug' of cleaning solution and move this slug around the entire pipeline. The slugs may vary from a few centimeters up to several meters in length. The area between the slugs contains a slower moving liquid film in the bottom of the pipe. The slug velocities developed with air injected two-phase flow can be 3 to 5 times higher, and the wall shear stress developed ten to twenty times higher than those in flooded CIP circuits. The contact time between the slug and pipe wall is significantly reduced, however.

Slug velocities of 7 to 10 m/s maximize the wall shear stress developed while minimizing the variation of shear stress along the pipe. The rate of air admission to the milkline should be controlled to achieve these slug velocities. Air admission rates above this maximum will result in reduced slug density and reduced mechanical cleaning action in the milkline. Methods for adjusting cycled air injection are presented by Reinemann et al (1997).

When cycled air admission is applied to the wash manifold, the pipes and components are alternately filled and emptied. This has been referred to as controlled flushing pulsation by Lind (1990). A recent study by Wolters (1993) showed that increased system vacuum improved the removal of residual milk from milking units, milk meters and milklines in flooded systems during the pre-rinse process. If the filling and emptying of the manifold is not complete in each cycle, significant variation can occur in the flow components (Reinemann et al 1997), and should be avoided in large milking parlor systems.

With proper system design and control strategies, the vacuum pump capacity required for cleaning most milking machines is less than the minimum recommended for milking. Additional vacuum pump capacity may be required on large systems using cycled air injection to multiple locations. A cardinal rule for efficient and effective CIP system design is to keep pipe lengths and number of fittings to a minimum. This will reduce the installation and operational cost of the CIP system as well as improve both milking and cleaning performance. The receiver should be located in such a way that the number of bends and fittings in the milkline are kept to a minimum. The receiver should not be placed in a location that will interfere with movement of the operators during milking. The wash sink is generally located near the bulk tank inlet to facilitate piping to switch from the milking to cleaning configurations. The length of piping from the milkroom to the parlor should be kept to a minimum to reduce cleaning water volume, heat loss during cleaning and difficulties controlling circulation.

Spray cleaning: Bulk tanks and other large vessels are cleaned by covering their inner surfaces with a sprayed sheet of water. The mechanical action and surface temperatures are significantly lower than for circulation cleaning. The chemical concentrations and wash water temperatures are therefore of critical importance for successful cleaning.

THERMAL AND CHEMICAL PROCESSES

Water rinses: A water rinse may be performed immediately after milking is completed, to remove most of the residual milk remaining in the system or between chemical washes to remove residual cleaning chemicals. These water rinses are usually between 38 C and 55 C. The upper limit has been specified in the belief that proteins may be 'baked' on to surfaces. The lower limit is set above the melting point of butterfat to ensure that fats will be removed and not redeposit. A second benefit of the initial rinse is to warm the equipment to reduce the temperature drop during the subsequent cycles this benefit is marginal, however, when the subsequent cycles are not started within 5 minutes after the rinse. These rinses should not be recirculated. Water rinses are recommended after every chemical cycle to remove residual chemicals from the milking machine.

Alkaline Detergent: Chlorinated-alkaline detergents are used to remove organic soils such as milk fat and proteins. Most detergents have a working temperature range between 43 C and 77 C, however there are also low temperature formulations available. The cleaning effectiveness of detergents improves as temperature is increased and as water hardness decreases. The detergent concentration must be adjusted to account for these factors as well as the presence of other elements such as iron or sulfur bacteria.

Acid Rinse: An acid rinse cycle may be performed to remove mineral deposits from water and milk. This may be a cold or warm rinse. The required frequency of acid rinse depends on the quality of the water used for cleaning.

Acidified boiling water: The acidified boiling water method is used in some parts of the world. An acid detergent solution is used at a temperature of nearly 100 °C. The wash solution makes a single pass through the system and is not circulated. The objective is to maintain all surfaces at a temperature above 77 C for at least 2 minutes. This method replaces the chemical action of alkaline detergents with intensified thermal action. It requires special equipment to achieve

elevated water temperatures and milking system components that can withstand these high temperatures.

Chlorine Sanitizers: Chlorine-based sanitizers are circulated immediately before milking to kill bacteria that have survived the cleaning process. This pre-milking sanitize step is performed on milking machines that stand idle for more than several hours between the previous wash cycle and the subsequent milking. A pre-milking sanitize is not practiced in many areas where a sanitizer is combined with either the detergent or acid rinse cycles and where water rinsing after each chemical treatment cycle is enforced.

Manual cleaners: Manual cleaners differ from chemicals designed for circulation cleaning and are specially formulated for this purpose.

TYPICAL CLEANING REGIMES

Very small herds (less than 30 cows) tend to have a high degree of manual cleaning and disinfecting. This usually involves hand cleaning of some or all of the milk harvesting and storage equipment. Small to medium herds (30 to 500 cows) commonly use automatic washing equipment. This equipment will automatically mix the chemicals with the appropriate water volume and temperature and circulate these solutions through the milking machine. On large farms (1000 cows or more), an attendant may be present to mix chemical solutions and operate valves for circulation.

The chemical processes described above are used in various combinations around the world. The most common routine in the US is a combination of: pre-rinse, alkaline detergent, acid rinse (frequency depending on water hardness), and pre-milking sanitize. In the Netherlands the standard cleaning of milking equipment consists of three phases: pre-rinse, combined alkaline detergent and sanitizer, followed by a post-rinse. A common practice in New Zealand is an acidified boiling water wash (alternated periodically with alkaline detergent) followed by a cold water rinse. A conventional Danish procedure is composed of: pre-rinse, alkaline detergent, cold water rinse, acid rinse, and then a pure water rinse immediately before milking.

The choice of which cleaning regime is used depends strongly on the habits and regulations of each country, the relative cost of energy for heating water, chemical cost and availability and effectiveness of the process.

ENVIRONMENTAL ISSUES

There are several environmental issues that are beginning to influence cleaning practices in some parts of the world. The discharge of cleaning and disinfecting chemicals into the environment can be an issue for elements such as phosphorous and chlorine. The use of enzyme cleaners and ozone sanitizers has been investigated but in general has not reached the market yet.

The volume of water used for cleaning and discharged into the environment can be an issue in areas with water shortages. The energy used for heating and pumping water also has environmental implications. Several of the research publications cited in the bibliography report on various methods to reduce water volume, chemical volume and energy requirements for cleaning through efficient system design and control, reuse of cleaning solutions.

CLEANING ASSESSMENT METHODS

Visual inspection: Cleaning failures usually result in a visual buildup or residual film on some part of the milk harvesting or storage equipment. Some of these films have a characteristic appearance, which can help determine the cause of the cleaning failure. There are two broad categories of residual films: Organic films such as fat and protein, and inorganic films such as hard water minerals, iron, and silica. Discoloration may also occur due to corrosion and/or pitting of surfaces. Protein films can appear as a brownish slime (applesauce) when wet. Mineral films usually have a rough porous texture and are invisible when wet. Organic films are generally alkaline soluble whereas inorganic films are generally acid soluble. Protein films are soluble in chlorine. Films can be diagnosed by scrubbing a small area with concentrated acid and/or detergent solutions.

Bulk milk cultures: The two main sources of bacteria in raw milk are organisms transported from the environment into the milking machine and mastitis organisms from within the udder. Bacteria deposited in milk handling equipment will multiply and become a major source of contamination if this equipment is not cleaned and sanitized properly. Some form of testing for bacterial contamination is done periodically on all farms to assure compliance with national, state, and local requirements.

The most common method used to assess the bacterial quality of raw milk is the standard plate count (SPC) or Total Bacteria Count (TBC). These are broad-spectrum tests that do not identify the types of organisms present. These tests provide an overall measure of milk quality but they have little diagnostic value in determining the source of bacterial contamination. High bacteria counts may result when certain types of mastitis organisms such as *Strep. ag.* or *Step. uberis* are present in the herd.

A major source of coliform bacteria in bulk tank milk is transportation of soil from the teats and udders into the milking machine. The Coliform count thus provides an indication of both the effectiveness of cow preparation procedures during milking and the cleanliness of the cows' environment. Coliform counts between 100/ml and 1000/ml are generally an indication of poor milking hygiene. Coliforms will also incubate in residual films left on milk contact surfaces. Coliform counts in excess of 1000 suggest incubation in milk handling equipment. A Coliform count less than 100/ml of milk is considered acceptable for raw milk for pasteurization. In states where raw milk may be sold to consumers, Coliform count must be less than 10/ml. Coliform counts less than 10/ml indicate excellence in both pre-milking hygiene and equipment sanitation.

Another bulk milk test which provides diagnostic value is Lab Pasteurized Count (LPC) or Thermotolerant count. These tests are performed in the same way as the SPC and TBC except that the milk sample is pasteurized at 63 C for 30 minutes before plating and incubation. This procedure kills the usual mastitis-causing bacteria (including coliforms) leaving only those organisms from the environment that can survive elevated temperatures. These types of organisms will grow and multiply in the milk handling equipment if cleaning and sanitation procedures are inadequate. Poor milking hygiene results in an elevation of both Coliform and SPC with a near normal LPC if the milking machine is clean. When milking equipment is not cleaned effectively, both Coliform and LPC will be elevated due to coliforms growing in soil films in the milking machine. Incubation of the milk films in the milking system will elevate

SPC, Coliform, and LPC. The LPC should be below 100/ml to 200/ml if equipment cleaning and sanitation are good. A LPC below 10/ ml indicates excellent equipment hygiene.

When the routine bulk tank testing indicates that a problem exists, more detailed tests can be performed to further isolate the source of the problem and recommend the most effective methods to solve it. Strategic sampling of milk in different **locations** will determine if the location of a cleaning failure and/or incubation problem is: in the milking units, milking line and receiver, in the milk transfer line (including filters and pre-coolers), or in the bulk tank. Strategic sampling of milk at different **times** during the milking process will determine if incubation in the milk handling system is a major source of contamination.

All of these bacterial tests rely on culture media and incubation from two to three days. Recent developments of ATP detection methods using a bioluminescence have been proposed as a rapid method for assessing the effectiveness of sanitation in the dairy industry. ATP bioluminescence is a rapid detection method suited for on-site sampling and takes less than five minutes to perform. Plate count methods also detect the presence of bacterial contamination on equipment surfaces, whereas ATP bioluminescence can detect both bacterial contamination and non-microbial contamination such as milk soil. ATP bioluminescence has the potential to be a useful tool to evaluate the effectiveness of cleaning procedures used on the milking machines.

The ATP method appears to be a more sensitive method to detect differences in cleaning effectiveness than bulk tank culture methods (Reinemann and Ruegg, 2000). There is considerable variation in the data collected, however, and the method must be used carefully and with sufficient number of test to obtain meaningful results. The required sample size will depend on the skill of the user and the stability of the system being monitored. Care must be taken to avoid contaminating the inner surfaces of components as they are opened for swabbing. The variability in the ATP data can be reduced significantly by using the same measurement locations over time.

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