



# **Optimal cleaning of equipment for automatic milking**

*Investigation of systems, procedures and demands*

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# **Optimal cleaning of equipment for automatic milking**

*Investigation of systems, procedures and demands*

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## Abstract

This report gives an overview of the cleaning systems and strategies of eight different automatic milking systems, based on information given by the manufacturers through interviews.

Three different cleaning procedures are distinguished: system cleaning, unit flush and cluster flush. The system cleaning is performed two to three times a day and cleans the complete system, which may consist of one or more units. The unit flush is meant to remove residues of abnormal milk (f.i. colostrum, milk with antibiotics) and only flushes that part of the system, which transports the abnormal milk. The unit flush is also used to flush the system after some idle time and in some cases after a certain number of milkings.

The cluster flush should minimise the number of pathogens in the teatcups and so prevent transport of pathogens between cows.

Based on the categorised information, large variation in water and energy intake and in duration of cleaning can be seen. Due to Dutch regulations all systems should perform a system cleaning three times a day. In some other countries however two times a day is also allowed. The optimal cleaning frequency for the system cleaning should be established by further research.

An important difference between cleaning procedures for the system cleaning is boiling water cleaning in a direct-to-drain system and a circulation cleaning at lower temperatures. In general the circulation cleaning needs more time.

The unit flush is a part of all systems. Next to its basic function of removing residues of abnormal milk, it is used to prevent drying of the milk inside the system after some idle time. Two systems are able to flush the unit after a certain number of milkings. The effect of flushing the unit on milk quality is so far unknown.

The cluster flush is performed after every milking for all AM-systems. Though the amount of water per flush is low, it takes a lot of water in total because the high number of milkings per unit. The effect on udder health of a rinse with a small amount of water should be established by research, including rinsing with added disinfectants.

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# 1 Introduction

Product quality and quality insurance are the issues in present animal husbandry. Automatic milking however was primarily introduced for reasons of labour saving and animal welfare. Improving milk quality has never been an issue; equal quality compared with conventional milking was good enough. As the hygienic quality of the milk was not an issue for improvement, only a relatively small effort was put in to the cleaning of the AM-system. Cleaning systems known from conventional milking machines were adapted for AM-systems.

Automatic milking however differs from conventional milking. To achieve maximum capacity for milking in an AM-system, only little time is available for cleaning where in a conventional milking machine there is plenty of time between consecutive milkings. And on the other hand, as an AM-system is working throughout the day, a more frequent cleaning could be necessary. Moreover, AM-systems are, due to the many valves and connections, more complex and therefore most probably more difficult to clean. Also, in a conventional system it is not a problem to do some things manually, because there is an operator around, in automated systems the need for manual activities should be avoided.

This report, meant to give more insight, describes the different systems based on information given by the manufacturers.

## 2 Cleaning

In the following paragraphs the different cleaning procedures are explained and parameters are given to evaluate the cleaning procedures. The demands are given and described is how cleaning procedures can be optimised.

### 2.1 Cleaning procedures

In all commercially available automatic milking systems different cleaning procedures are distinguished. In general this comes down to three procedures:

- *system cleaning*: the whole system, which may consist of one or more units, is rinsed, cleaned and disinfected
- *unit flush*: the unit, in total or partly, is rinsed in order
  - a) to avoid contamination of the bulk milk with contaminated milk (colostrum, mastitis pathogens, large numbers of somatic cells and/or drugs) and
  - b) to prevent milk in the system from drying out and adhering to the material after some idle time of the unit
  - c) to remove milk residues and therefor avoid bacterial growth in the milking system by flushing the unit after a certain number of milkings
- *cluster flush*: the cluster is rinsed with water (with or without a detergent / disinfectant), to avoid transport of (mastitis) pathogens between cows

#### 2.1.1 System cleaning

The system cleaning is meant to clean, wash and disinfect the system regularly (two to four times per day). The system cleaning in all cases consist of three cycles: a pre-rinse cycle, cleaning and disinfecting cycle and a post-rinse. Between cycles the system should be drained thoroughly, to avoid the following cycle to be contaminated.

The purpose of pre-rinse is to remove most of the milk residues in the system. To avoid the milk fat to solidify and the system to cool down too much, it is advised to use lukewarm water of about 40 °C without circulation ('direct-to-drain').

The cleaning and disinfecting cycle should sanitise the system. Detergent is used to dissolve the substances into the fluid running in the system. Agitation of the cleaning fluid helps to clean the surfaces by shear force. Agitation is normally provoked by air inlet into the system, which is under vacuum.

Chemical disinfectants, high temperature or a combination of both are needed to reduce bacterial contamination to a minimum. Also the time of exposure is important: chemical exposure should last at least 5 minutes, for 'sterilisation by temperature' the product of time and temperature is important, e.g. 2 minutes at 77 °C. This has lead to an important distinction between cleaning procedures:

- Boiling water cleaning. Disinfection of the system is done by a high temperature. The initial temperature of the cleaning fluid is at least 95 °C. Chemicals (acid or alkaline) are used as a detergent and to support disinfection. It is important that the inner surface of all milk-contact-parts of the system reach a temperature of at least 77 °C during two minutes [British Standard (1991)].
- Circulation cleaning. The cleaning fluid contains detergents and disinfectant and is used at a temperature between 85 and 45 °C. To have sufficient disinfection, the exposure time has to be at least 5 minutes. Therefore in this type of cleaning the cleaning fluid is circulated through the system for some time. Otherwise a very large quantity of cleaning solution is needed. At the end of the circulation cycle the temperature of the fluid should be at least 40 °C

In both types the cleaning agent is alternated between alkaline and acid, although different frequencies are used. It is common (but not necessary) to use more often a caustic agent.

The post-rinse has to remove the remains of the cleaning solution, to avoid contamination of the milk with detergents and disinfectants once milking is resumed. For the post-rinse direct-to-drain is preferred above circulation of the water because the remains of the cleaning solution are washed away.

### 2.1.2 *Unit flush*

The general purpose of this procedure is to remove milk residues, after a cow was milked which had abnormal milk (e.g. colostrum, milk from cows treated with antibiotics, milk with too much somatic cells). That part of the system that transports the abnormal milk has to be flushed to minimise milk residues.

The same procedure is also used to rinse the system after some idle time, to avoid bacterial growth in the milk that remains uncooled in the system and to avoid drying out of the milk on the inner surface of the system and thereby causing problems with cleaning afterwards.

### 2.1.3 *Cluster flush*

To avoid cross contamination with pathogens between cows, clusters are flushed after the milking of each cow. Clusters are flushed in the direction of the milk flow during milking (from the head of the liner towards the receiver) or in opposite direction ('back flush'). Some systems also use the cluster flush to flush the outside of the mouthpiece of the liner.

To minimise pathogens disinfectants could be used. For an effective disinfection however exposure time and temperature are important. When cold or lukewarm water is used, exposure time should be at least 5 minutes.

## 2.2 **Evaluation of cleaning procedures**

The most important criteria for judging the cleaning of robotic milking systems are:

- effectiveness
- consumption of water, energy and chemicals
- time consumption
- required manual activities
- influence on materials

### 2.2.1 *Effectiveness*

The most common parameter to judge the effectiveness of cleaning is the total bacterial count (TBC) in the bulk milk. The TBC however is not only the result of the cleaning of the milking system, but also of the cooling of the milk, the cleaning of the bulk tank and the hygienic circumstances in the barn in combination with the cleaning of udders and teats. Next to TBC also specific groups of bacteria like thermotolerant bacteria, coliforms and lactobacillus can add valuable information on the effectiveness of cleaning.

Another way to look at the cleaning is the appearance of debris in the system. Especially in places with low turbulence during cleaning, debris can build up during some weeks. This debris is measurable by ATP (Adenine-Tri-Phosphate).

A technical way of judging the effectiveness of the cleaning procedure is testing for a good drainage of the system between cycles of the system cleaning. For instance, the amount of milk residues in the cleaning fluid caused by an ineffective pre-rinse can easily be measured by the Chemical Oxygen Demand (COD) of the cleaning fluid.

The effectiveness of the post-rinse in removing the cleaning components can be measured by conductivity and checked with indicators like phenolphthalein (after a caustic cleaning only).

### 2.2.2 *Water, energy and chemicals*

An AM-system is a rather small, but complex installation compared to a conventional milking machine. Further on, it is used throughout the entire day and therefore has to be cleaned more often.

Also the risk that the teatcups will act as a vector in spreading mastitis pathogens through the herd, is higher as a result of more cows being milked more often with the same set of teat-cups. Flushing the teat-cups between two milkings is therefore very common in automatic milking.

In general the reduction of the consumption of water, energy and chemicals has not been an issue yet. Though there is a lot of information available in this field from the cleaning of conventional milking machines, which can be very useful for improvements in the cleaning of AM-systems.

### 2.2.3 Time consumption

The time needed for cleaning the system should be as short as possible, to have enough time to create a high throughput of each milking system. A reduction from 30 to 20 minutes, gives half an hour extra milking time each day assuming 3 system cleanings per day. More important is the waiting time for cows, approaching the system when cleaning. Depending on the time of day, cleaning could lead to waiting lines before the system and discouraging cows to be milked a next time. So it is important to choose 'quiet periods' to perform a system cleaning.

Also a system cleaning during the emptying and cleaning of the bulk milk tank is, in case of a single tank system, an option to save time.

### 2.2.4 Manual activities

In some cases the operator has to fulfil some tasks in cleaning, for instance to start the cleaning or to replace the filter. The need for manual activities makes the system dependent on the operator's presence and judgement of the situation. For instance, for the operator the capacity of the system could have priority above a cleaning in due time. So the liability of the AM-system can be increased, especially in regard to activities that need a certain frequency, when the need for manual interference is minimised.

### 2.2.5 Influence on materials

Some components (like rubber and plastic compounds) in milking systems are known to be susceptible for chemicals and/or high temperature, leading to a shorter lifetime or a poorer performance. Important factors in the degrading of materials are time and frequency of exposure, temperature and concentration of chemicals.

## 2.3 Demands for an effective cleaning

An effective cleaning should assure a good and stable milk quality, support a good udder health of the cows and should not negatively influence lifetime and performance of parts of the milking machine.

To assure a good quality of milk, the following demands for cleaning should be met:

- low bacterial counts in bulk milk (it is preferred to have TBC < 10.000/ml, thermotolerant bacteria < 200/ml, coliforms < 100/ml),
- no visible residues or other deposits on milk contact surfaces after a system cleaning,
- no residues of bacterial or somatic cells on milk contact surfaces after a system cleaning (to be measured with for instance ATP-measurements),
- no residues of chemicals, used for cleaning or disinfecting, in the milk,
- no residues of antibiotics and/or other veterinary drugs in the milk
- low residues of water (freezing point of bulk milk < -0.510 °C)

## 2.4 Optimisation of cleaning procedures

For an optimal cleaning it is important:

- that the cleaning fluid reaches all milk contact surfaces,
- that the inner surface is smooth,
- that the system is drained well after each cycle,
- that enough force is applied to the cleaning fluid to remove adhered debris and

- that the right concentration of active detergents and disinfectants is used during the right time at the right temperature.

Most of the systems can be optimised in one or more of these aspects.

#### *2.4.1 Construction*

In general the construction of AM-systems as of other dairy equipment, should be of hygienic design [IDF (1996)] and constructed from materials which are allowed for food processing (as far as it concerns milk contact surfaces) and which are resistant to the cleaning procedures used. Next to these general demands, there are some specific remarks to make for AM-systems [Wolters & Schuiling (1998), Lind et al (2000)].

The inlet of the cleaning fluid should always be at the end of a line, so that there are no dead ends which have none or insufficient contact with the cleaning fluid. As there are a lot of valves mounted in an AM-system, the risk for dead ends is high.

Were holes are made and pipes or tubes are connected, the surface should be smooth and without brims and burrs. When rubber tubes are connected to pipes, care should be taken that no space between the rubber tube and the pipe can be formed under different pressure conditions. In these cases (milk) residues could be gathered in these spaces and can enter the milking system on unpredictable times. Also when double clamps are used, the first should give a perfect seal already.

To lower the amount of cleaning fluid needed, it is important that 'dead space' is avoided, meaning that some fluid is stationary during some time in one or more parts of the system. For instance the amount of fluid in the receiver or in milkmeters should be as low as possible during cleaning. Also the slope of lines and well placed draining points (at the lowest point) are very important.

#### *2.4.2 Installation of an AM-system*

After a new AM-system is installed, the cleaning procedures should be tuned to the construction and circumstances [Verstappen et al (1999)]. Differences between farms are e.g. length of the delivery line, temperature of the water coming in to the system (tap water, water from heat recovery) and water pressure. The optimal amount of cleaning fluid needed for an efficient cleaning, the right concentration of detergent and the duration of cleaning cycles should be checked and optimised at least after installation.

It is important to have a well documented procedure for the technicians.

#### *2.4.3 Drainage of the system*

To remove milk residues at the start of the cleaning procedure a pre-rinse with water is performed. This pre-rinse should be direct to drain with lukewarm water, to prevent the milkfat to solidify and to prevent the cooling down of the system before the start of the cleaning cycle. It is important to drain the system very well after the pre-rinse to remove all milk residues. These residues can react with the detergents and disinfectants in the cleaning solution and decrease the activity of these components. Common problems with an ineffective draining are insufficient slope of lines, bad draining of containers and too little time or air for 'drying' the system with an air-stream forced through the system by pressure differences.

#### *2.4.4 Forming of slugs*

To create enough force of the cleaning fluid, it is important that slugs are formed and transported through the system. To form slugs with enough speed the pressure difference and air flow created by the vacuum pump should be big enough. This can be achieved by using a higher vacuum during cleaning and / or using air blasts. However no standards for AM-systems are available today.

### 3 Material and Methods

During this investigation eight companies were selling AM-systems. Some systems use the same robot technology, but differ for instance in equipment for the milk collection, milk measurement and transport. These differences also reflect on the way the system is cleaned so all the companies were part of the investigation. See table 2.1 for a list of systems and companies. For collecting the information a checklist was used (see appendix 1). In this report the systems are presented by code.

Table 2.1. List of automatic milking systems, which are commercially available

Name of system	Company
Astronaut	Lely Industries
Freedom / Liberty *	AMS Liberty
Galaxy	Galaxy
Leonardo	Westfalia
Merlin	Fusion
Solos / Miros *	Manus Holland
VMS	DeLaval
Zenith	Gascoigne Melotte

\* resp. a one-unit version and a version with 2 or more units.

## 4 Results

In the following paragraphs the three cleaning procedures are explained and the differences between AM-systems are given. In paragraph 3.4 the different ways to control the procedures are given.

### 4.1 System cleaning

The system cleaning does clean the whole milking system, from the teatcups up to the valve, mounted on the inlet of the bulk milk tank.

Two methods for the system cleaning can be distinguished: boiling water cleaning versus circulation wash. The two types of cleaning are described in §1.1.1.

The compulsory frequency of cleaning for all the AM-systems is 3 times per day, due to Dutch regulations. The cleaning frequency or interval can be set to a wide range, to comply with the farmers needs and local regulations.

The milkfilter must be replaced manually. It is advised to replace the filter before cleaning. Some systems have or are working on an option for automatic changing of filters.

None of the systems tries to reduce the use of water and chemicals by re-using fluids.

See table 4.1 for a summary of the system-settings.

#### 4.1.1 Boiling water cleaning

Three of the eight AM-systems do use boiling water cleaning. The system cleaning has three phases, a lukewarm or cold pre-rinse, boiling water cleaning and post-rinse. All the phases are direct-to-drain. Alternately an alkaline or acid detergent is used in the cleaning phase to avoid a film building up on the surfaces, especially on measuring instruments and sensors. The frequency of the usage of alkaline or acid detergent ranges from 3:1 to 1:2.

The cleaning starts automatically at fixed intervals or at fixed times and takes 9 – 20 minutes per cleaning. The total water consumption per cleaning per unit is 70 to 90 l, including pre and post rinse.

#### 4.1.2 Circulation wash

Most of the systems use a circulation wash. The system cleaning has three phases, a lukewarm pre-rinse, circulation wash and post-rinse. The pre- and post-rinse are direct-to-drain, the circulation wash circulates a couple of minutes. In one system the cleaning needs a manual start, in the other AM-systems the cleaning starts automatically with fixed intervals or at pre-set times. Alternately an alkaline or acid detergent is used in the cleaning phase.

The system cleaning takes 20 - 40 minutes per cleaning. The total water consumption per cleaning varies between 55 and 90 l per unit, including pre and post rinse.

### 4.2 Unit flush

The unit flush is performed after milking a cow with abnormal milk and after some idle time: when the AM-system is not used for some time (20 - 60 minutes) the unit flush starts automatically. The farmer has to mark in the management system of the AM-system the treated and fresh cows, after which milking the unit flush should be carried out.

Two systems can also perform a unit flush after a certain number of milkings. For one system this is the default setting (after every 10 milkings).

One system does not distinguish between a unit flush and a cluster flush, due to the construction. In most systems the discard valve of abnormal milk is in the line after the milk receiver and/or milk meter. In this case the discard-valve is in the long milk tube, which makes that only a short circuit will be contaminated and that the unit flush and the cluster flush are flushing the same components of the AM-system.

In none of the systems detergents are applied to the unit flush.

The main difference between the unit flush of AM-systems is direct to drain versus circulating. The two types of unit flushes are described.

#### *4.2.1 Direct to drain*

In five AM-systems the unit flush has only one phase, direct-to-drain. The cold or lukewarm water goes from the teat cups via the antibiotic (and colostrum) valve to the sewer. One system does perform a post-rinse with cold water after a lukewarm flush.

The unit flush takes 1.5 - 10 minutes and uses 12 to 30 l water per unit.

#### *4.2.2 Circulation flush*

Three AM-systems circulate during the unit flush by returning the water from the receiver-outlet to the cluster-inlet for some time.

The unit flush takes 10 minutes and needs 8 to 15 l water per unit.

### **4.3 The cluster flush**

All the AM-systems do have a cluster flush to reduce the risk of transfer of pathogens from cow to cow. In all cases this is a direct-to-drain flush. The cluster flush is performed after every milking. In five cases the cluster flush can be switched off; in two cases the option is to perform a cluster flush only after a suspicious cow.

In most cases the cluster is flushed from the head of the liner to the discard valve, in three systems it is flushed in the opposite direction: back-flush. The amount of water varies between 0.14 and 1.0 l/flush. Only one system does use a disinfectant as standard procedure, for one system this is optional.

### **4.4 Control-sensors**

The effectiveness of cleaning is among other things dependent on volume, temperature and amount of detergent. These values could be checked by the system.

In most cases the volume is checked by a level-sensor. In some cases volume of all cleaning cycles is based on water inlet time. A level-sensor is independent of the water pressure in the main line, so it will be more accurate.

The temperature at the end of the cleaning cycle is very important for the result of the cleaning. Five systems do check this temperature of the cleaning cycle and report inappropriate temperatures to the operator.

The concentration of detergent in the cleaning solution is not measured. All the systems add fixed volumes to the cleaning solution, some systems check the presence of detergent in the container or in the line. In some cases stock-control has to be performed by the operator.

### **4.5 Additional support**

The effect of the cleaning can be supported by forming slugs during cleaning and force these slugs through the installation. This can be achieved by additional air-inlet and raising the vacuum-level during cleaning. Only one system is using these techniques to improve cleaning.

Table 4.1. Overview of the cleaning procedures of eight AM-systems

	1	2	3	4	5	6	7	8	
<b>System cleaning</b>									
Time	30-40	30	35	30	20	15-20	15	9	minutes
Frequency (advise: every 8 hours)	MS	MS	MS	FT/MS	FT	FT	FI	FT	Fixed Time/Fixed Interval/Manual Start
Pre-rinse	D/C	D/C	D/C	D	D	D	D	D	Direct to drain / Circulating
Cleaning	C	C	C	C	C	D	D	D	Direct to drain / Circulating
Post-rinse	D/C	D/C	D/C	D	D	D	D	D	Direct to drain / Circulating
Warm water supply	I	I	I	E	E	E	I	I	Intern / Extern
Volume pre-/post-rinse (1 per unit)	22,5	17,5	22,5	25	30	15	20-25	13-16	liter per uni based on 2-BOX ( Volume:2)
Volume cleaning (1 per unit)	30	20	30	20	30	40	30-45	35-45	liter per uni based on 2-BOX ( Volume:2)
Controle volume pre-/post-rinse	L	L	L	L/T	L	T	T	T	Level/Time
Controle volume cleaning	L	L	L	L/T	L	L	L	T	Level/Time
Temperature pre-rinse	LW	LW	LW	LW	LW	LW	C	LW	Lukewarm/Cold
Temperature cleaning	W	W	W	W	W	H	H	H	Initial temp.: Warm (> 80 °C)/ Hot (> 95 °C)
Check final temperature cleaning	no	no	no	yes	yes	yes	yes	no	
Vacuum	MV	MV	MV	MV+10 kPa; AI	MV	MV	MV / MV -15 kPa / MV	MV	MV=Milking vacuum, AI=Air Injection
Drainage	T/CA	T/CA	T	T/CA	T/CA	CA	T	CA	Time/Compressed Air
Detergent	AC	AC	AC	AC	AC	A	A	A	Alcalic/Alcaline Chlorine
Alcalic:Acid	3:1	3:1	3:1	1:1 - 6:1	6:1	3:1	2:1	1:2	
Check quantity detergent	yes	yes	yes	yes	no	no	yes	no	
<b>Unit flush</b>									
Time	10	10	10	1	8-10	10	1.5-3	4	minutes
Pre-rinse	D/C	D/C	D/C	D	D	D	D	D	Direct to drain / Circulating
Desinfection				D					
Post-rinse				D					
Volume unitflush	15	8-9	10-15	0,9	30	12	20	20	Direct to drain / Circulating
Controle volume	L	L	L	T	L	T	T	T	liter per unit
After non consumable milk	yes	yes	yes	yes	yes	yes	yes	yes	Level/Time
After stand still	30	45	30	20-30	20	60	45	60	minutes
After .... Milkings				(5 - 8)			10		
Temperature pre-rinse	LW	LW	LW	C	LW	LW	C	C	Lukewarm/Cold
<b>Cluster flush</b>									
Frequency	1, off	1, off	1, off	1, S	1	1	1, 2, 3, off	1, 2, 3, S, off	after # milkings (S = selected cows)
Time	15	15	15	60	25	30	8	10	seconds
Pre-rinse	D	D	D	D	D	D	D	D	Direct to drain / Circulating
Desinfection and postrinse				D					Direct to drain / Circulating
Volume clusterflush	0,14	0,14	0,14	0,9	1	0,75	0,5	0,75	liter per milking
Controle volume	T	T	T	T	T	T	T	T	Niveau/Time
Direction	F	F	F	F	B	B	B	F	Flush / Backflush
Disinfectant	no	no	no	yes	no	no	optional	no	

## 5 Discussion and recommendations

- Frequency of cleaning

The hygienic quality of the milk is the first concern when optimising the cleaning frequency. On the other hand, as automatic milking is a continuous process throughout the day, every interference in this process should be avoided, in order not to disrupt cow traffic and to reduce throughput.

Starting with a clean and disinfected system and milking the first cows, it will take some time for bacteria to adapt to the environment. It is important to start the next cleaning before the bacteria have adapted.

Bacterial growth however is not only depending on cleaning frequency, but also on how well milk residues in the system are flushed away during the milking of the next cow. In this regard the construction in general, and in particular the inner surface, the slope towards the receiver and the absence of 'dead ends' are important, as is the remaining volume in the receiver and the length / volume of the delivery line. Also the storage and cooling of the milk is an important factor which influences bacterial growth.

Some work has been done in the past with simulated AM-systems and with the first generation of AM-systems [Frost et al (1999); Ipema (1997); Schuiling (1995) and Verheij (1992)]. Because of the high number of AM-systems on farms now, the effect of cleaning frequency should be studied with different AM-systems.

- Effect of unit flush

The unit flush is mainly intended to wash away abnormal milk like colostrum and milk with antibiotics. In case a cow suffers from a clinical mastitis a flush with cold or lukewarm water could not be sufficient regarding the EU-directive 89/362/EEC, which says that cows should be milked last, milked by hand or by a separate milking machine. This directive however was made long before the introduction of AM-systems. To be milked last with an AM-system is a demand that is hard to meet when milking continuously. When all the precautions are taken to prevent (residues of) this milk come into the bulk tank and to prevent spreading of the pathogen(s) to other cows, the goal of the directive is fulfilled.

The effect of the unit flush after a certain number of milkings or after a certain idle time, to avoid bacterial growth in milk residues and adhering of milk components to the inner surface of the milking system, is not established yet. Possible advantages are: diluting the number of bacteria in the system, changing the environmental conditions of the bacteria and so prolonging their 'lag-phase' and avoiding milk residues to dry out and adhere to the inner surface of the milking machine, which could interfere negatively with good cleaning. Disadvantages are a higher input of water and energy, a possible loss of effective milking time and too much water in the milk (to high freezing point).

As can be seen from the interviews a wide range of intervals is used (between 20 and 60 minutes of idle time). Within 1 hour idle time bacterial growth will be minimal [Frost et al (1999); Ordolff & Bölling (1992)]. In practice a 60 minutes idle time will be rare, but possibly will occur more often when cows are grazed.

- Effect of cluster flush

The milking cluster is an important vector in the transfer of mastitis pathogens. In an AM-system more cows are milked with the same cluster, so the risk of spreading pathogens from cow to cow is higher. On the other hand the possibilities to flush or disinfect the cluster between the milking of cows are better and can be automated.

Some data are available on flushing-systems in conventional milking installations. No data are so far obtained with AM-systems.

- General demands for AM-systems  
Looking at most of the systems from a cleaning perspective, optimisation in efficiency, time, water, energy and chemicals is possible. This is obvious by the large variation in for instance time needed and water consumption. But also the construction could be improved: one can think of no dead ends which are hard to clean, no 'dead space' during cleaning forcing to use more water than strictly needed and efficient draining between cleaning cycles.

## 6 Conclusion

- All the data given are according to the response of the companies. It is possible that in practical situations the water consumption may differ from the given ones, due to different settings in the software and/or different pressure in the water line. Especially when the amount of fluid is based on time instead of level, water line pressure does influence the results.
- As the investigation was conducted in The Netherlands, Dutch legislation was very often the standard. So, in all cases 3 times system cleaning per day was advised, though the farmers are free to change the frequency. The flexibility of the software allows the farmer to meet his demands and/or the legislation. Some farmers will try to reduce the cleaning frequency to have more effective milking time and to reduce the manually change of filters.
- System cleaning time varied between 9 en 40 minutes, where boiling water cleaning (9 - 20 min) took up less time than circulation cleaning (20 - 40 min). The variation shows that improvements can be achieved for both types of cleaning.
- The amount of water used per unit varied between 55 and 80 l/system cleaning. The unit flush needs between 8 and 30 l/unit. The cluster flush uses 0.14 to 1.0 l/flush.  
The total water consumption can be estimated, assuming 3 system cleanings/day, 150 milkings/day, after 1,67 % of the milkings a unit flush has to be carried out (average 2,5 milking/day) and after every milking a cluster flush.  
The average water consumption of an AM-system is 0,375 m<sup>3</sup>/day, using the former assumption.  
When a unit flush is conducted after every 10 cows, an extra 15 x 20 l = 0,300 m<sup>3</sup> should be added.  
The variation in total consumption however is huge and lies between 0,207 and 0,495 m<sup>3</sup>/day.  
When a unit flush is conducted after every 10 milkings, the maximum consumption is 0,665 m<sup>3</sup>/day.
- One improvement mentioned very often, was automatic changing of the filter. This still is a manual activity, which preferably should be carried out so that the dirty filter is removed before cleaning and the new filter is placed after cleaning. This is not practical, so the standard procedure is changing of the filter before cleaning. And even then, in a lot of cases filters will be changed at convenient times for the operator.  
Some developments are started to solve this problem, for instance a system with two parallel filters. Care should be taken that these kinds of systems can be sanitised well and that no 'dead ends' are created.
- Three systems need a manual start of the system cleaning; in the other AM-systems cleaning starts at fixed intervals without manual interference which makes it likely that changing of filters is not always done at the recommended moment in the cleaning process. With a manual start of the cleaning however, it is likely that the cleaning is postponed during night hours and at times when a lot of cows are waiting to be milked.

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## Appendix 1.

### Project EU WP7. Checklist ‘Cleaning of AM-systems’

Company :

date:

Spoken with :

		System cleaning			Unit flush		
		pre rinse	cleaning	post rinse	pre rinse	cleaning	post rinse
System	Cleaning cycle						
	Circulation/direct to drain						
	Reuse						
	Source of warm water						
	Components cleaned						
	Time needed						
	Air injection or other						
	Drainage						
	..						
Frequency	Fixed						
	Variable						
	Operator controlled						
	System controlled						
	Default / advised						
	..						
Temperature	Fixed						
	Variable						
	Default / advised						
	Autocheck start temp.			X			X
	Autocheck end temp.			X			X
	..						
Volume	Fixed						
	Variable						
	Default / advised						
	Autocheck (time / level)						
Vacuum	Fixed						
	Variable						
	Default / advised						
	Autocheck vacuumlevel						
Cleaning Agent	Alkaline						
	Acid						
	Other						
	Autocheck concentration						
	..						
Manual activities	Filter change						
	..						
	..						
Remarks							