DeLaval

Efficient milk filtration

Your solution – every day

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About this booklet

This is the first edition of the Efficient Milk Filtration booklet, edited and published by DeLaval International AB. This booklet is the result of our extensive experience in dairy farming and milk filtration, starting in the late 19th century when our founder, Gustav de Laval, invented the revolutionary cream separator. Ever since, milk separation and filtration have formed the very heart of our operations.

The Efficient Milk Filtration booklet draws on the vast collective knowledge of milk filtration experts from all over the world. It has been created to give farmers, consultants and advisers, students and other individuals with an interest in high quality milk production, a tool with which to familiarise themselves with successful, efficient and ultra-hygienic on-farm milk filtration. Furthermore, it outlines the critical role of milk filtration within a high-quality milk production process.

Milk filtration – clean technology for quality milk production

Milk is one of the most important and complete human foodstuffs; rich in proteins and numerous essential nutrients. Quality milk production depends on healthy cows consuming a nutritious food ration and plentiful fresh, clean water.

Although commercially produced milk is processed, it remains entirely natural. And so is modern milk filtration. Today's professional on-farm milk filtration uses entirely clean technology, based solely upon molecular size – it requires absolutely no additives. This clean technology helps farmers to produce milk of the highest quality and value, and to comply with the increasingly rigorous demands of both public authorities and consumers.

As well as maximising the quality and value of milk, the installation of a good filtration system also protects both milking and cooling equipment from potentially harmful foreign particulates. This means that farmers benefit from filtration in two ways: they save money by maximising the longevity and minimising the maintenance of their milking equipment, and by producing milk of the highest possible quality they can command the best market price.

Although milk is subsequently filtered at the milk plant, effective milk filtration on the farm plays an important role in:

- producing raw milk of the highest quality for the dairy company
- indicating the effectiveness of teat cleaning prior to milking
- identifying udder health problems (e.g. mastitis)
- identifying cow environment problems
- ensuring optimum plate cooler efficiency and hygiene.

Did you know?

Wet-laid milk filter fabric
Wet-laid materials are highly uniform fabrics that provide excellent porosity control, uniform filtering characteristics, high wet strength, and good dimensional stability.

Image (top):
Milk tanker in Sweden

Image (bottom left):
DeLaval milk filter boxes

Image (bottom right):
Dairy products

Did you know?

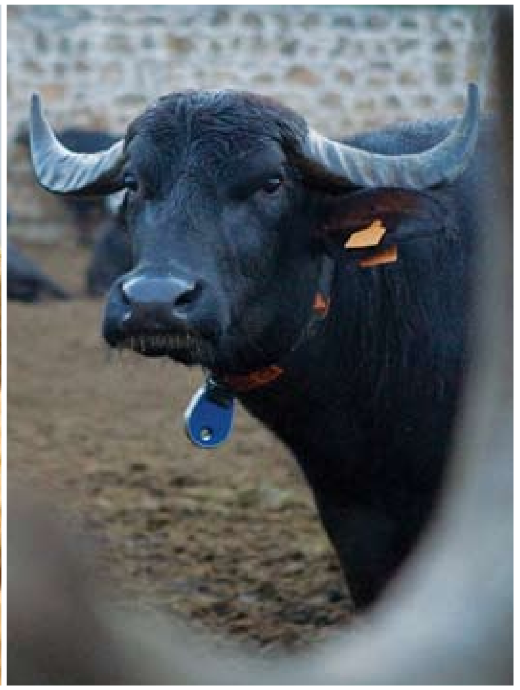
Filtration enhances good milking practise
Milk filtration should not be used to rectify unsatisfactory milking procedures. It is a complementary procedure to protect milking and cooling equipment and enhance milk quality and value.

Factors affecting milk filtration

People all over the world consume the milk of many different species of animal, but cows, sheep, goats, and buffalo form the primary sources, forming the basis of commercial milk production across the globe.

Table 1: Trends in world milk production – a comparison with other dairy species

Parameters (%)	Year 2000	2001	2002	2003	2004
Increase in world cow milk	2	1	2	2	0
Cow milk of total world milk	85	85	85	84	84
Total world cow milk (Mt)	488 057 837	494 618 011	505 222 503	514 035 351	513 312 002
Increase in world buffalo milk	3	4	3	4	1
Buffalo milk of total world milk	12	12	12	12	12
Total world buffalo milk (Mt)	67 417 389	70 414 905	72 288 775	75 372 769	75 833 191
Increase in world sheep milk	-3	4	-3	2	1
Sheep milk of total world milk	1	1	1	1	1
Total world sheep milk (Mt)	7 198 400	7 459 725	7 250 519	7 393 335	7 438 527
Increase in world goat milk	2	3	1	1	0
Goat milk of total world milk	2	2	2	2	2
Total world goat milk (Mt)	11 065 482	11 456 111	11 560 801	11 708 274	11 716 286
Increase in world camel milk	3	5	0	4	0
Camel milk of total world milk	0	0	0	0	0
Total world camel milk (Mt)	426 085	430 268	433 278	434 000	434 450
Total world milk (Mt)	564 453 649	574 165 193	584 379 020	596 755 876	608 943 729
Increase in world milk		1.69	1.75	2.07	2.00



The composition of milk differs vastly between species, breeds, and even between individual animal and lactation phases. The factors affected include the types and pro-portion of protein, the fat and sugar content, vitamin and mineral levels, the size of butterfat globules and the curd strength.

Table 2: Composition of milk from different species

Constituents	unit	Cow	Goat	Sheep	Water Buffalo
Water	g	87.8	88.9	83.0	81.1
Protein	g	3.2	3.1	5.4	4.5
Fat	g	3.9	3.5	6.0	8.0
Carbohydrate	g	4.8	4.4	5.1	4.9
Energy	kcal	66	60	95	110
Energy	kJ	275	253	396	463
Sugars (Lactose)	g	4.8	4.4	5.1	4.9
Fatty Acids:					
Saturated	g	2.4	2.3	3.8	4.2
Mono-unsaturated	g	1.1	0.8	1.5	1.7
Polyunsaturated	g	0.1	0.1	0.3	0.2
Cholesterol	mg	14	10	11	8
Calcium	IU	120	100	170	195

Given the differences in milk composition, professional milk filters must be capable of performing well under varied conditions in order to achieve the best possible result.

The role of on-farm milk filtration

Filtration is the process used to separate one substance from another. Depending upon the industry and the substances to be separated, many types of filter system are available, including electrostatic precipitators, centrifuges, cyclones, scrubbers and mechanical separators.

In on-farm milk filtration, a mechanical filter is used to separate the raw milk from any solid particles that may become suspended in it, before it reaches the bulk milk tank. This includes material such as dirt, manure, straw, hair, clots and insects – all of which can potentially cause problems for milking equipment and, of course, contaminate the bulk tank milk. But on-farm milk filtration is not a way to fix poor or unhygienic milking procedures. It is a best practice that plays an important role in good, holistic milking management.

It is important to note that although filtration is an effective method of removing dirt and other particles from the raw milk, it does not remove bacteria or other material that may have dissolved in the milk. Milk continues to flow across any sediment trapped in the milk filter and this can dislodge bacteria that may be stuck to the particles, potentially increasing the bacterial count of the bulk milk.

Inspection of the milk filter after milking has finished can provide an excellent guide to the herd's udder health and to whether the teat preparation regime is adequate. Any signs of mucous or clots on the milk filter indicate clinical mastitis in the herd.

The mechanics of on-farm milk filtration

The mechanical filtration method used to filter milk on the farm is also called barrier filtration. This is because the filter provides a porous physical barrier with highly specialised properties that enable the raw milk to be separated from the solids.

The driving force of the filtration process is the difference in pressure between the two sides of the milk filter. When raw milk is pumped across the porous surface of the milk filter, a pressure difference either side of the filter is created. The pressure difference forces those elements that are smaller than the pore size of the milk filter (such as water, fat, proteins etc.) to pass through. Any elements that exceed the pore size of the milk filter (including straw, hair, insects, etc.) are unable to pass through and remain in the milk filter.

The process of forcing milk through the milk filter by using a pump is the most common method in modern milking plants. The milk filter resembles a sleeve, or sock, that fits over a perforated metal support, or cage, within a cylindrical tube. Optimum filtration performance is achieved when milk flows at a low but continuous pressure across the milk filter.

With in-line milk filtering, it is important that the milk is filtered prior to cooling, because milk fat can pass through the filter more easily when the milk is warm. Filtering the milk prior to cooling also ensures that solids do not pass through to the cooling plate, as a build-up of sediment will not only compromise its heat-exchange efficiency, but also contribute to increased bacterial count in the bulk milk.

Did you know?

Milk filters protect the efficiency of the cooling equipment
By filtering milk before cooling, any sediment in the milk is trapped before it reaches the cooler plate. Sediment reaching the plate cooler will clog the plate and reduce the surface area available for heat exchange, reducing heat transfer efficiency.

Image(right):
Milk filters and plate heat exchanger

What makes a good milk filter?

As mentioned previously, the role of on-farm milk filtration is to enable farmers to produce milk of the highest possible quality and value, as well as helping to protect the milking and cooling equipment. To ensure these demands are met efficiently, a good milk filter must possess certain physical properties. It is essential that the selected filter is the correct size and capacity to match the demands of the milking equipment and herd size. It must also be manufactured from highly uniform fabric, incorporating:

- high wet strength
- even pore size and distribution
- a strong seam
- dimensional stability
- food compliance.

Finally, it is essential to choose a milk filter that complies fully with EU and FDA regulations, as well as USDA requirements.

Positioning the milk filter for optimal performance

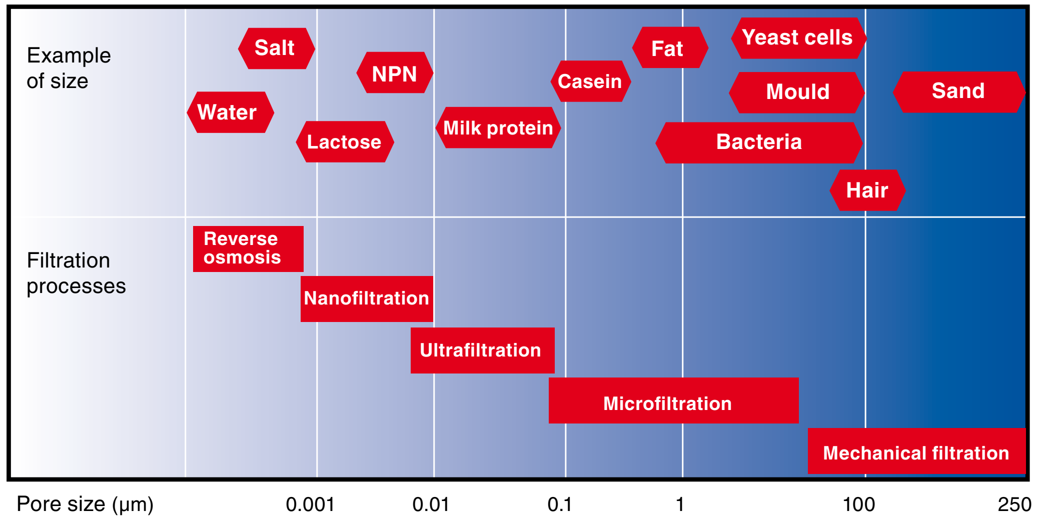
In order to achieve optimal performance in on-farm filtration, the position of the milk filter is critical. Milk should always be filtered before it reaches the cooling system. Warm milk, within the temperature range of 36°–38°C (98°–100°F), can be filtered very efficiently as the milk fat can pass readily through the milk filter. When milk is cold however, between 0°–5°C (32°–40°F) for example, problems can arise. Milk fat in cold milk can block up disposable milk filters as it can not pass easily through the filter. This causes the milk flow through the filtering unit to be reduced to an unacceptable level.

Did you know?

Milk should always be filtered before it is cooled
A milk filter should be positioned so that the milk can be filtered before it is cooled. Filtering warm milk enhances the passage of the milk fat through the milk filter.

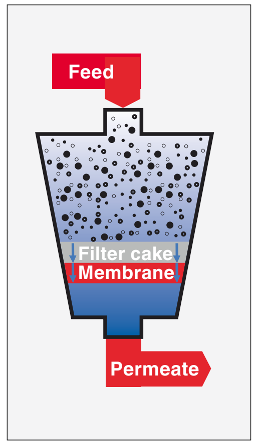
Filtration methods

There are many different methods of filtration, with one common objective: to separate various substances from each other. On the dairy farm, the objective is to separate unwanted particles from the milk.



There are various ways to classify filtration methods. The most common filtration methods are:

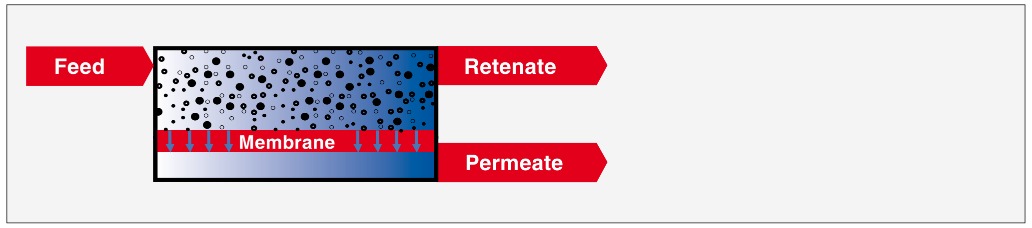
- Dead-end filtration
- Cross-flow filtration



Dead-end filtration
In the dead-end filtration process, the raw milk passes through the milk filter and all the elements that are larger than the filter's pore size (e.g. straw, hair, clots and insects) are retained on the surface. After a time, the particles build up a "filter cake" on the surface of the milk filter. In on-farm milk filtration, dead-end milk filters have a real advantage over cross-flow filters. Inspection of the "filter cake" retained on the surface of the dead-end milk filter after a milking session can provide the farmer with valuable information about the health of the herd and the adequacy of the teat cleaning procedures prior to milking. Any signs of mucous or clots on the milk filter indicate the presence of clinical mastitis within the herd, while the presence of other materials may suggest that the farm's teat preparation regime needs to be improved.

> To aid in the identification of clinical mastitis, coloured milk filters are available. Clinical mastitis can be identified easily by the appearance of white flecks of mastitic milk, but these are difficult to see on a white filter. Coloured filters offer a great advantage to the farmer by providing a quick and much more easy to see mastitis check.

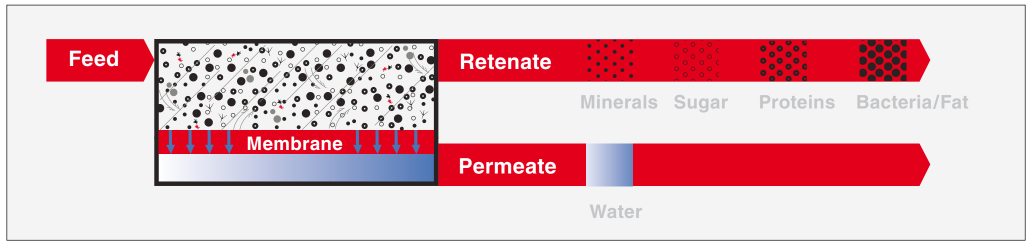
Cross-flow filtration
In cross-flow filtration, the raw milk passes over the milk filter tangentially. This tangential motion of the milk over the filter means that those elements larger than the filter's pore size do not collect on the surface and build up into a "filter cake", but are rubbed off and disposed of.



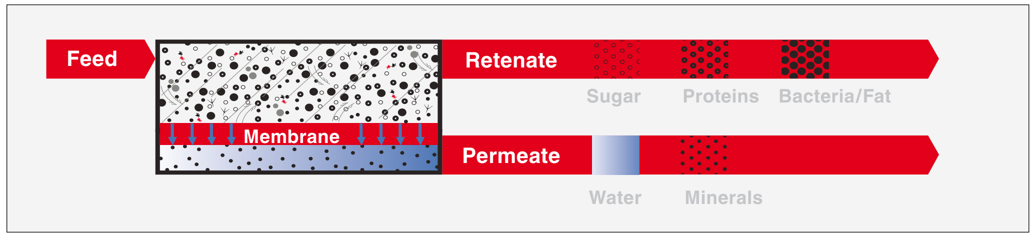
Filtration can be categorised on the basis of the filters' pore size and the size of the elements they are required to separate out. From the smallest to the largest pore size, these methods are:

- Reverse osmosis
- Nanofiltration
- Ultrafiltration
- Microfiltration
- Mechanical filtration

Reverse osmosis
Reverse osmosis uses the tightest possible membrane in liquid separation, with an average pore size of less than 1 nm. It only operates with a pressure range of 2–80 bar. In principle, water is the only material that can permeate the membrane. No other materials (salts, sugars, etc.) are able to pass through.

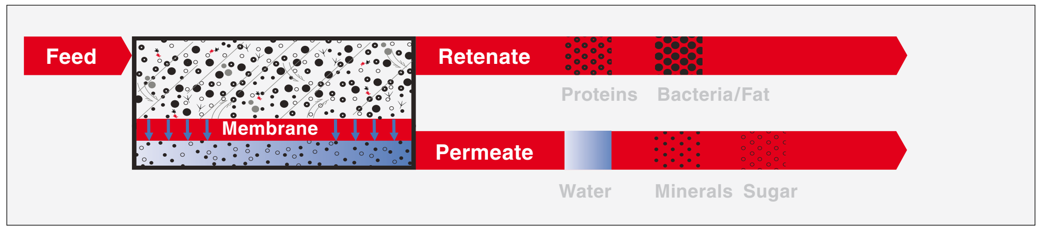


Nanofiltration
Nanofiltration is a slightly coarser separation process than reverse osmosis, characterised by pore sizes that range from 1 to 3 nm and operating pressures of 5 to 40 bar. Nanofiltration allows small ions to pass through while larger ions and most organic components are retained by the filter.



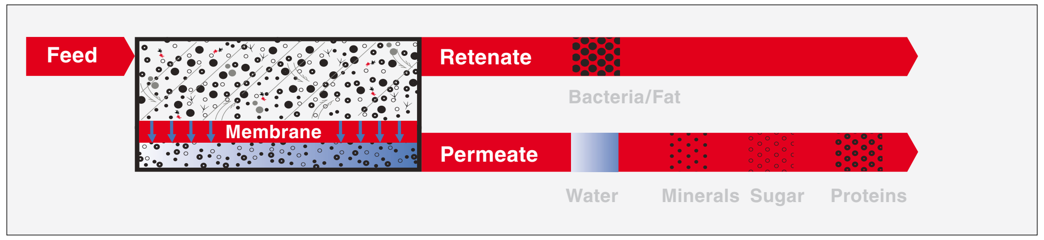
Ultrafiltration

Ultrafiltration involves membranes with pore sizes ranging from 3 to 50 nm. Salts, sugars, organic acids and smaller peptides are able to pass through under relatively low pressure, while some proteins, fats and polysaccharides are retained by the filter. Ultrafiltration is widely used in the dairy processing industry to adjust, for example, the concentration of proteins in cheese production.



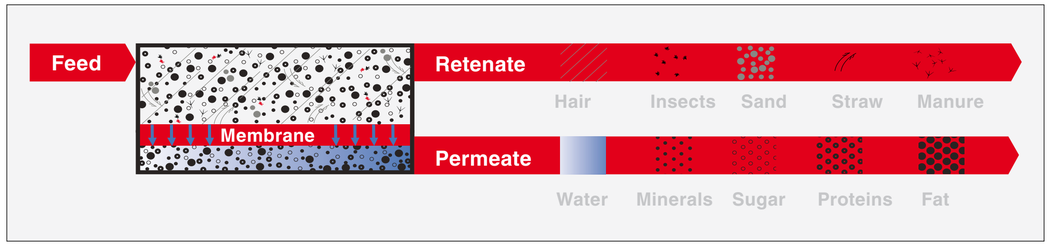
Microfiltration

In microfiltration, suspended solids, bacteria and fat globules are normally the only substances not allowed to pass through. Microfiltration is characterised by pore sizes of 50 nm or larger and operating pressures below 2 bar. Microfiltration is often used to produce the so called "ideal whey", which is found in protein drinks and baby formula, for example.



Mechanical (barrier) filtration

Mechanical filtration is the process used in on-farm milk filtration, characterised by pore sizes between 100 and 250 µm and operating pressures of about 0.5 bar. Fat globules and the other valuable components of raw milk are allowed to pass through the milk filter while elements such as manure, insects or other particle materials are retained.



Image(right):
Parallel combined
milk filter units

Milk filter fabric properties

In on-farm milk filtration, the fabric the milk filter is made from must possess the right qualities in order to protect the milking equipment and to ensure that the milk maintains its high quality – the better the filtration, the better the quality and value of the raw milk.

Filters today are available in many different fabrics, made from many different types of fibres. The characteristics of filter fabrics can be classified according to:

- thickness
- fibre orientation
- nature of fibres
- temperature resistance
- chemical resistance
- colour.

But milk filters used in different applications require different and highly specialised fabric properties in order to perform in the most appropriate and efficient way.

> An automatic milking system where cows are milked one after the other requires an entirely different milk filter than an 80-stand rotary system.

These characteristics, combined with the technology used to produce the fabric, largely determine the physical properties of the milk filter.

The fibres used in milk filter fabric production

Most fabrics are manufactured from organic polymers plus some kind of support material. But although there are hundreds of polymers which can form a flat sheet, only a few of these fulfil the essential requirements of a good milk filter:

- able to form a thin sheet
- good swelling characteristics
- high wet strength
- hydrophilic (water loving)
- comply with EU and FDA regulations, as well as USDA requirements.

A strong, efficient and high-hygiene filter fabric contains a mixture of polymers, typically cellulose, cotton, viscose and polyester. Each of these fibres has characteristics which are advantageous for milk filters.

Cellulose
Cellulose is one of the most common organic compounds on earth, forming around 33% of all plant matter. It is expressed by the formula $(C_6H_{10}O_5)_n$. Cellulose properties, including its fibre length, strength and absorbency, make it a perfect raw material for milk filter production. Cellulose for commercial production, is mainly obtained from wood pulp and cotton.

Did you know?

Characteristics of milk filtration
On-farm milk filtration is characterised by filter pore sizes that range from 100 to 250 µm and operates at pressures below 0.5 bar.

Image (top left):
Rolls of blue and white milk filter fabric

Image (top right):
Blend of polymer fibres

Image (bottom right):
Viscose, cotton and cellulose fibres

Cotton
Cotton is a soft fibre that grows around the seeds of the cotton plant. Processing the cotton results in hair-like fibres of 90% cellulose, with a high degree of strength, durability, temperature and chemical resistance as well as absorbency – excellent properties for producing hygienic and durable milk filters.

Viscose
Viscose is a soft, man-made material with natural origins, created by dissolving cellulose and reforming it in filaments. It is one of the most absorbent fibres in common use. When water – the major component of milk – comes into contact with the viscose fibres they swell, decreasing the pore size of the milk filter. This enhances the efficiency of the filtration process.

Polyester
Polyester is a man-made material created from synthesised polymers, and is the most widely used man-made fibre in the world. It possesses many advantageous properties that do not exist in natural fibres, including a high degree of strength, low shrinkage, good heat stability and chemical resistance. As a result, polyester fibres are often spun together with natural fibres.

Did you know?

The ideal milk filter
A professional milk filter should provide controlled porosity, high wet strength and good dimensional stability.

Image (top):
Flecks of mastitis milk
on blue filter

Image (bottom left):
Milk passing through a
professional milk filter

Image (bottom right):
Resistance test
(tensile strength)

Did you know?

Milk filters provide an easy-to-use milk quality check
The condition of the milk filter at the end of a milking session can provide a valuable indication of the herd's udder health. Any signs of milk flecks or clots on the filter indicate a clinical mastitis problem in the herd. Coloured milk filters make identification simple.

Fibre characteristics for strength and absorbency

Apart from the importance of blending a mixture of polymer fibres (viscose, cotton, cellulose, polyester) to produce a fabric with particular properties, fibre length and diameter are also critical factors in the formation of a strong and stable filter. Generally speaking it is the short and fine fibres that deliver the properties necessary for good filtration, whereas the longer fibres promote strength and durability. Therefore, a good milk filter must contain a perfect blend of short, fine and long fibres.

Chemical and temperature resistance

High hygiene is essential on dairy farms. Milk filters must therefore be capable of resisting both higher temperatures and the acidity (low pH) or alkalinity (high pH) of the chosen detergent in order to protect the milking and cooling systems during cleaning.

However, the formulation of dairy detergents is complex, and the actual ingredients are often a trade secret of the manufacturer. It is therefore necessary to test every cleaning detergent to find out how to predict how it may affect a milk filter fabric. Depending on the detergent deemed most appropriate for a farm's cleaning routines, it is essential to know the limits within which a milk filter can be used without risking damage to the milking and cooling equipment.

Milk filters are available with particularly high-resistance filter fabrics and seams, making them capable of withstanding both higher temperatures and high or low pH values. However, it is important to note that these milk filters must be replaced after each cleaning cycle. They are designed to be used once only.

The role of coloured milk filter fabrics

Although milk filters are traditionally white, in many countries they are now available in a rainbow of colours. Coloured milk filters were developed to aid in the identification of mastitis within the herd. Finding mastitic milk flecks, mucous or clots on the milk filter following a milking session, indicates clinical mastitis in the herd. But these flecks are white and very difficult to see against a milk filter of the same colour. A coloured milk filter can therefore be a great asset on a busy dairy farm.

A key technical point to note regarding the coloured milk filters available on the market concerns the fibre blend. The optimal filter fabric is a fibre blend that includes polyester, viscose, cotton and cellulose, but not all manufacturers include viscose fibres in their coloured filter fabrics. As already noted, viscose fibre is hydrophilic, it is highly absorbent. When water, the major component of milk, makes contact with the viscose fibre it swells, decreasing the size of the fabric pores and thereby improving filtration. Decreasing pore size does affect milk flow rates, but not to the extent of creating bypass. And ultimately, the better the filtration, the better the quality and value of the milk.

Did you know?

Chemical and temperature resistance
Milk filters are available that have been specially designed to withstand higher temperatures and pH values. These milk filters can protect the milking and cooling systems during even the most rigorous cleaning cycles.

Milk filter fabric manufacture

Professional disposable milk filters for on-farm milk filtration are manufactured from a nonwoven material which is based on a fibrous web. A milk filter's physical properties are determined by the characteristics of the web, which in turn is determined by the method used to form the web. Modern technology means different fibres can be combined using various different techniques and this allows a diverse range of nonwovens to be manufactured for different applications.

Nonwoven production generally comprises three stages – web formation, web bonding and finishing treatments. However, modern technology means that more than one stage can take place at a time – all three stages together in some instances.

Nonwovens

A manufactured sheet, web or batt of directionally or randomly orientated fibres, bonded by friction, cohesion, adhesion; excluding paper and products which are woven, knitted, tufted, stitch-bonded incorporating binding yarns or filaments, or felted by wet-milling.

Web formation

Nonwoven webs can be formed using many methods. The method chosen to form a web is generally determined by the length of the fibres to be used. Traditionally, webs formed from staple-length fibres were based on the textile carding process, whereas webs formed from short fibres were based on papermaking technologies. Although both of these technologies are still in use, newer methods have since been developed, and today, the two common technologies for manufacturing nonwovens are known as dry- and wet-laid web forming.

Dry-laid technology

Dry-laid refers to manufacturing techniques where no water is used. Different dry-laid techniques include blowing fibres onto a moving wire to form the web, or extruding polymers into filaments that are subsequently blown onto a moving web. It is more difficult to produce a uniform web with equally distributed pores using the dry-laid, rather than the wet-laid technique. There are two dry-laying methods – carding and air-laying.

Carding

The carding process begins in a very similar way to spinning. Firstly the bales of fibre, both natural and man-made, are opened and blended in the appropriate proportions to meet the characteristics required of the milk filter. After homogeneous blending, the fibres are processed into a web on the carding machine. The configuration of the carding drums is critical, as this controls the milk filter's fabric weight and fibre orientation. In a secondary process, the web can be parallel-laid, meaning that most of the fibres are laid in the direction of the web travel, or they can be random-laid. Carded webs that are parallel-laid typically result in a web of low elongation and low tear strength in the machine direction, while they typically have the opposite properties in the cross direction.

Air-laying

Another technology to transform fibres into a nonwoven fabric is air-laid technology. In air-laying, the fibres are fed into an air stream and directed onto a moving belt or perforated drum, upon which they form a randomly-oriented web. Compared with carded webs, air-laid webs have a lower density, greater softness and an absence of laminar structure.

Image (top left):
Milk filter manufacture

Image (top right):
Milk filter disc manufacture

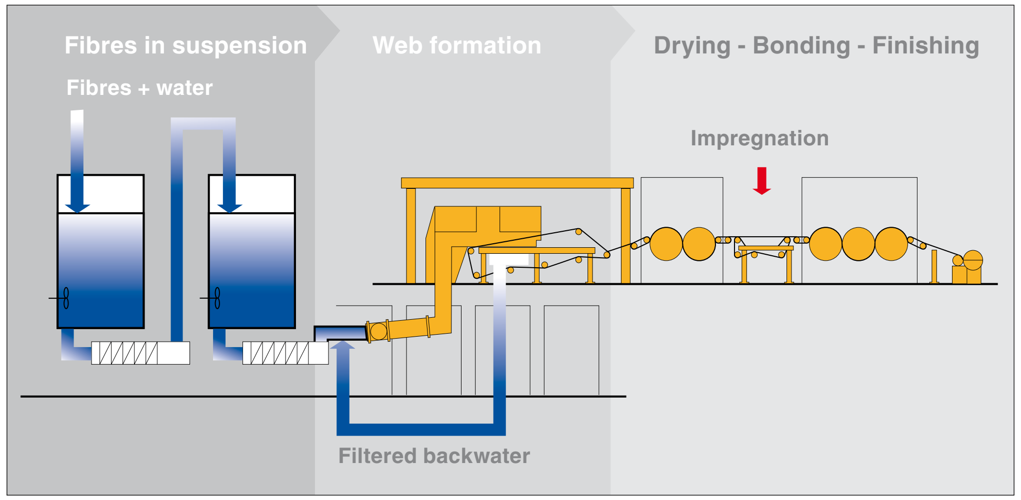
Image (bottom):
Quality control of glued milk filter

Webs that are directionally orientated (parallel) in the machine direction result in milk filters with poor tensile strength and low dimensional stability. Webs with randomly-oriented fibres are highly uniform fabrics and provide controlled porosity, high wet strength and good dimensional stability.

Wet-laid technology

In the wet-laid filter fabric manufacturing technique the fibres are first dispersed in water to create a homogeneous stock. The mixture is then pumped onto a mesh conveyor belt or perforated drum, where the fibres settle randomly and the water drains away. The nonwoven fabric finally moves on to the drying process. Modern technology has made it possible to manufacture webs with up to three layers of fibres, each with a unique composition. Wet-laid materials are highly uniform fabrics combining controlled porosity with excellent filtration characteristics, high wet strength and dimensional stability. Wet-laid technology is commonly used in the manufacture of paper and is the preferred technique for a number of specialist technical nonwovens, including milk filters.

Illustration:
Wet-laid filter fabric production process



Wet-laid webs result in highly uniform milk filters which provide controlled porosity (pore sizes), high wet strength, and dimensional stability.

Web bonding

Regardless of the technology used to produce a nonwoven web (wet- or dry-laid), all webs must undergo a process known as bonding. Once the fibres are formed into a web, the fibres remain loose and lack strength, so the web has to be consolidated in some way. The bonding process is as critical in defining the physical and functional properties of the milk filter as the types of fibre used to create the web. There are several bonding options that complement the chosen fibres to create the appropriate characteristics of different milk filters.

The three primary bonding methods are:

- chemical (adhesion)
- thermal (cohesion)
- mechanical (friction).

Chemical or adhesion bonding

This is probably the most commonly used technology in milk filter production. With this method, a liquid-based binding agent is applied to the web, either uniformly by impregnating, coating or spraying the web, or intermittently. Intermittent application of the binding agent is known as print bonding and is used to bond the web in specific patterns, leaving most of the fibres binder-free for functional reasons. Chemical bonding generally results in an end-product that is more rigid than nonwovens bonded using other technologies, with excellent tensile strength and resilience.

Thermal or cohesion bonding

In this method, the thermoplastic properties of certain man-made fibres are used to bond the web under a controlled heat process. Sometimes fibres within the web itself can be used (e.g. polyester), but more often the binding agent is a low-melt bi-component fibre. There are several thermal bonding systems available:

- Calendering – Calendering combines heat with high pressure applied by rollers to weld the fibre web.
- Through-air – Through-air thermal bonding is the ideal method for bulkier products. A carefully controlled hot-air stream bonds a web containing fibres that melt at low temperatures.
- Drum and blanket – Drum and blanket systems combine pressure and heat to produce nonwovens of average bulk.
- Sonic bonding – Sonic bonding uses a patterned roller to excite the fibre molecules, creating high-frequency energy that internally heats, softens and bonds the fibres.

Mechanical or friction bonding

Mechanical bonding strengthens the web by physically entangling the fibres, creating friction between them. The two methods of mechanical bonding are needlepunching and hydroentanglement.

Needlepunching

The needlepunching method is suitable for almost every type of fibre. Specially designed needles are pushed and pulled through the web to entangle the fibres. Moreover, separate webs with different characteristics can be needled together to produce a gradation of properties that is difficult to achieve by other methods.

Hydroentanglement

Hydroentanglement is the method applied predominantly to carded or wet-laid webs, to produce a fabric with good strength. Fine, high-pressure jets of water are concentrated on the web, which interlaces the fibres, without the need for any additional chemical bonding. The pressure of the water jets defines the strength and porosity characteristics, and can be adjusted according to the requirements of the fabric.

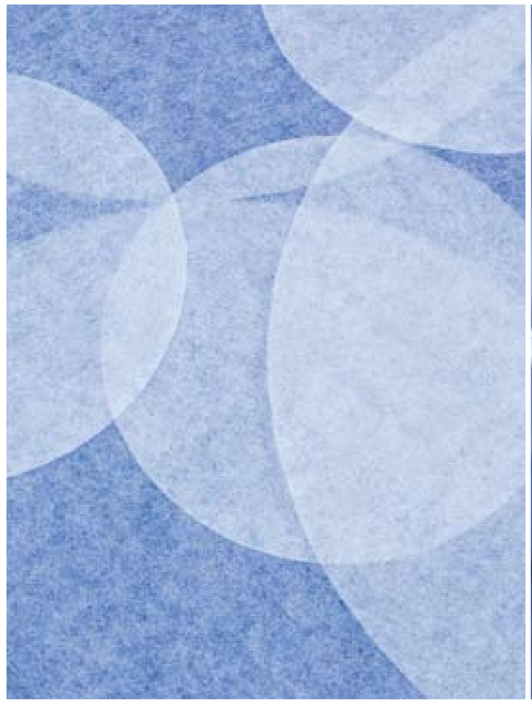
Finishing treatments

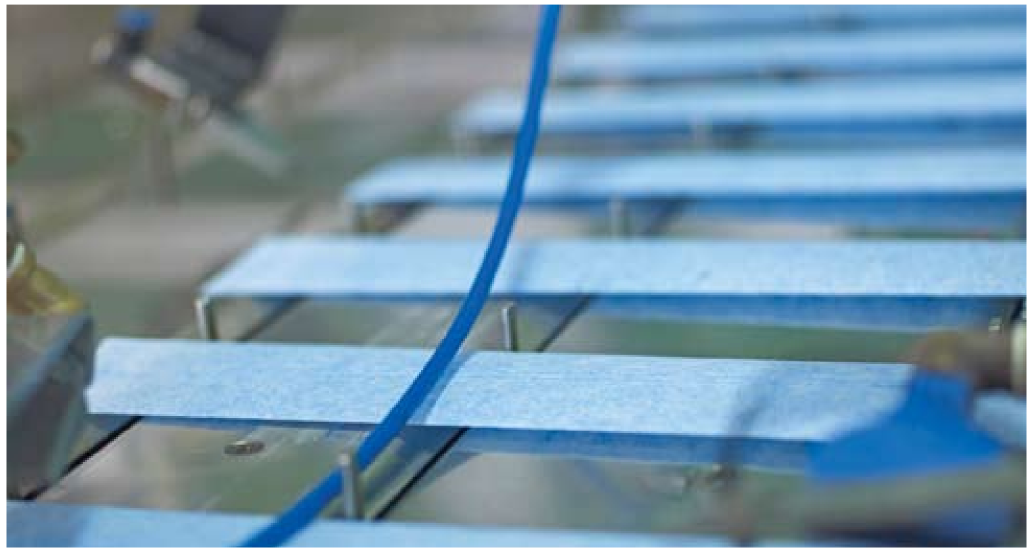
All nonwovens, however produced, require a finishing treatment. A variety of substances can be used to modify or add to the properties of the web in order to meet a milk filter's precise specifications. Finishing treatments can be applied before or after binding and finalise the production of the milk filter fabric.

Image (top left):
Milk filter discs made
from 20 gram fabric

Image (top right):
Quality control of
sewn milk filters

Image (bottom):
Modern gluing
machine for milk filters





Web geometry

Web geometry refers to the predominant orientation of the fibres (directional or random), the shape of the fibres (straight, hooked or curled) and the extent of inter-fibre entanglement and crimp. Fibre diameter and length, web weight and the chemical and mechanical properties of the polymers also influence a web's characteristics. In milk filters, the fibre orientation of the web in terms of the machine direction/cross direction ratio is especially important. A web can be directionally orientated (parallel-laid), whereby the majority of the fibres are laid in the direction of the web travel, or it can be random-laid.

Directionally-orientated webs result in milk filters with poor tensile strength and dimensional stability in the machine direction. Webs with randomly orientated fibres make highly uniform fabrics with controlled porosity, high wet strength and dimensional stability. Therefore, most on-farm milk filters today are made from randomly orientated, wet-laid material as this provides the optimum solution for effective and efficient filtration.

Milk filter fabric weight

Disposable milk filters come in a wide range of fabric weights, measured in grams per square metre and ranging from about 20 grams per square metre up to approximately 160 grams per square metre. The weight refers to the fabric from which the milk filter is made, rather than the filter itself. For example, a 60 gram milk filter is manufactured from fabric that weighs 60 grams per square metre, while the milk filter, depending on its size, could weigh more or less than 60 grams. The fabric weight does, however, determine the thickness of a milk filter, so a 160 gram milk filter, for example, will feel much thicker than a 60 gram milk filter.

Suppliers that are genuine solution providers, rather than just selling single weight milk filters, will offer a wide range of milk filters with different fabric weights and characteristics in order to fulfil every customer need.

Milk filter seams

Once the nonwoven web material has been produced, it must be formed into a sock or sleeve to create a functional milk filter. It is therefore necessary to join the fabric using a seam, and milk filters require strong seams. Various types of seams are used in the production of milk filters, the three most important methods being sewing, gluing and welding.

Sewn seams

Milk filters can be stitched by needle and thread. The industrial sewing machines used to stitch milk filter seams have complex gears and arms that pierce the thread through the layers of the milk filter and interlock the stitches. The modern threads used to stitch milk filter seams are specially designed to withstand the stresses involved in the filtration process (pressure, moisture) as well as the cleaning cycle (high temperatures, chemicals). The threads must also comply fully with EU and FDA regulations and USDA requirements (be approved for food).

Glued seams

Glued seams are bonded with adhesive on machines. The long edges, and in some instances one pair of short edges are glued to form seams. Gluing machines comprise glue guns and drying units. All adhesives used to seam milk filters must comply fully with EU and FDA regulations and USDA requirements (be approved for food). Although glued seams are widely used in on-farm milk filters this technology does have limitations as, for technical reasons, it can only be used on fabric weighing up to 80 grams per square metre.

Ultrasonic welding

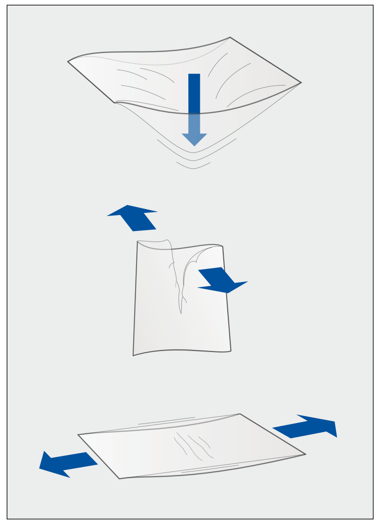
This is an industrial technique used in a range of applications, but most commonly in bonding plastics or dissimilar materials. In this technique, the overlapping edges of the milk filter fabric are held together under pressure and subjected to high-frequency ultrasonic acoustic vibrations, which create a solid-state weld. The main benefits of ultrasonic welding are the cost and speed of production and that no additional yarn, adhesives, or other materials are required to create the seam.

The physical properties of milk filter fabric

As discussed above, the physical properties of a milk filter fabric depend largely on the web geometry, which is itself determined by the method used to form the web. It is these physical properties that determine the characteristics of the filtration process, and thereby the quality and value of the milk produced. In on-farm milk filtration the most crucial physical properties of a milk filter are:

- bursting strength
- tear strength
- tensile strength
- filtration capacity
- filtration efficiency
- air permeability
- compatibility.

A professional on-farm milk filter must possess an optimal balance of characteristics. It must offer excellent capacity, efficiency and permeability and it requires excellent strength (bursting, tensile, and tear strength) in order to secure optimal filtration conditions and protection – the stronger the milk filter, the better. Generally speaking, there are two main groups of tests used to characterise nonwovens for milk filtration. The first of these groups concerns the structural properties of the milk filter, such as the mean porosity of the filtration layers and air permeability. The second group of tests measures the dynamic changes in filtration efficiency and airflow resistance during the filtration process, and determines the filter's retention capacity. Standard test methods for nonwovens are provided, for example, by ASTM International (www.astm.org).



Bursting strength
Bursting strength measures the pressure at which a milk filter will burst. Used as a measure of resistance to rupture, a filter's bursting strength depends largely on its tear strength, tensile strength and extensibility. Bursting strength is commonly expressed in pounds per square inch (psi) or in kilograms per square metre.

Tear strength
Tear strength measures the force required to initiate or continue a tear in a milk filter under specific conditions. It is measured in newtons (N).

Tensile strength
Tensile strength measures the force required to pull a milk filter to the point where it breaks. It is measured in newtons per square metre (N/m²) or pascals (Pa).

Filtration efficiency
Efficiency is the ability of the milk filter to retain specific particles. A milk filter that is over-efficient will quickly become clogged, causing milk flow problems. The efficiency of a milk filter is primarily determined by the distribution and size of the pores.

Filter capacity
Capacity is the ability of the milk filter to retain the previously removed particles without obstructing further milk flow.

Air permeability
Air permeability measures the rate that air can flow through a known area of a milk filter under a prescribed air pressure differential between its two surfaces. It is expressed in litres per square metre per second (l/m²/s) and depends primarily upon the fabric's weight, thickness and porosity.

Air permeability and pore size are strongly correlated – the larger the pores, the higher the air permeability (flow rate).

Fabric weight (g/m²)	25	60	60 coloured	120
Pore size (µm)	224	140	130	125
Air flow rate (l/m²/s)	5680	2900	2610	2200

Table 3:
Properties of different milk filter fabrics

Compatibility
The strength of a milk filter is influenced by both temperature and chemical compatibility; a chemically incompatible or overheated medium is highly likely to fail structurally. Milk filters are available that combine specially developed filter fabrics and seams and are capable of withstanding both higher temperatures and a range of pH values. These types of milk filters can protect the milking and cooling systems (up to 95 degrees) during even the most rigorous cleaning cycles. However, it is important to note that these milk filters must also be replaced after each cleaning cycle. They are designed to be used once only.

Types of milk filter

Nearly all the raw milk produced on farms is filtered by disposable milk filters. Permanent stainless steel milk filters do exist but are very seldom used on farms. But regardless of whether a milk filter is disposable or permanent, the basic principles of filtration are common to both.

Image (left):
Changing of a disposable milk filter

Disposable milk filter
Disposable milk filters are constructed from nonwoven fabrics and are designed for single use (one milking session) only.

Permanent milk filters
Permanent milk filters are designed to be placed directly in the pipeline system (in-line milk filter). They use very similar filtration technology to disposable milk filters. But where a disposable milk filter is made of nonwoven fabric, permanent milk filters may be made of fine stainless steel or plastic screens (mesh). Whichever material is used, it must be temperature and chemical resistant. A range of screens (meshes) can be combined to achieve the desired filtration required for different milking systems.

As with disposable milk filters, the filtration method is based on the principles of mechanical filtration – the driving force being the pressure difference between the two sides of the filter basket when the milk is pumped through it. The milk passes through an inlet to the filter basket and finally through an outlet. Any unwanted particles, such as manure or insects, are retained by the mesh of the filter basket.

Unlike disposable milk filters, permanent milk filters are designed to run continuously. They therefore need regular thorough cleaning to remove any trapped sediment and maintain the filter's sanitary conditions. Cleaning is carried out manually, by removing the filter basket and washing it. All the materials in a permanent milk filter (the mesh and the housing) must comply fully with EU and FDA regulations, as well as USDA requirements.

Image (top left):
Blue milk filter sleeve

Image (top right):
Milk filter sock
with a good flow rate

Image (bottom):
Milk filters are
available in different
sizes

Did you know?

Milk filter sleeve
A milk filter sleeve is a folded sheet of milk filter fabric with ONLY its longitudinal edges joined by a seam. It resembles an open-ended tube.

Milk filter shapes

Disposable milk filters are designed for single use. Three types of milk filter are available:

- Socks
- Sleeves
- Discs

Milk filter sock
A milk filter sock is a folded sheet of milk filter fabric that is joined at the seam along its longitudinal edges and one pair of end edges, to form a tubular sock that is open at one end.

Milk filter sleeve
A milk filter sleeve is also made from a folded sheet of milk filter fabric, but it is only seamed along its longitudinal edges to form a filter tube that is open at both ends.

Milk filter disc
Flat sheets, or so called disc milk filters, are either round or rectangular sheets and are used mainly in bucket or pipeline milking equipment. Milk filter discs do not normally provide the high filtration capacity offered by sleeve or sock filters and are therefore rarely used in industrial scale milking.

Milk flow direction

In milk filter units that use milk filter socks or sleeves, the milk stream can either flow from the outside to the inside of the milk filter or vice versa. In an outside-to-inside (outside-in) unit, the milk flows inwards and the filter cake builds up on the outside of the milk filter. In an inside-to-outside (inside-out) unit the milk flows outwards and the filter cake is retained inside the milk filter sock.

An outside-in, dead-end milk filter provides a real built-in advantage in that it can help in the identification of mastitis problems within the herd. By inspecting the filter cake that has accumulated during the milking session, white flecks of mastitic milk or clots may be observed, indicating clinical mastitis. Coloured milk filters enhance the identification process as it is much easier to see the white flecks against a coloured background.

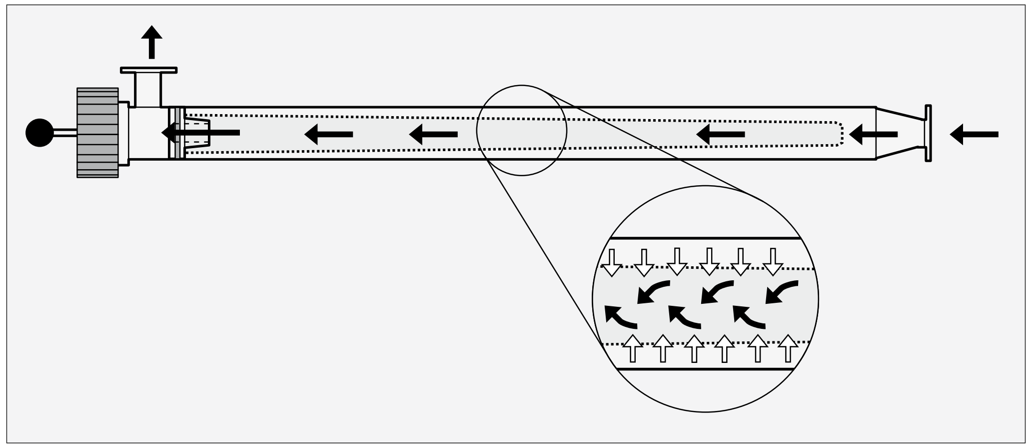


Illustration:
Outside-to-inside milk
filter unit

Did you know?

Milk filter sock
A milk filter sock has its longitudinal edges AND one pair of end edges seamed to form a tubular sock, open at one end.

Milk filter size
In modern milking plants, milk is usually forced through the in-line milk filter by pump, and it is crucial to establish the correct size of milk filter that is appropriate for the milk flow and the filter housing.

A milk filter that is too small for the task has insufficient surface area for good, efficient filtration. As the filter cake builds up on the milk filter during a milking session, the flow rate through it gradually reduces. This could lead to milk by-passing the filter, or in extreme cases the filter could burst. This could result in unfiltered milk contaminating the bulk milk or damaging the plate cooler. If the milk filter's capacity and flow rate is not in harmony with the milk pump capacity it will not withstand the pressure of the milk flow and will burst.

On the other hand, a filter that is too large is not cost efficient, as the farmer pays for filter capacity and filtration properties that cannot be capitalised on. There is also a common misconception that an over-sized milk filter can be used for a longer time, but this is not the case.

Professional milk filters are available in various sizes to cope with different requirements, and it is essential to select a filter of the correct size. Milk filter sleeves and socks are more efficient than milk filter discs as they have a large surface area and their design maximises milk flow. This is why these types of filters are used most often in modern milking plants today.

In order to achieve the high capacity and filtration conditions that exist in large scale milking plants, several regular milk filter units can be combined to operate in parallel.

> Professional milk filters are available in different, highly specialised fabrics and different sizes. It is essential to select the right filter to solve different tasks in the most appropriate way. For example, an automatiac milking systems (AMS) where cows are milked automatically one after the other, places entirely different demands upon a milk filter than an 80-stand rotary system (please see Table 4 : Differences of milk filtration in automatic milk systems and conventional parlours).

It pays to replace milk filters in good time
To produce milk with the highest quality and value, and to comply with the many rigorous requirements from both public authorities and consumers, it is vital that milk filters be replaced at the right time.

Generally speaking, disposable milk filters should only ever be used for one milking session, and also for a limited duration. Depending on the milking equipment and herd size as well as the cleanliness of the animals (and especially their teats), disposable milk filters have a lifespan of approximately 8 hours, but should always be replaced after every milking session, regardless of the duration of that session. As long as these rules are observed, a milk filter will operate to its optimum potential, enabling the farmer to produce milk of the highest possible quality and value.

Did you know?

Disposable milk filters should be replaced after every milking session
Disposable milk filters should only be used for one milking session. Failure to replace a milk filter after each milking can damage milk quality.

Image: Replacement of a milk filter

Failure to replace the milk filter after each milking session can harm the quality of the milk produced and continual use will reduce its effectiveness. Sediment that has been trapped by the milk filter continues to be washed by the milk flowing through, which can dislodge any bacteria adhering to the particles and increase the bacterial count of the bulk milk.

The performance of a milk filter decreases over time as its surface and/or pores become clogged with retained particles. The milk flow therefore reduces over the course of a milking session, and the efficiency of filtration at the outset of the session can never be sustained. Cleaning can not extend the lifespan of a milk filter, nor improve its performance. While it may be possible to reduce the deposition of retained particles on the milk filter surface, they can never be eradicated from within the porous structure of the filter fabric. Therefore, attempting to clean a disposable milk filter will result in a reduction in milk quality.

> Cleaning can not extend the lifespan of a milk filter, nor improve its performance. Attempting to clean a disposable milk filter will result in a reduction in milk quality.

Image (top left):
Large scale milking plant (rotary)

Image (top right):
Milk filter dispenser box

Image (bottom):
DeLaval voluntary milking system VMS – an automated milking system

Did you know?

Milk filter life in an automated milking system (AMS)
For optimal maintenance of milk quality and to protect the milking and cooling equipment in automatic milking systems, milk filters should be replaced at least every 8 hours.

Automatic milking systems (AMS) place special demands on milk filters. In AMS, cows are milked consecutively, resulting in a time lapse between the milking of individual cows. This results in a sporadic flow of milk through the milk filter. AMS also normally operate right around the clock every day. Under these conditions, it is essential that milk filters in AMS are replaced at least every eight hours.

The higher the throughput of a milking plant, the faster a milk filter's effectiveness will be reduced. Although these milking systems have a high and steady milk flow, the large volume of milk is also likely to transport and build up a greater amount of sediment on the filter. Bacteria can be dislodged from the built up particles by the continued milk flow and contribute to an increase in the bacterial count in the bulk milk.

	AMS	Conventional parlour
Milk flow	Low	High
Milk flow frequency	Irregular	Consistent
Milk flow direction	Inside – Out*	Inside – In*
Milk filter replacement	Every 8 hours	After/during milking
Cows milked	One at a time	Many at the time
*in most cases		

Table 4:
Differences of milk filtration in automatic milk systems and conventional parlours.

Milk filter storage
The very highest levels of hygiene are essential in milk production, and it is therefore vital that milk filters are stored carefully prior to use. Milk filters should be stored in dry, clean and cool conditions, protected from dust, insects, moisture or any other contaminants. Dispenser boxes designed especially for milk filter storage are available and these provide perfect storage conditions as long as they are kept in a dry environment.

DeLaval filtration concept

At DeLaval, we take pride in offering a total milking solution. We can supply farmers with optimised and cutting-edge milk filters that take every aspect of on-farm milk filtration into consideration. Our milk filters are designed and produced to match the parameters of all kinds of milking equipment and offer optimal milk composition, hygiene, and ease of use.

DeLaval is one of the very few companies that has its own test facilities. These test facilities (in Tampere, Finland), allow our expert staff to develop milk filters for all needs and requirements. We also have our own dairy farm in Tumba, Sweden, where we extensively test all milk filters in all kinds of milking equipment.

Did you know?

Milk filter storage
It is important to store milk filters in dry, clean and cool conditions protected from moisture, dirt and other contaminants.

Acknowledgements

DeLaval appreciates the valuable contribution of the many farmers, researchers and engineers from the international dairy farming community, and from within DeLaval itself, involved in the creation of this Efficient Milk Filtration Book.

References and Links

ASTM International. Retrieved May 12, 2008, http://www.astm.org

FAO (2004) Food and Agriculture Organization of the United Nations. Retrieved December 20, 2004. http://www.fao.org

Contamination and spoilage milk and milk products. Rai Foundation College, India.Retrieved May 21, 2008.
http://www.rocw.raifoundation.org/biotechnology/MScBioinformatics/foodmicrobiology/lecture-notes/lecture-20.pdf

Rupp J., ed., 2008. Drylaid nonwovens. Retrieved June 21, 2008
http://www.textileworld.com/Articles/2008/March_2008/Technical_Textiles/Drylaid_Nonwovens.html

DeLaval International AB, 2000. Efficient cooling. Tumba, Sweden

Alfa Laval Agri. Raw milk filtration – why and how? Tumba, Sweden

APV Systems, W.K. Nielsen ed., 2000. Membrane filtration and related molecular separation technologies. Silkeborg, Denmark.

Wagner J., 2001. Membrane Filtration Handbook Practical Tips and Hints. 2nd ed. Osmonics Inc., Minnesota, USA.

US Environmental Protection Agency, 2005. Membrane Filtration Guidance Manual, Cincinnati, USA.

Dairy Management Inc., 2000. Opportunities for membrane filtration of milk, Innovations in Dairy. Dairy Industry Technology Review, USA.

Notes

Notes

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