Separators from GEA for milk clarification and bacteria removal

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Contents

1. Introduction

Clarifiers from GEA and bacteria-removing clarifiers are used in the dairy industry to improve milk quality. Centrifugal and/or membrane technology are used to separate impurities and bacteria from the milk.

Examples of undesired constituents in raw milk are particles of dirt, blood residues, udder cells and a great many different bacteria. This technical documentation explains clarifying and bacteria removal efficiency in relation to the processes used in the field. Among other things, this clearly shows the composition of the phases discharged in batches when clarifiers and bacteria-removing clarifiers are used, and the extent to which these phases can be recycled.


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2. Milk clarification & bacteria removal

2.1 Milk clarification

The most important part of clarifying milk is the separation of non-milk solids (NMS). In the dairy sector, different processes are able to reduce bacteria and NMS in the product. The efficiency of different equipment is therefore of significant importance. (Fig. 1)

A distinction is generally made between the different methods used by processors to improve the quality of milk.

2.1.1 Clarifying milk using filters

This method of improving the quality of milk has been more or less abandoned these days for a variety of reasons.

One of its biggest drawbacks is the drop in flow rate over time because a thicker and thicker filter layer builds up. Running time is limited. The entire milk flow is passed through the filter layer. This allows bacteriological problems to arise due to entrainment, there is a risk of bacterial growth in the filter layer and thus reinfection of the milk. What is more, if there are cracks in the filter tissue, the clarifying effect is considerably reduced. Cleaning the filters after production is also an extremely laborious process.

The use of filters to improve milk quality should not, however, be confused with initial straining to separate "coarse" impurities such as foreign bodies, wood, cellulose, or packaging residues from returned milk. It is essential that the milk is strained before processing continues so as to prevent damage to sensitive parts of the line. Pore width may not exceed 0.2 mm.

2.1.2 Clarifying milk using the skimming separator

Independent of the separation of milk into skim milk and cream, every skimming centrifuge has a secondary effect, namely separation of solids from the milk. The separated solids are discharged in batches by means of partial ejections. The clarifying effect achieved with a milk separator is more efficient and stable than the use of filter technology.

However, the separation rate of solids is even higher in clarifiers especially designed for this purpose than it is in skimming separators.

2.1.3 Clarifying milk using the clarifier

Clarifiers are machines specifically designed for solids/liquid separation. The specific design of this machine enables it to achieve an optimum separation rate for impurities. We will go into the design differences in more detail at a later stage.

2.1.4 Clarifying raw milk cold – process technology
This method is frequently used in countries with a poor infrastructure, where the milk from small-scale producers is collected at central points. Centrifugal cleaning to improve quality is then performed before the milk is taken on for central processing at the dairy.

2.1.5 Composition of solids discharged by separators
Complex studies have been conducted to obtain precise information about the solids discharged by self-cleaning separators during milk clarification. Samples from different milk regions using separators of different sizes have been analysed, thus ensuring a representative cross-section.

Partial ejections were performed on all separators. The time between two consecutive partial ejections was selected so that the solids had a dry mass of 14 to 16 percent. This ensured that at each partial ejection, all the solids separated were discharged. The results of the study are shown in Fig. 2.

COMPOSITION OF A PARTIAL EJECTION

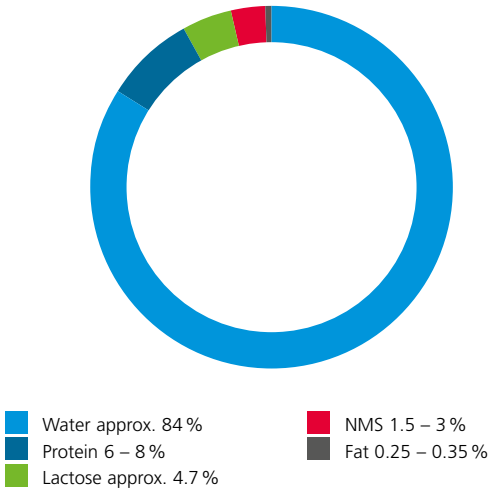


***Fig. 2** Analysis values for an ejection*

DEGREE OF CLARIFICATION

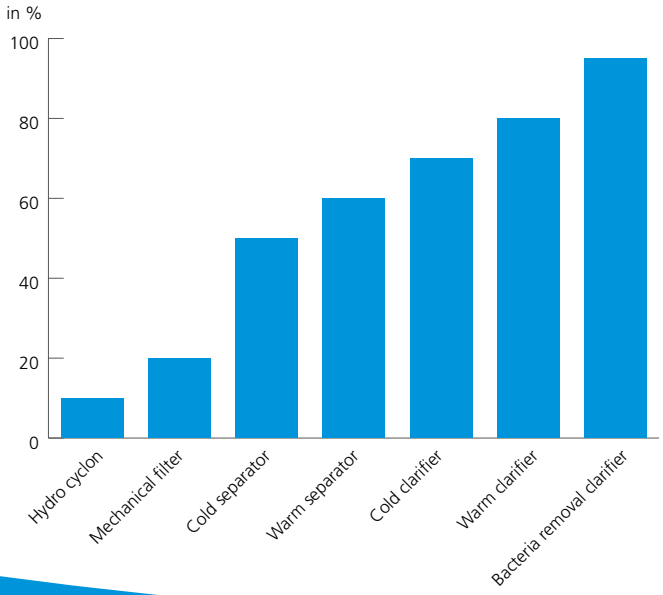


***Fig. 1** Degrees of clarification in comparison*

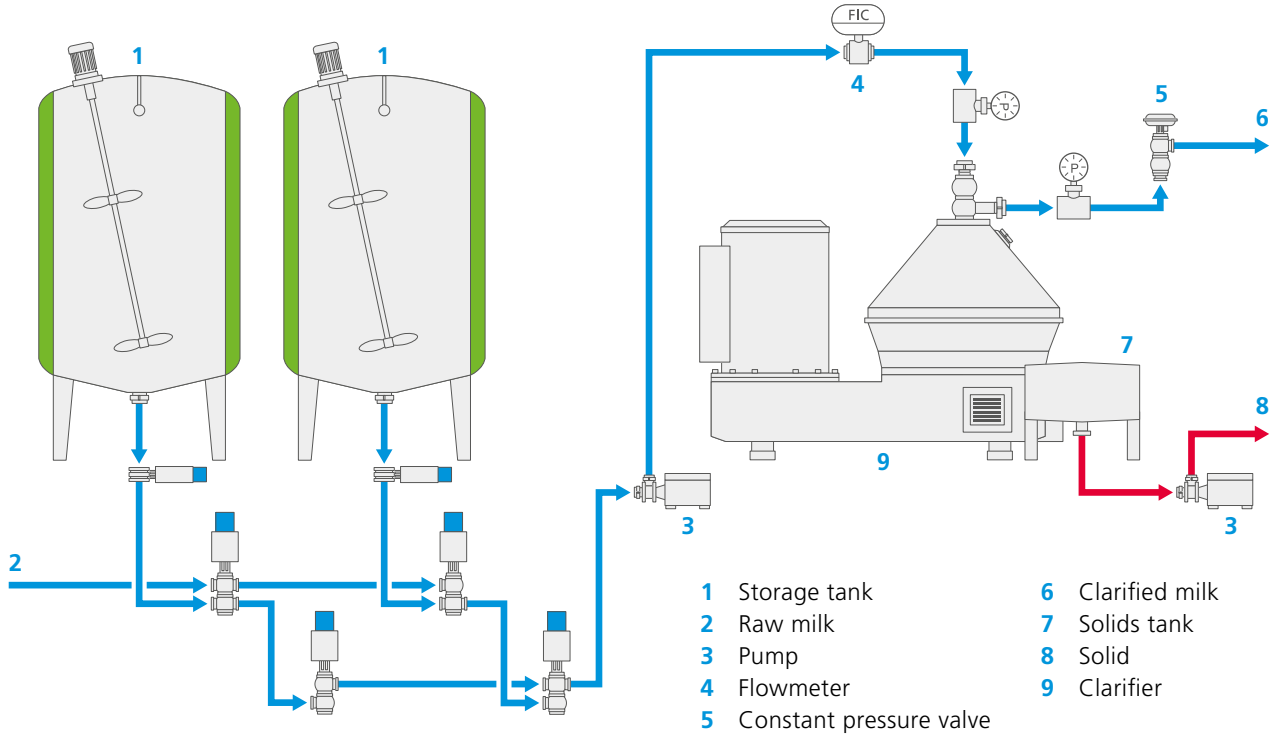


Fig. 3 Method for clarifying raw milk cold

The values shown in Fig. 2 are based on the following further conditions:

- 0.05 – 0.1 percent by volume related to the quantity of raw milk fed in was discharged by partial ejection
- Separation temperature was between 45 and 55 °C
- The significance of separation temperature will be explained in more detail later on in the documentation.

2.1.6 Temperatures when clarifying milk

A temperature either between 8 °C and 15 °C (storage temperature) or between 52 °C and 58 °C is recommended.

The recommendation of these limited temperature ranges is based on two pieces of information:

- Between 15 °C and 35 °C, there is an increased risk of damage to fat. This has been found as a result of the rise in free fat (FF) when the milk is under mechanical load (e. g. from pumps). Lipases are still active up to approx. 50 °C.
- The temperature range from 30 °C to 45 °C represents an optimum for the growth of bacteria (even if these are present only in theory).

2.1.7 Clarification effect when using skimming separators

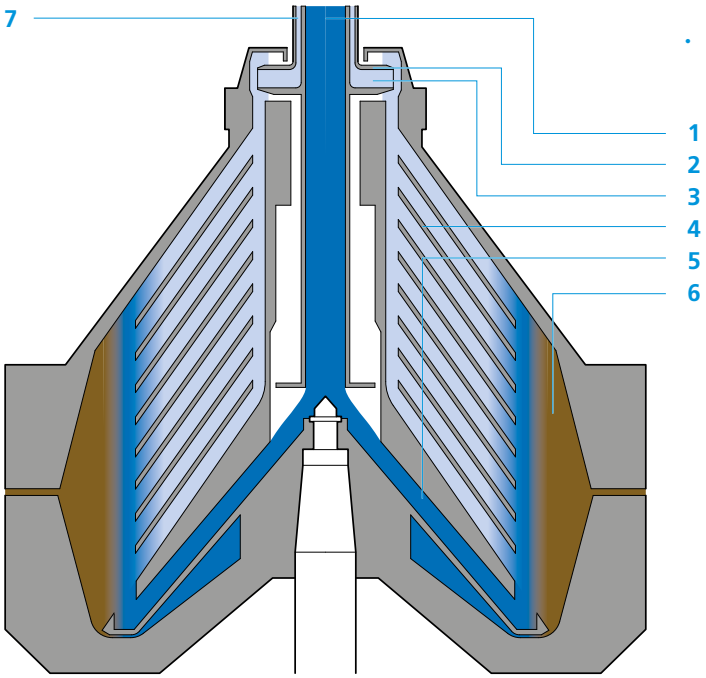
In many areas of the dairy industry, it is customary for milk clarification to be combined with skimming. The current state of knowledge, however, allows a much greater clarification effect to be achieved with the use of clarifiers than is possible with skimming separators. Extensive in-house investigations have shown that only 30 to 50 percent of the NMS are separated from the milk in a skimming separator.

2.1.8 Method of operation of clarifiers

These days, GEA generally supplies clarifiers with a GEA hydrosoft feed system. This system combines the benefits of softstream and a hydrohermetic feed.

- Adequate flow cross-sections mean low feed pressure
- Optimum design means great flexibility with regard to feed quantity
- No ribs in the feed chamber mean no shear forces – gentle product treatment
- Hydraulic seal means no air trapped in product

Fig. 4 Bowl cross-section of a clarifier



1 Feed tube
2 Centripetal pump
3 Centripetal pump chamber
4 Disc stack
5 Feed to disc stack
6 Solids chamber
7 Discharge, clarified milk

Fig. 4:
The milk to be clarified flows through central feed tube (1) in the feed chamber which rotates at bowl speed. The feed to disc stack (5) is effected by bores in the base of the distributor.

The cleaned milk flows inwards and arrives in centripetal pump chamber (3). The milk is taken out of the rotating separator bowl under pressure and without foam by stationary centripetal pump (2). The solids slide outwards and accumulate in double cone-shaped solids chamber (6). A hydraulic system discharges the solids from the bowl at intervals which can be selected. Ejection is performed at full bowl speed.

2.2 Bacteria removal

The first attempts at removing bacteria from milk by centrifuge go back to the 1950s. However, it was not until the 1970s that bacteria were successfully removed from cheese milk on an industrial scale. In the 1980s, this technology finally experienced a breakthrough due to the development of bacteria-removing clarifiers with a high degree of separation at simultaneous hourly outputs of up to 25,000 l/h.

In recent years, the use of bacteria-removing clarifiers has finally expanded successfully into other areas of milk processing. In addition to centrifugal removal of bacteria, filtration using membrane technology is also performed. In both methods, impurities and undesired germs or bacteria are separated from the milk. When milk is temperature-treated to inactivate bacteria and spores, undesired side effects such as changes in flavour may occur. However, methods such as irradiation with UV light or high-pressure technology do not currently play a role in the dairy industry.

2.2.1 Reasons for bacteria removal from milk

A number of objectives are pursued in removing bacteria from milk. In milk processing, for example, spore-formers can cause considerable problems.

In the production of fresh milk, aerobic spore-formers (Bacillus cereus) impair shelf life as a result of sweet clotting.
In the production of milk powder, especially "low-heat" products, aerobic and anaerobic spore-formers (Bacillus cereus, Clostridium perfringens) lead to the product spoiling.
Under certain conditions, the removal of bacteria secures shelf life in soft cheese products – for example, in cases where the so-called ascospores of the moulds Byssochlamys nivea or Byssochlamys fulva have a negative impact on quality.
In whey processing, removal of bacteria makes particular sense when serum proteins are to be obtained from the clarified skimmed whey in concentrated form (WPC whey protein concentrate) by means of ultrafiltration. The long dwell time of the product in the filtration unit, some of that time spent at optimum incubation temperatures, leads to vigorous bacterial growth. According to the information available to us, there exist quality standards which stipulate that, for example, the content of anaerobic spores in 80 percent WPC may not exceed maximum five spores per gram of powder. This suggests that centrifugal removal of bacteria is the solution to improving quality.

Skim milk can also be treated by bacteria-removing clarifiers before being processed into high-quality casein/caseinate so that it is of perfect bacteriological quality. Lactate-fermenting anaerobic spore-formers which are not killed off by normal milk heating can lead to butyric acid fermentation in the production of cheese. Greater attention is therefore paid to spore-formers of the genus Clostridium tyrobutyricum which cause late blowing in cheese. Lactobacilli also have to be removed in the production of raw milk cheese. As the milk is not heated above 50 °C at any point in the entire process, the lactobacilli which have not been killed off would lead to faults in the cheese.

Bacteria removal temperature

This should be between 55 °C and 62 °C. In this range, milk viscosity is relatively low. According to Stokes' law, the sedimentation velocity of the bacteria to be separated off is higher than at lower temperatures. At higher temperatures, however, there is a risk of damage to protein.

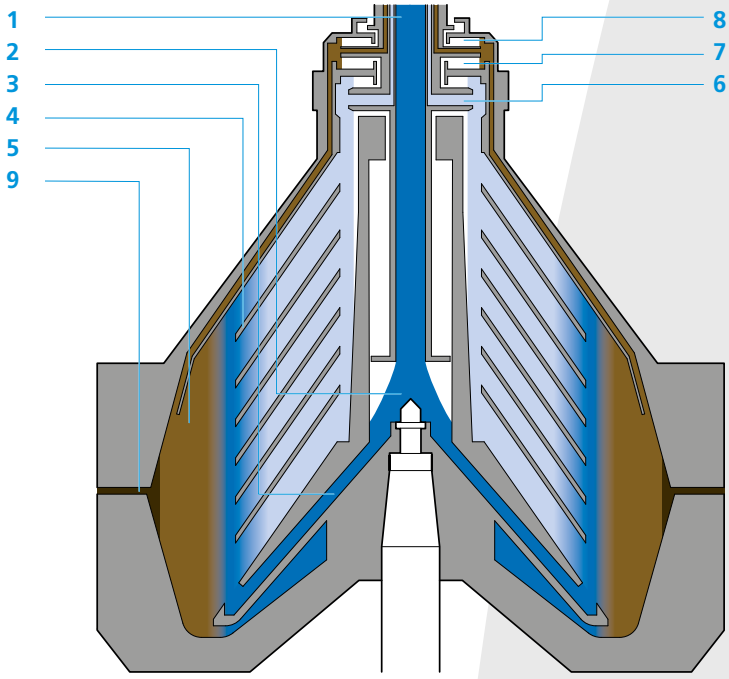
Separator feed capacity

Exceeding nominal capacity on the one hand results in a considerable reduction in bacteria-removing efficiency. Undershooting nominal capacity, on the other hand, only achieves a limited increase in efficiency.

2.2.2 Some applications for BRCs:

- **Cheese milk**
  Anaerobic (clostridia) spores reduce cheese quality and can blow it up by producing gases.
- **Liquid milk**
  Extended shelf life by reduction of bacteria spores
- **Low heat milk powder**
  Reduction of total bacteria count in a low heat process
- **UHT milk**
  Reduction of heat resistant spores that can survive even the UHT process at 140°C
- **Whey processing, WPC production**
  Reduction of germs in a process very favourable for bacteria growth (long times at ~35°C)
- **Culture plants**
  The production of pure bacteria cultures requires the elimination of all other microorganisms

Fig. 5 Bowl cross-section of a bacteria-removing clarifier



1 Feed tube
2 Feed chamber
3 Base of distributor
4 Disc stack
5 Concentrate chamber
6 Centripetal pump for milk
7 Separating disc
8 Concentrate centripetal pump
9 Discharge ports

Milk
Bacterially clarified milk
Concentrate
Solids

2.2.3 Bacteria removal from fresh milk – process technology
In this method, the separation of Bacillus cereus is of particular interest. This germ is heat-resistant and thus still active after pasteurization, so sweet clotting of milk can be the result. The specific weight and size of this bacillus make centrifugal separation difficult. Adapting separator feed capacity to the specific conditions, however, allows bacterial clarification efficiency of over 90 percent to be achieved. In studies of pasteurized milk, orders of magnitude of 300 spores per litre were found for B. cereus.

At a storage temperature from 8 to 10 °C and a generation time of about 6 hours, the bacillus multiplies from 1 spore per ml to over 107 spores per ml in around 6 days. This results in sweet clotting. This suggests that at a level of less than 1 spore per ml (e.g. at 1 spore per litre), shelf life can be extended by 10 generations, corresponding to around 2.5 days. Lower storage temperatures of the bacterially clarified and pasteurized milk (e.g. 4 to 6 °C) can extend the shelf life by up to 10 days. Centrifugal removal of bacteria enables spores to be reduced by a factor of more than ten, corresponding to more than 3.5 generations.

Reduction in total bacteria count is often considered in assessing the removal of bacteria from fresh milk. However, it should be noted that the generally unknown distribution of flora across the various bacterial strains present can have a considerable influence on separation rate. One reason is the fact that the occurrence of small, lightweight bacteria may be comparatively low on one occasion and comparatively high on another.

Fig. 7 shows the results of recent years which gives a relatively good picture of the range of separating efficiency (related to total bacteria count) which can normally be achieved.

2.2.4 Method of operation: bacteria-removing clarifiers
Bacteria-removing clarifiers also have a GEA hydrosoft feed system. The milk for bacteria removal flows through central feed tube (1) into feed chamber (2) which rotates at bowl speed. The feed to disc stack (4) is effected by bores in base of the distributor (3). The bacteria are separated off by centrifugal force. Their higher specific weight causes them to slide outwards into concentrate chamber (5). Bacteria are separated either directly out into the concentrate chamber or on the liquid route inwards as soon as the bacteria reach the underside disc surface of the disc above.

At this point, the speed of the liquid flow in the disc interspace is virtually zero, so that the bacteria are no longer entrained by the product flow. The separated bacteria slide outwards along the bottom surface of the disc under centrifugal force towards the end of the disc and leave the separation chamber. The milk with bacteria removed flows towards the centre of the bowl and is pumped to the discharge point by centri-petal pump (6). The bacteria concentrate continuously drawn off flows over separating disc (7) into the top centripetal pump chamber. Concentrate centripetal pump (8) pumps the entrained liquid to the discharge point under pressure and without foam.

In addition to continuous discharge of the concentrate by the centripetal pump, partial ejections also take place. At set intervals, sliding piston is moved hydraulically and part of the contents of the solids chamber are ejected through the discharge ports (9) in the bowl bottom.

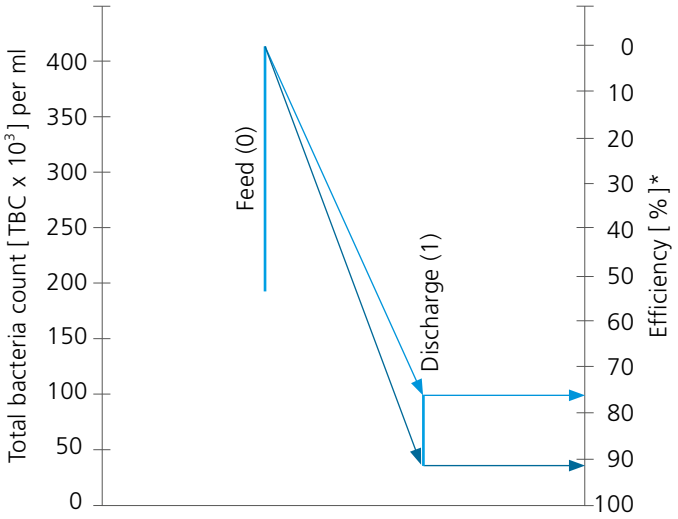


Fig. 7 Separation based on total bacterial count in modern bacteria-removing clarifiers (Here the efficiency is shown for the specific total bacterial count of 400,000 cells/ml)

$$*Efficiency = \frac{TBC_0 - TBC_1}{TBC_0} \cdot 100$$

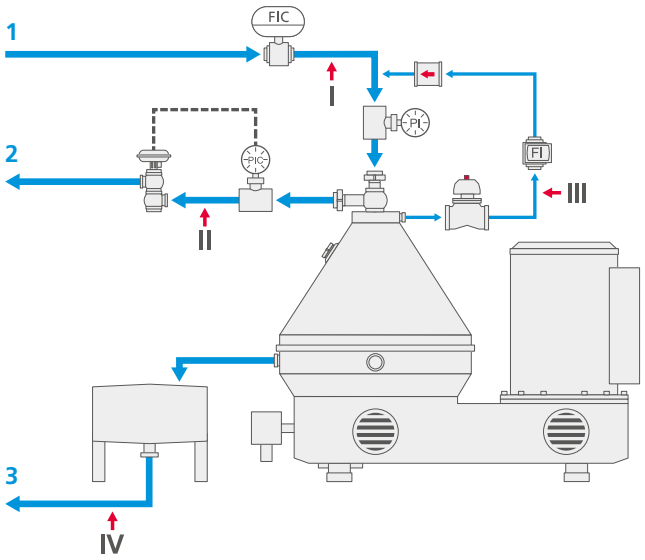


Fig. 6 Diagram of a bacteria-removing clarifier

1 Feed of milk
2 Discharge of bacterially clarified milk
3 Ejections

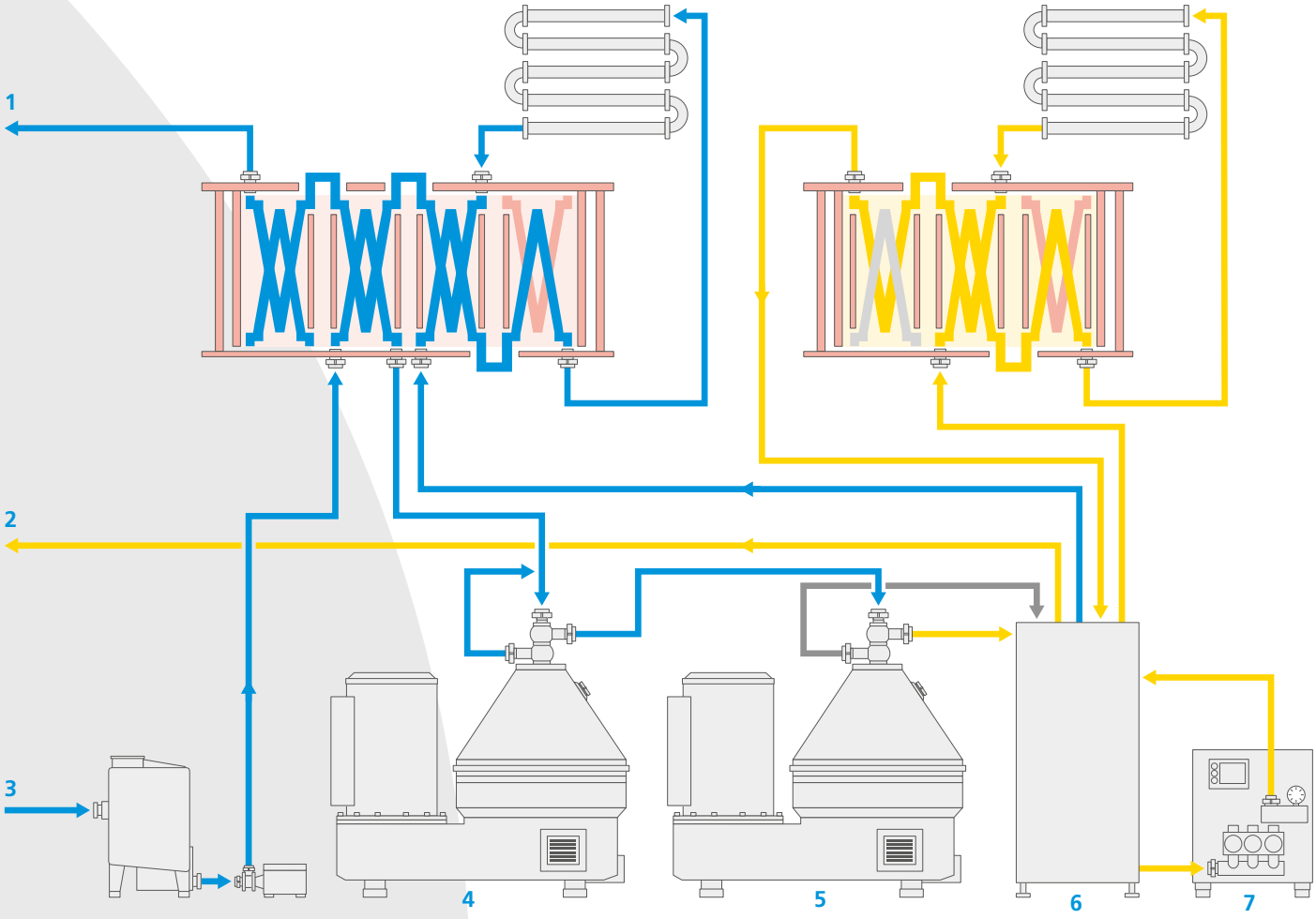


Fig. 8 Bacteria removal from fresh milk – Stage 1

1 Bacterially clarified and standardized fresh milk
2 Excess cream
3 Raw milk
4 Bacteria-removing clarifier
5 Skimming separator
6 Standardizer
7 Homogenizer

3. Integration of the separator

3.1 Bacteria removal from fresh milk – Stage 1

In this process variant, the entire milk stream has bacteria removed at 55 °C and is then fed directly to the skimming separator. In the separator, the milk is separated into skim milk and cream. The cream is then pasteurized and the fraction required to standardize the milk is diluted to a fat content of approx. 15 percent and homogenized. The cream is then mixed with the skim milk in the standardizer. The standardized fresh milk thus obtained is finally pasteurized and cooled. Both the fresh milk and the excess cream have had bacteria removed.

3.2 Premium milk with a longer shelf life with the GEA prolong process

The production of premium milk with a longer shelf life is a question of freshness, naturalness, taste, vitamin content, and the number of actually necessary shelf life days.

Freshness and quality indicators are advantages of prolong

The content of ß-lactoglobulin on the one hand and lactulose on the other are common parameters for the milk quality and heat indicators. The content of ß-lactoglobulin in raw milk is approx. 3,500 mg/l. The greater the extent to which milk protein is denatured by means of heat treatment, the greater is the extent to which this value declines. In the case of fresh milk, it amounts to 3,000 mg/l in conjunction with pasteurization; in the case of micro-filtered milk, the figure falls to approx. 2,500. In the case of milk subject to high heat treatment, it falls further to 1,000 to 1,600 mg/l, and may even be lower than 1,000 mg/l in conjunction with indirect heating. By way of comparison, the indicator in conjunction with the prolong process remains at the level of fresh milk of approx. 3,000 mg/l.

On the other hand, lactulose is not present in raw milk. It is a by-product of the chemical reaction of a heat treatment. The intensity of heat treatment is directly related to the quantity of lactulose to be found in the milk. In the case of pasteurized fresh milk, lactulose attains a value of 10 mg/kg; in the case of filtered milk, this figure is 17, and in the case of UHT milk, the figure is between 25 and (in conjunction with indirect heating) 32 mg/kg. With the prolong process, this factor is also identical to the fresh milk factor of 10 mg/kg. Both indicators for freshness and quality thus clearly underline the benefits of the GEA prolong process.

Two bacteria-removing clarifiers connected in series

For this purpose, two bacteria-removing clarifiers connected in sequence are generally used directly upstream of the skimming separator in order to achieve a high degree of reliability with regard to removing the spores. This ensures that bacteria are genuinely removed from the entire quantity of raw milk, including the cream. The milk is then treated in the skimming separator with fat content adjustment and short-time heating.

An attractive economic aspect is that the separators can be used for other duties in the dairy, for example cheese production. An additional major benefit for dairies is also that bacteria-removing clarifiers can be integrated in existing pasteurizing lines with minimal technical input.

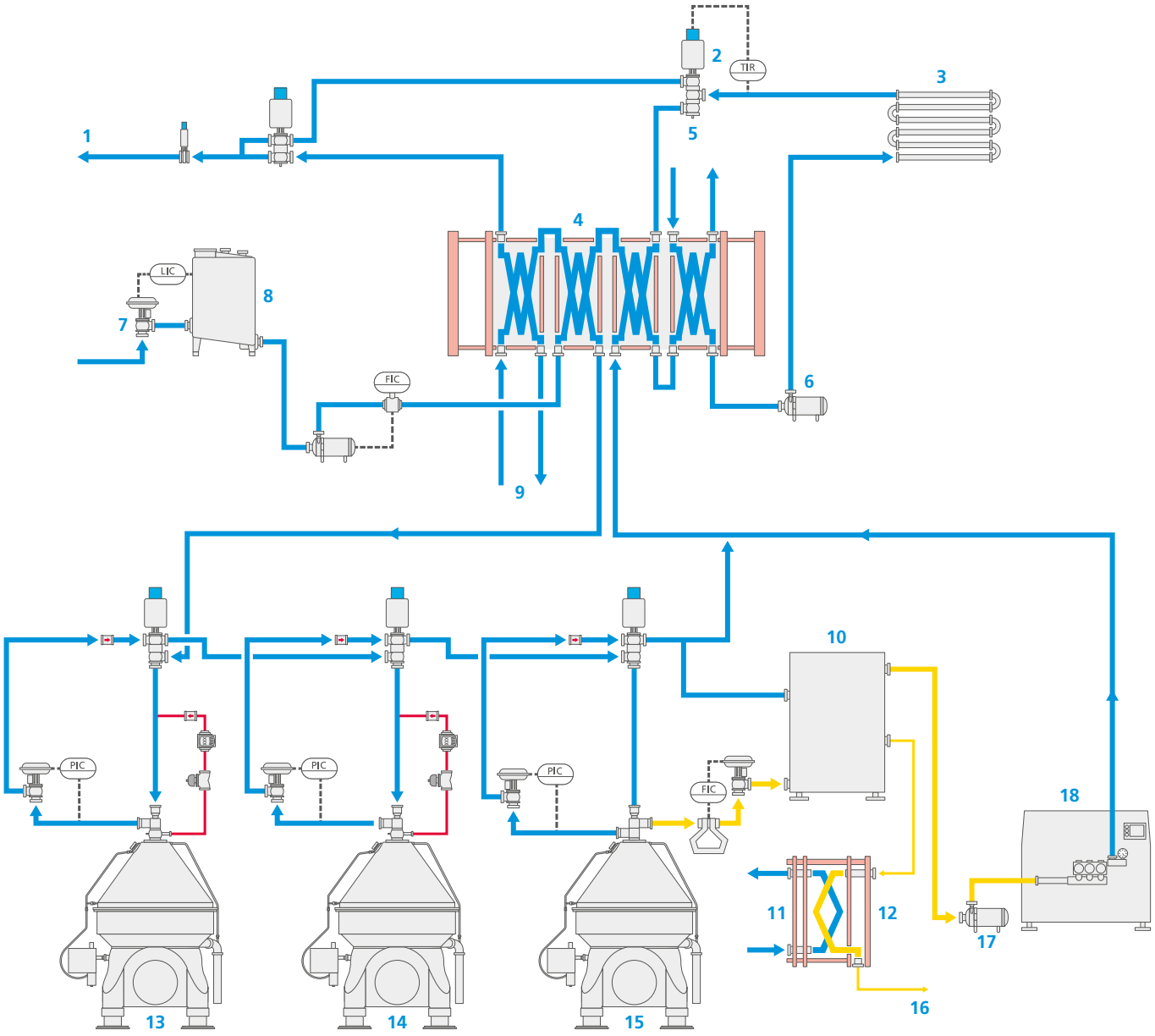


Fig. 9 GEA prolong process

1 Pasteurized, standardized milk
2 Flow diverting valve
3 Holding tube
4 Heat exchanger
5 Hot water in/out
6 Booster pump
7 Raw milk in
8 Balance tank
9 Ice water
10 GEA standomat MC
11 Ice water
12 Cream cooler
13 Bacteria removal clarifier I
14 Bacteria removal clarifier II
15 Skimming separator
16 Surplus cream, cooled
17 Product pump
18 Homogenizer

3.3 ESL milk – process technology

In addition to "pasteurized fresh milk" and "long-life milk", both of which have been on the fresh milk market for a long time, another kind of milk has come onto the market in the past few years, so-called "ESL fresh milk". ESL is short for extended shelf life. Like pasteurized milk, ESL milk has to be kept in a cool chain to prevent it spoiling. Compared to long-life milk, there are fewer changes in the flavour of ESL milk, its "fresh character" being retained. Measures which lead to an extended shelf life in ESL milk are:

- Greater reduction in germ count compared to normal pasteurization
- Avoidance of recontamination following pasteurization.
- One of the technical solutions for a drastic reduction in germ count is microfiltration

Arrangement of a line to produce ESL milk using a microfiltration unit

Fig. 9 shows the arrangement of a line of this kind. The milk is heated up to 55 °C, polished in the bacteria-removing clarifier and separated into skim milk and cream in the skimming separator. Bacteria are then removed from the skim milk during microfiltration and the cream is subjected to UHT. A standardizer divides the flow of cream into excess cream and cream to standardize the milk. More or less heated cream is returned to the skim milk depending on the fat content the standardized ESL milk is supposed to have. Before remixing, this cream is diluted with skim milk and subjected to partial stream homogenization. After skim milk with the bacteria removed has been mixed together with UHT-treated homogenized cream, the standardized milk is pasteurized and cooled. The bacteria-removing clarifier in the first stage means that an optimum production time is achieved for the line downstream.

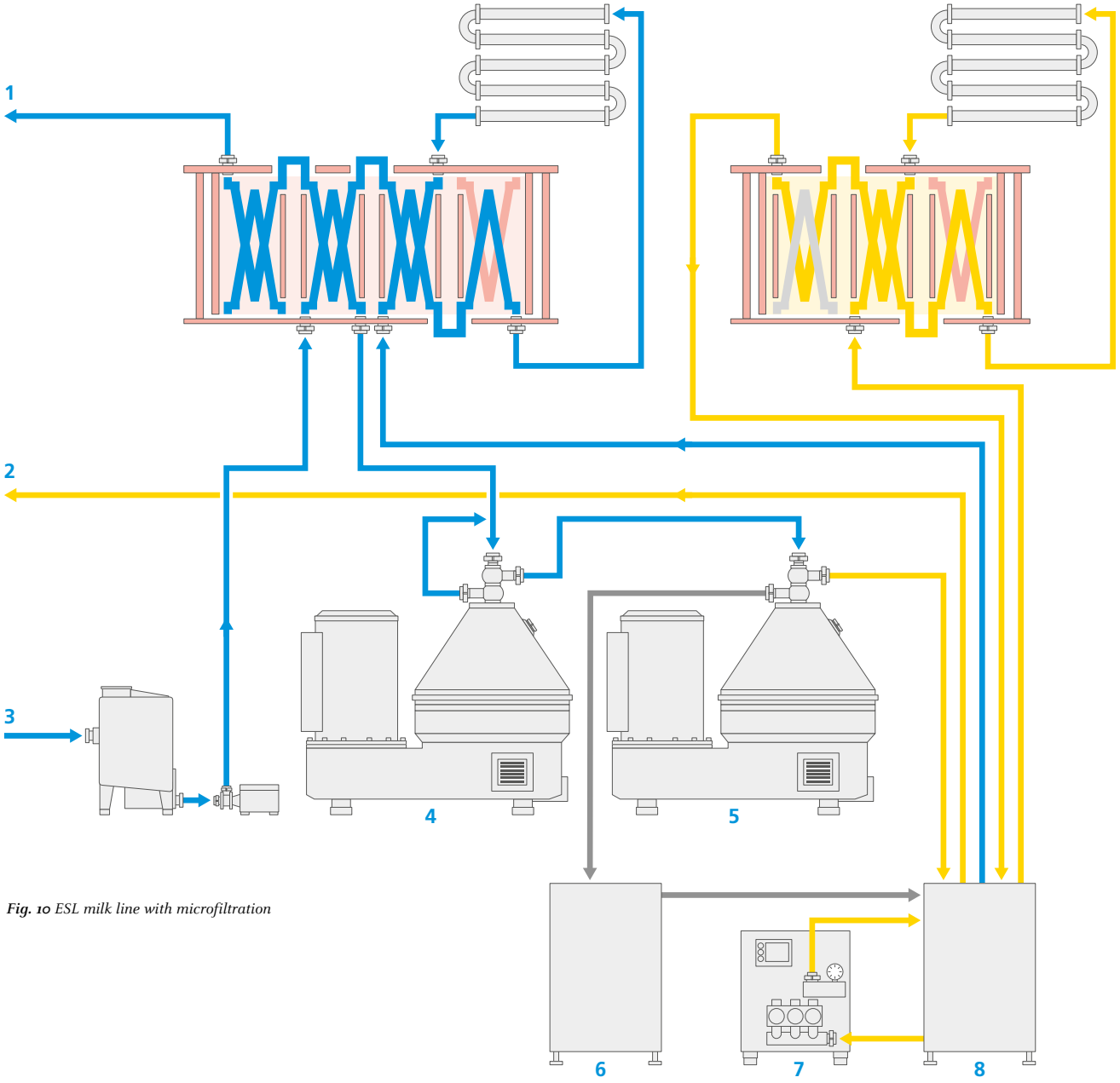


Fig. 10 ESL milk line with microfiltration

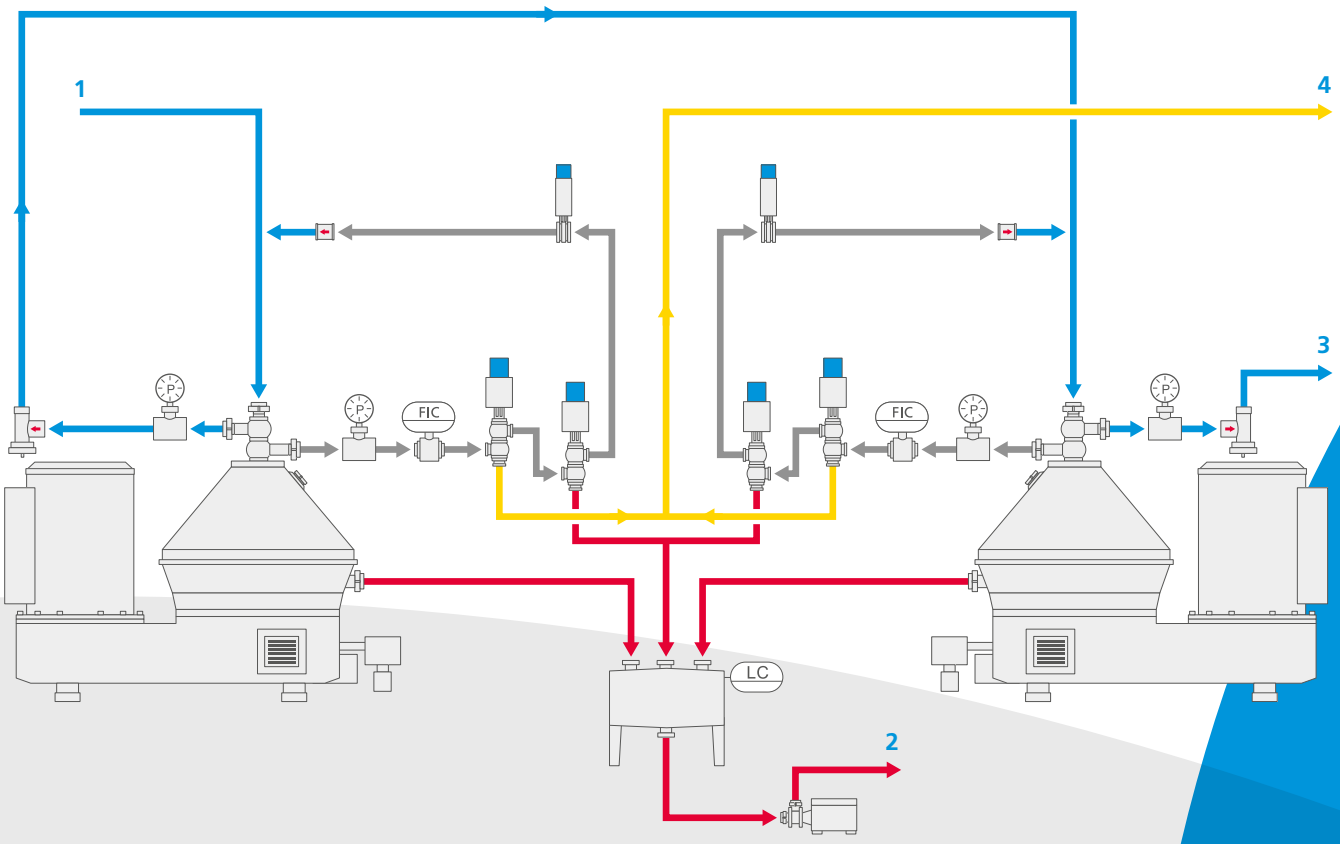
1 Standardized ESL milk
2 Excess cream
3 Raw milk
4 Bacteria-removing clarifier
5 Skimming separator
6 Microfiltration
7 Homogenizer
8 Standardizer

3.4 Double bacteria removal

If a single-stage bacteria removal process is not adequate to produce cheese without the addition of nitrate, for example, it is possible to arrange two bacteria-removing clarifiers in series. In this arrangement, the second separator acts as a polisher and ensures low germ values in vat milk under all operating conditions in the production line.

Fig. 11 shows an example of an installation for double bacteria removal. The continuous concentrate can optionally be returned to the feeds or routed away for sterilization. There is also the option of merging all the concentrates produced both continuously and batch-wise (ejections) and of routing them for further processing.

Fig. 11 *Diagram of 2-stage bacteria removal*



1 Unclarified milk
2 Concentrate and solids
3 Bacterially clarified milk
4 Continuous concentrate

4. Taking samples

In the clarifiers the raw milk is separated in to the heavy phase “sludge” and the light phase “clarified milk”. Directly after the light phase leaves the clarifier, a sample has to be taken in order to avoid any recontamination. The sample must be cooled to a temperature < 3 °C using iced water or dry ice. This temperature may not be exceeded until the samples are examined after no more than 24 hours.

For detailed information about the sample taking procedure please contact GEA.

Evidence of	Used in (product)	Damage caused	Name of method	Reference method
Total bacteria count	Fresh milk, factory milk, whey	General quality defects	Koch's plate method	IDF standard 100B: 1991, colony count MB* Vol. VI, 6.3.1
Aerobic spores of the Bacillus genus, e. g. Bacillus cereus	Fresh milk, UHT milk	Sweet clotting, slime formation, gas formation, swelling	Plate method using GCA agar	MB Vol. VI, 7.17.2
Anaerobic spores e. g. Clostridium tyrobutyricum, C. butyricum	Cheese milk	Late blowing in cheese, butyric acid formation	Nizo method, setting up dilution series, evaluation as per MPN method, Weinzirl sample	MB Vol. VI 7.18.2 7.18.3 7.18.4

Fig. 12 Typical test methods
** Handbuch der landwirtschaftlichen Versuchs- und Untersuchungsmethodik, Methodenbuch Band VI [Manual of agricultural experimental and test methods, method book volume VI] published by the VDLUFA [Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten – Association of German Agricultural Test and Research Institutes]*

5. Machine types

The following table shows the capacities of milk-clarifiers.

Clarifier	Flow rate (in l/h)	BR clarifier	Flow rate (in l/h)
GEA ecoclean	3,000 – 15,000	GEA ecoclear	3,000 – 8,000
MSE 100	15,000 – 30,000	CSE 100	8,000 – 12,000
MSE 200	30,000 – 40,000	CSE 140	10,000 – 15,000
MSE 250	40,000 – 55,000	CSE 230	15,000 – 30,000
MSE 350	55,000 – 75,000	CSE 400	30,000 – 45,000
		CSE 500	45,000 – 60,000

If products other than raw milk are clarified, enquire about the corresponding capacities.

Bacteria removal clarifier type CSI 400

Clarifier type MSI 350

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GEA is one of the largest technology suppliers for food processing and a wide range of other industries. The global group specializes in machinery, plants, as well as process technology and components. GEA provides sustainable solutions for sophisticated production processes in diverse end-user markets and offers a comprehensive service portfolio.

The company is listed on the German MDAX (G1A, WKN 660 200), the STOXX® Europe 600 Index and selected MSCI Global Sustainability Indexes.

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