Process Concepts for the **Production of ESL Milk**

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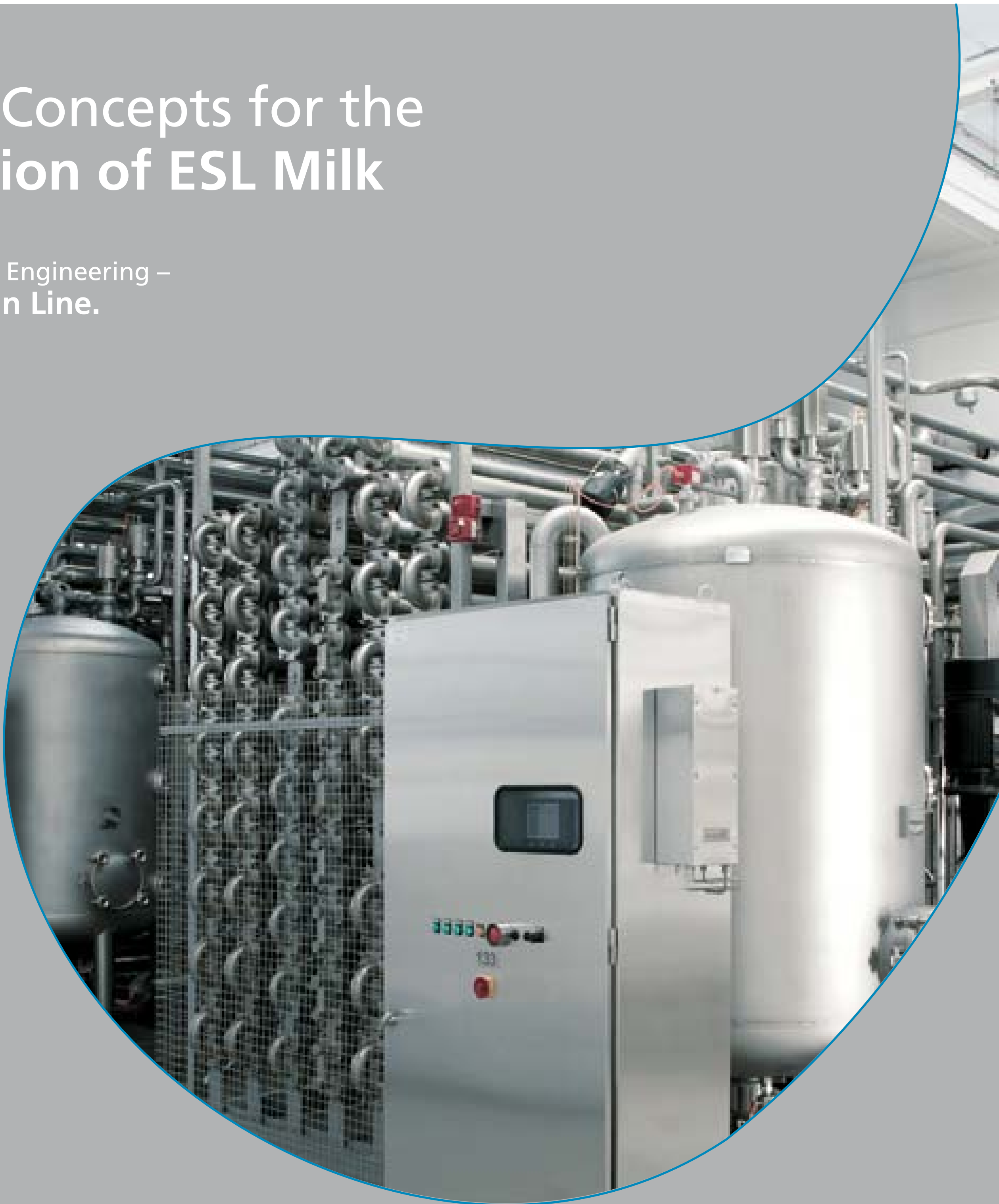


GEA Process Engineering

GEA TDS GmbH

Fundamentals and Direct Heating M

… are the basis for an extended fresh milk shelf life.

Fresh milk with an extended shelf life is also referred to as ESL milk. An exact, generally accepted definition of the term ESL milk with regard to shelf life does not yet exist.

GEA TDS uses the following definition for ESL milk:
ESL milk is milk with a shelf life of at least 21 days when stored at ≤ 8° C. From a sensory quality point of view, virtually no loss can be detected in comparison with conventional fresh milk (shelf life of 6–12 days).

ESL milk is more than a product with an extended shelf life. It is also synonymous with the high hygienic standard of the process technology required to produce it.

Methods …

The chart illustrates the factors contributing to the extension of shelf life.

The first column shows the general factors, such as requirements placed on raw milk quality, processing and packaging technology as well as an uninterrupted cold chain.

Microbial reduction methods which, compared to traditional pasteurisation, destroy an additional percentage of the surviving microorganism are listed in the second column.

On the following pages we will discuss the general factors from the first column. We will then outline the individual microbial reduction process concepts.

Shelf life of ESL milk	
General factors	**Microbial reduction methods**
raw milk	direct heating
process technology	indirect heating with tubes
packaging technology	modificated pasteuriser
continuous cold chain	microfiltration
	deep-bed filtration
	bacteria-removing separation

General Shelf Life Extending Facto

Quality of raw milk, process and packaging technology as well as the cold chain are counted among the general factors which influence the shelf life of ESL milk.

Process standards				
category	**valve technology**	**storage tank design**	**filling technology**	**expected shelf life at ≤8° C**
standard	standard valve technology	no air blanketing	standard line	10 days
clean	standard valve technology	unpressurised tanks blanketed with sterile air	closed system, sterile air above the filling element	14 days
ultra-clean	special single-seat or double-seat valves	unpressurised tanks blanketed with sterile air	closed system, sterile air above the filling element and decontamination of the package	> 21 days
aseptic	sterile valves	pressurised sterile tanks	aseptic line	up to 30 days

Quality of raw milk:
To produce ESL milk, a low original bacterial count in the raw milk is recommended. A microbial count of 100,000 cfu should not be exceeded.

Process technology:
Depending on the plant design, further microbial growth in the milk can be prevented. The chart process standards classifies the categories: standard, clean, ultra-clean and aseptic. Standard and clean ensure a fresh milk shelf life of 10–12 days. The production process for ESL milk falls into the ultra-clean or aseptic category.

Special single-seat or double-seat valves are used in ultra-clean processes. Besides perfect cleaning, sterilisation of the heat exchanger line and hot water disinfection at temperatures of 95° C – 115° C or steam sterilisation of the downstream product paths are also required. After hot water disinfection or steam sterilisation, the product-carrying pipes are blanketed with sterile air.

This prevents recontamination from the atmosphere. Shelf lives of just over 21 days are achieved.

The use of sterile valves and hot water sterilisation at > 135° C or steam sterilisation followed by blanketing with sterile air of the product pipes enables shelf lives of approx. 30 days to be achieved in aseptic processes.

Packaging technology:
When it comes to avoiding recontamination in the final product, the most important factors in the entire process are the quality of the filling technology and the package. Sterile air blanketing of filling elements or an aseptic filling machine have generally been accepted in the market as basic requirements for the production of ESL milk. Another important aspect is the integrity and proper decontamination of the package material. Defects in the package will dramatically reduce the product's shelf life. Hydrogen peroxide and hot air are used to sterilise the cartons prior to filling. The requirements placed on the stability of the package have also been increased. Due to the extended shelf life the material must withstand extended storage in cold and humid cold stores.

Continuous cold chain:
A final factor affecting shelf life is the importance of an uninterrupted cold chain. A temperature of < 8° C until the date of consumption must be maintained during storage and transport.

The high product requirements are not only defined by the shelf life of the ESL milk. The sensorial test and the content of lactulose and ß-lactoglobulin are additional quality parameters examined when assessing product quality in comparison with pasteurised fresh milk. The quality parameters lactulose and ß-lactoglobulin are explained below. Lactulose cannot be detected in untreated milk and is formed from lactose during heat treatment. The lactulose content in milk is therefore regarded as a chemical indicator of heat treatment. The lactulose content of pasteurised fresh milk is approximately 10 mg/kg.

The ß-lactoglobulin content in unheated milk is approximately 3,500 mg/l. The residual content of ß-lactoglobulin in its native form after heat treatment is a generally accepted quality indicator. The ß-lactoglobulin content in pasteurised fresh milk is roughly > 3,100 mg/l.

Microbial Reduction Methods …

… which destroy an additional percentage of the surviving micro-organism and therefore add to extending shelf life.

On the following pages the most used microbiological reduction methods are introduced, which are categorised in heating and filtration processes.

Heating processes
1. direct heating
2. indirect heating with tubes
3. modified pasteur

Filtration processes

4. microfiltration
5. deep-bed filtration
6. bacteria-removing separation

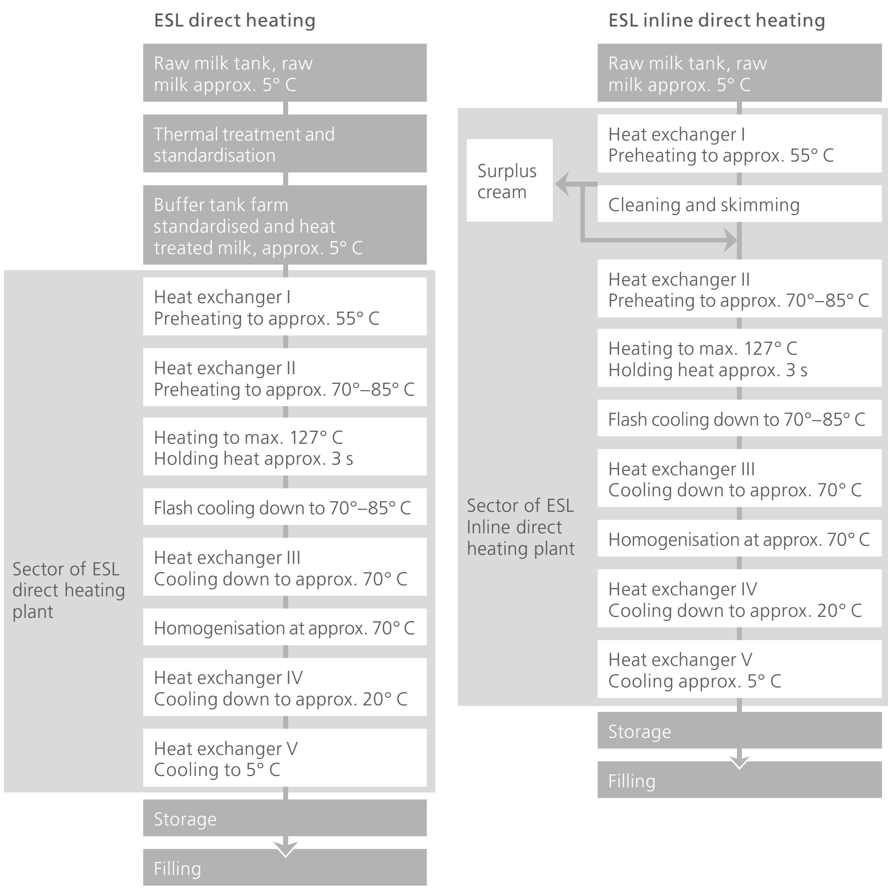
Direct Heating

The following two direct heating processes can be used to produce ESL milk:
ESL direct heating plant and ESL inline direct heating plant.

The starting product for the ESL direct heating plant is a standardised and heat-treated milk. The inline direct heating plant uses raw milk that has been separated and standardised in the heating plant.

Process sequence of the ESL direct heating plant
The raw milk is standardised and heated in the thermizer. In a storage tank, the milk is buffered for further processing. In the ESL direct heating plant, the product is preheated to 70° C–85° C and is then heated to max. 127° C with direct steam.

Block diagram for direct heating process variants

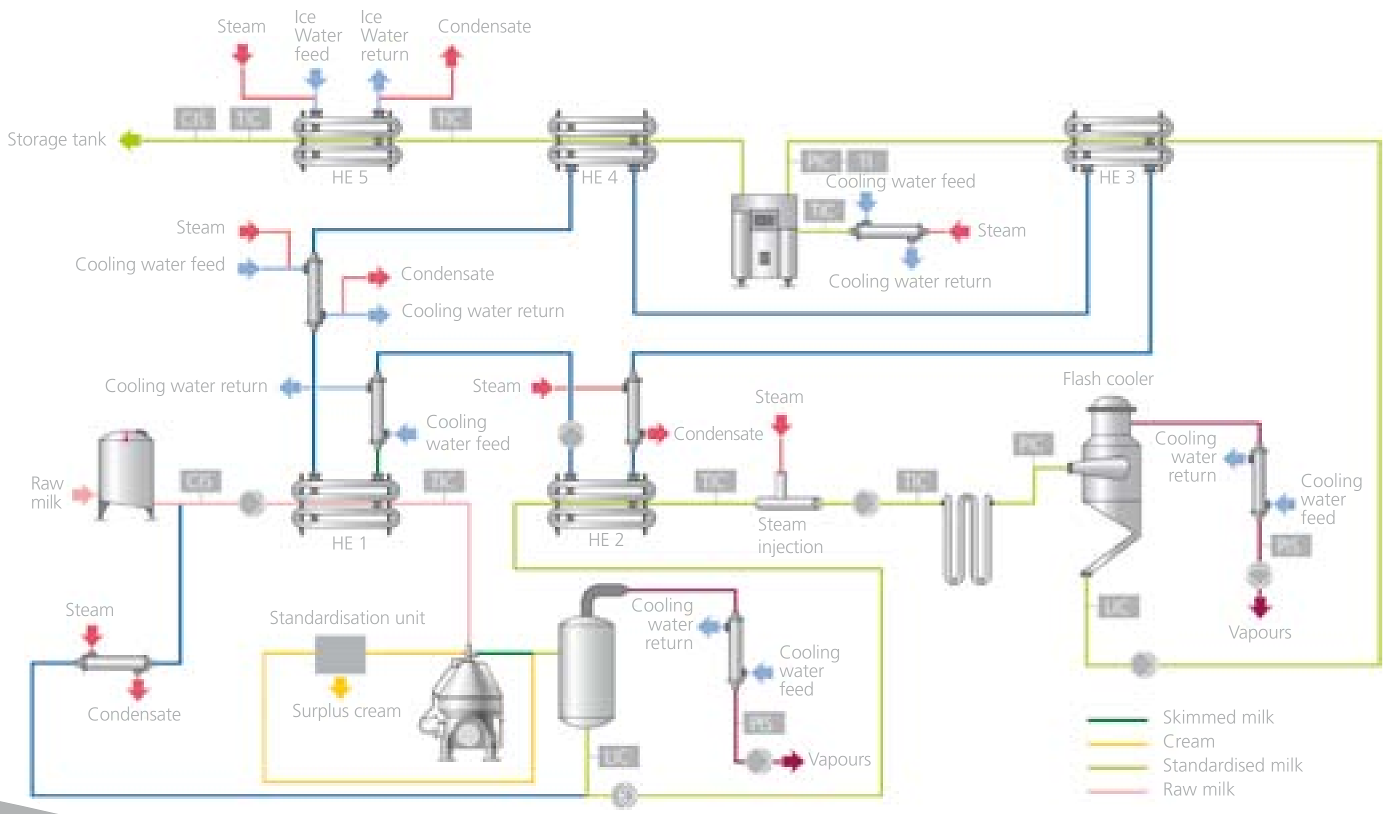


The milk passes through the holding tube in about 3 seconds and is then cooled down to 70° C–85° C in the flash cooler. Aseptic homogenisation at a temperature of about 70° C is necessary for a well stabilised product. The product is generally cooled further by means of regenerative and indirect heat transfer and is then buffered in filling tanks upstream of the filling line at approx. ≤ 5° C.

Process sequence of the ESL inline direct heating plant

From the raw milk tank farm, the milk is supplied to the ESL inline direct heating plant. The product is preheated to a temperature of approx. 55° C, cleaned and separated. This temperature ensures an optimum skimming efficiency. The cream required for standardising the fat content is added to the skim milk phase. The standardised milk is degassed downstream of the separator. Flow rate fluctuations during partial desludging of the separator are balanced out in the degassing vessel. A positive pump conveys the milk from the vessel into a heat exchanger where it is further heated up to 70°–85° C. Direct steam is then supplied to heat the product to max. 127° C and hold it at this temperature for approx. 3 seconds. The milk is cooled down to 70°–85° C in a flash cooler. To stabilise the product, aseptic homogenisation at a temperature of about 70° C is required. The product is cooled further by means of regenerative and indirect heat exchange and is buffered in a tank farm at approx. 5° C prior to filling. The schematic process of inline direct heating is shown in the illustration below.

Schematic process diagram of an ESL inline direct heating plant



Direct Heating

With direct processes, lactulose contents of < 25 mg/kg in the milk can generally be obtained, while the ß-lactoglobulin content is > 1,600 mg/l.

The quoted values refer to an ESL inline direct heating plant with a ß-lactoglobulin starting content in the raw milk of approx. 3,500 mg/l.

Due to these extremely short heating and cooling times at a high heating temperature, the direct process offers the advantage of a high product quality compared with indirect heating. Taste tests have shown that the product from an ESL inline direct heating plant and from an ESL direct heating plant are comparable from an organoleptic point of view with conventional pasteurised fresh milk.

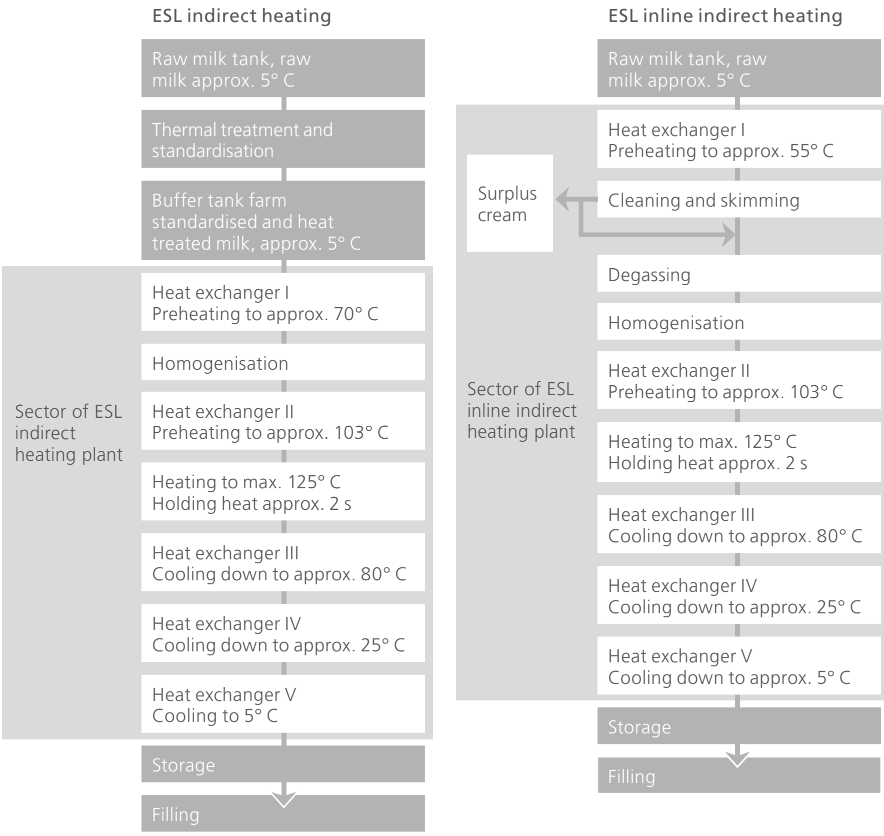
Direct heating plant. The photo shows tube modules and ash cooling unit.

Indirect Heating

The following indirect heating process variants are used to produce ESL milk: ESL indirect heating plant and ESL inline indirect heating plant.

An ESL indirect heating plant processes heated milk with a standardised fat content, while the inline indirect heating plant uses raw milk, which is standardised and heat-treated in the process.

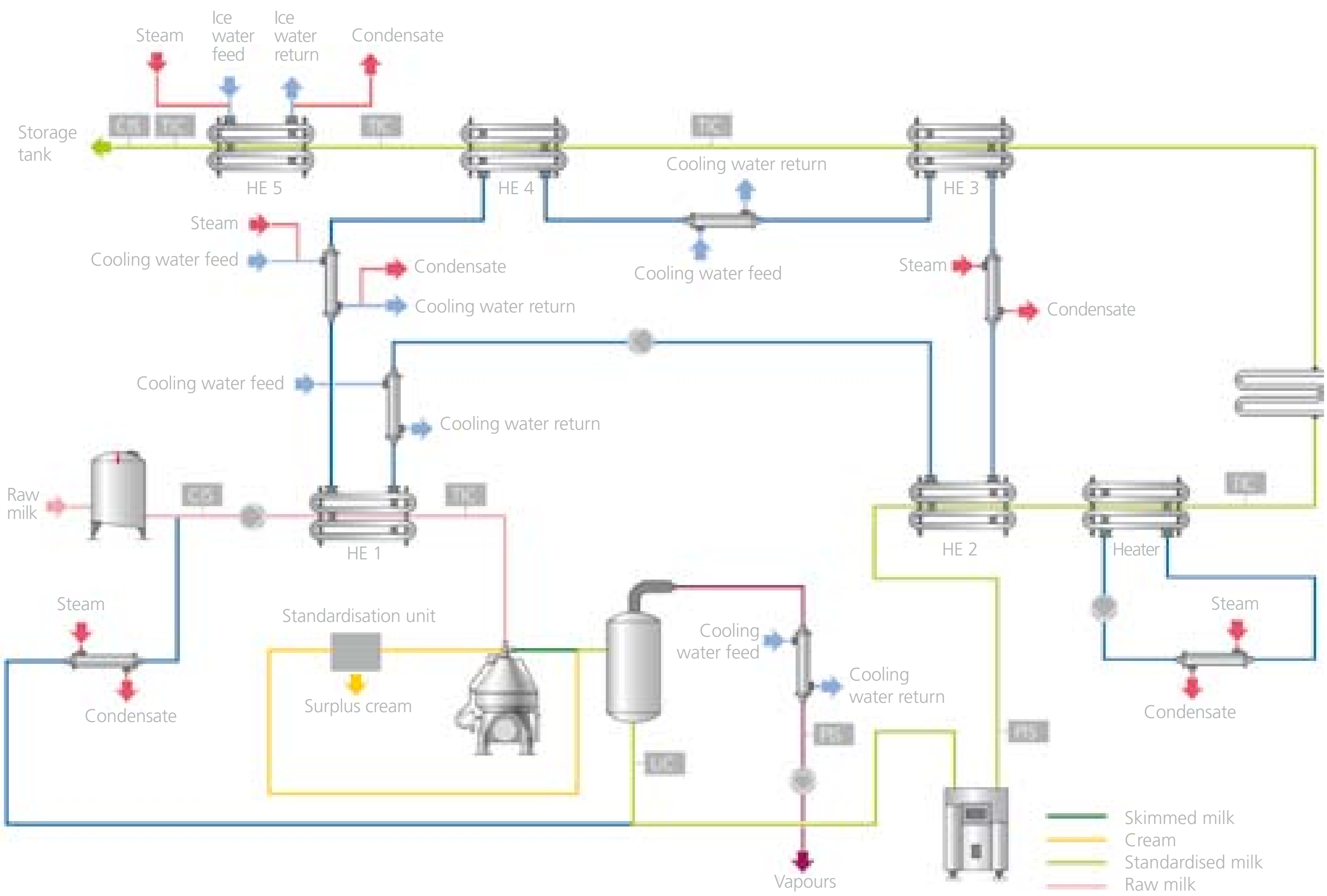
Block diagram for indirect heating process variants



Indirect Heating

Process sequence of the ESL indirect heating plant
As shown in the block diagram, the raw milk is first standardised and heated in a thermizer. From a storage tank farm the product is supplied to the ESL indirect heating plant. By regenerative heat transfer from product to water the milk is preheated to 70° C and then homogenised. Afterwards the product is preheated to approx. 103° C by regenerative heat transfer and then heated to 125° C in the heating section. The medium passes through the holding tube in about 2 seconds. In the next sections of the heat exchanger the milk is cooled down to approx. 5° C and made available for filling in a filling tank.

Schematic process diagram of an ESL indirect heating plant



Process sequence of the ESL inline indirect heating plant

In the first tubular section, the raw milk is preheated to separation temperature, cleaned and skimmed. After fat content standardisation, the milk is homogenised. To ensure continuous flow in the tubular heat exchanger a buffer tank is installed between the separator and the inlet back into the tubular heat exchanger. The buffer tank also fulfils the function of a degassing vessel, which minimises the air content in the product. Low air content in the milk enhances the product quality and reduces incrustation in the heating plant, thus increasing the production time. The product is preheated to approx. 103° C by regenerative heat transfer. In the heating section the medium is heated to 125° C and held at this temperature for approx. 2 seconds. In the following sections of the heat exchanger the milk is cooled down to approx. 5° C and is then made available for filling in a process tank. On the left side the schematic process is shown in summary.

The ESL inline indirect heating plant is an alternative to ESL inline direct heating. The indirect plant is less complex from a process engineering point of view and investment and operating costs are considerably lower.

The lactulose value is approx. 32 mg/kg and the β-lactoglobulin value approx. 1,000 mg/l. Despite the less favourable values, consumer experience has shown that the product is definitely comparable with directly heated ESL milk from a sensorial point of view.

Indirect heating plant

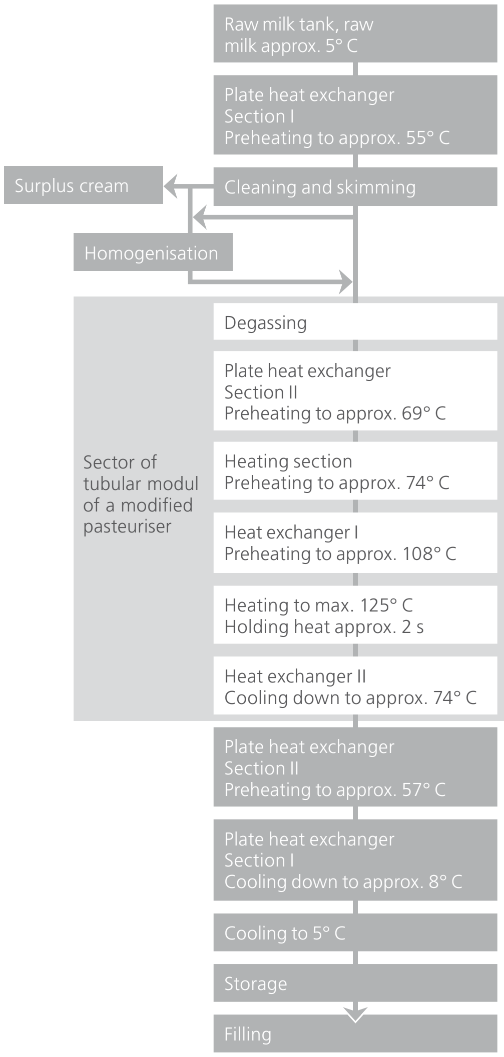
Heat recovery amounts to approx. 81 percent, which is far more than is achieved in direct plants. High energy savings over the entire life time of the plant can thus be expected. This high heat recovery rate is supported by the use of special surface-treated tubes. Production times of up to ten hours can be achieved.

Modified Pasteuriser

The modified pasteuriser is a process concept developed and patented by GEA TDS.

A conventional milk pasteuriser is equipped with an additional tubular module which heats the milk from 74° C to 125° C and cools it down again to 74° C. The tubular modules can easily be refitted to existing milk pasteurisers.

Modified pasteuriser block diagram



Process sequence of the modified pasteuriser

The raw milk is pumped from the raw milk tank farm to the milk heat exchanger. In accordance with the conventional process the product is cleaned and skimmed after the first plate heat exchanger unit. The cream required for fat content standardisation is homogenised in a separate stream. For product degassing and for maintaining a continuous flow during partial desludging of the separator, the pasteuriser line must also include a degassing vessel. The standardised milk is preheated in the plate heat exchanger to 74° C.

Modified pasteuriser

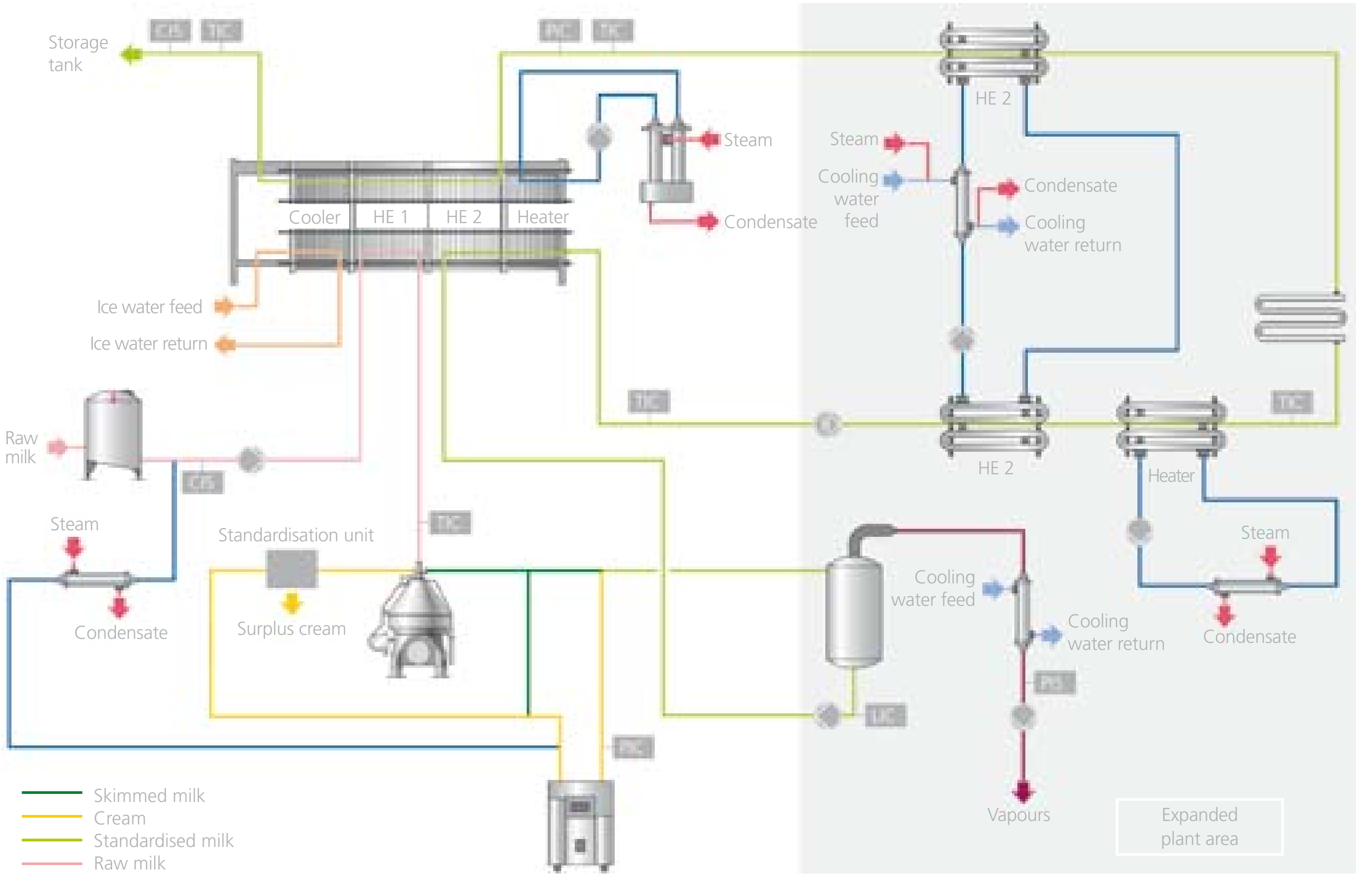
After the heating section, the milk is heated to approx. 108° C in a tubular heat exchanger and then to 125° C in the downstream heating section. The medium is held at this temperature for about 2 seconds. The milk is cooled down again to 74° C by regenerative heat transfer from product to water and leaves the tubular heat exchanger section. It is further cooled down to 5° C as it passes through the return circuit of the plate heat exchanger sections.

The modified pasteuriser is a process according to the indirect heating principle. Refitting the tubular modules to an existing heat exchanger is more cost-effective than setting up a new indirect heating plant. The scheme shows the extensions made to the conventional pasteuriser in green. Apart from the tubular modules and the degassing vessel, a sterile water circuit (not shown in the illustration) must also be added to the pasteuriser. After production and cleaning, the tubular module and the pasteuriser are sterilised at approx. 127° C.

This is by far the most favourably priced process and can be used if a pasteuriser is already available.

The modified pasteuriser is fitted with special surface-treated tubes. A heat recovery rate of up to 81 percent and production times of up to ten hours can thus be achieved.

Schematic process diagram of a modified pasteuriser



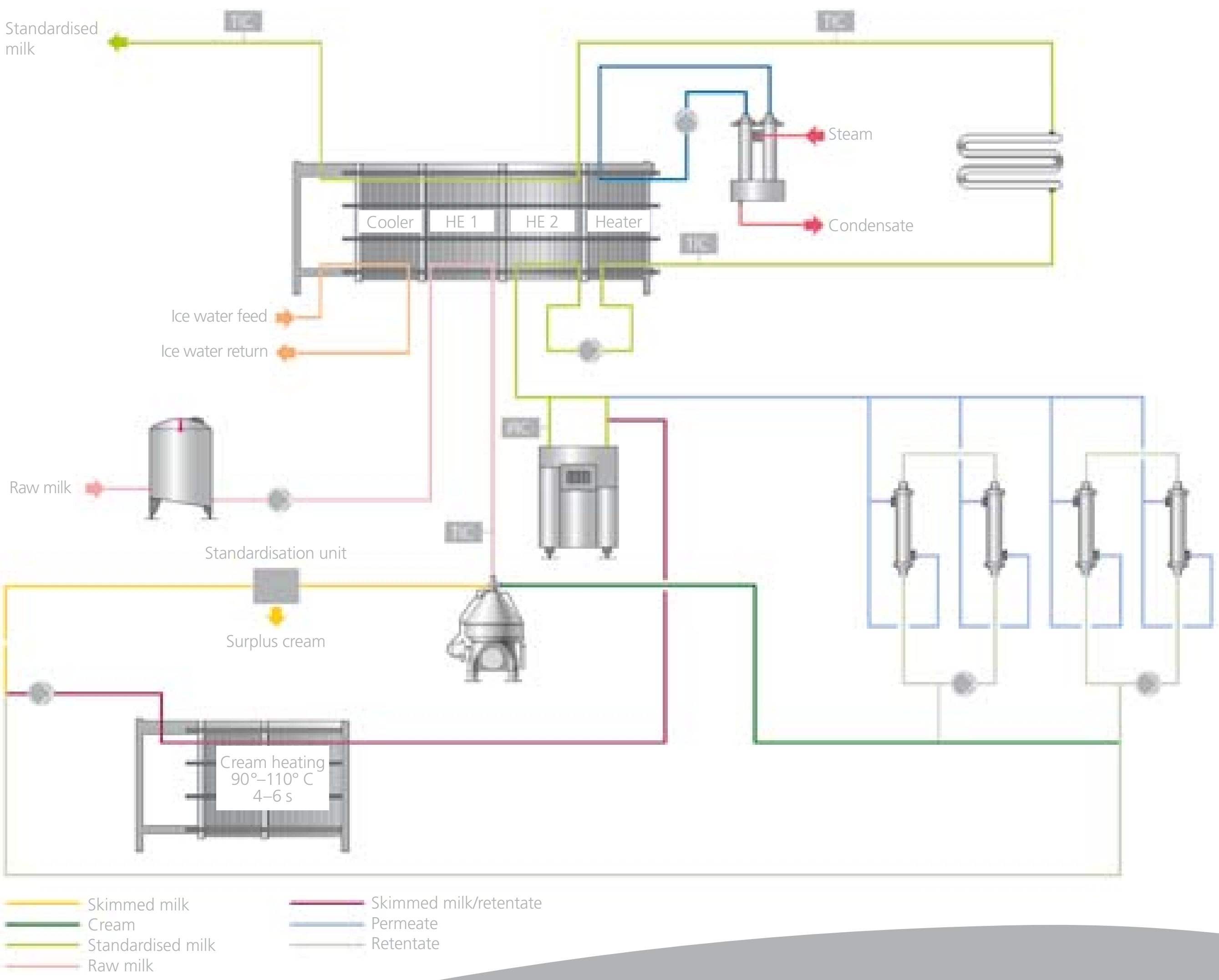
Microfiltration

For the microfiltration process ceramic membranes with pore sizes of 0.8–1.4 µm are used. Bacteria removal rates of more than 99.5 percent are achieved.

We are talking of cross-flow filtration resulting in a bacteria-reduced permeate and a bacteria-enriched retentate. The bacteria concentrate is 20 or 100–200 times concentrated. After 20 times concentration, the retentate is high-heat treated and added to the permeate. 100–200 times concentrated retentate is not used for the production of ESL milk.

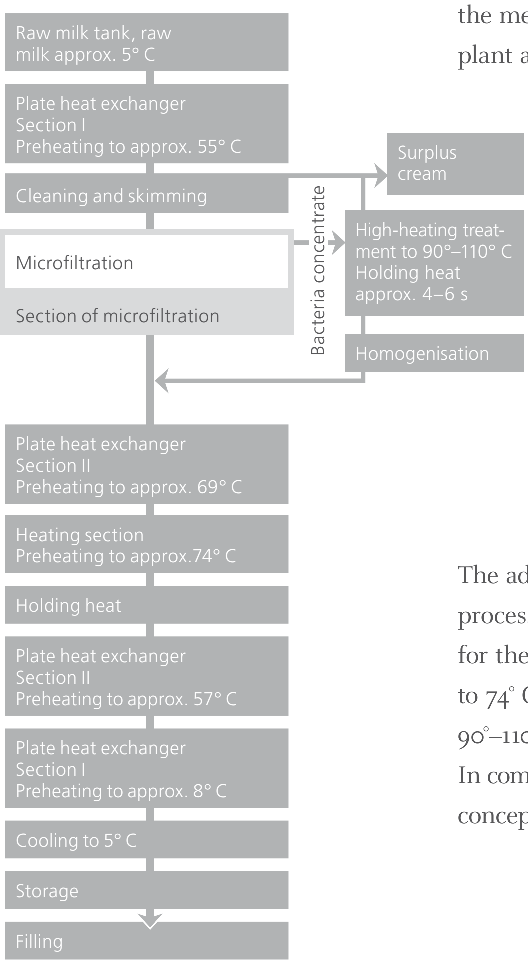
Microfiltration process sequence
In the first heat transfer section of the milk heat exchanger the raw milk is preheated and then cleaned and skimmed in the separator. The skim milk is heated to filtration temperature and microfiltrated. The cream required for fat content standardisation is high-heat treated together with the

Schematic diagram of a microfiltration plant



retentate yielded from microfiltration at approx. 90°–110° C for 4–6 seconds. After high-heat treatment the cream is homogenised in a partial stream. The standardised milk is pasteurised in the milk heat exchanger, then cooled down to 5°–6° C and made available for filling in the filling tank farm. The block diagram is showing the process scheme in summary.

Schematic process diagram of microfiltration



A ceramic membrane unit consists of the module housing and the ceramic membrane. The photos show ceramic membranes of the type used for the production of ESL milk.

The filtration plant is cleaned with ready-made alkaline and acidic detergents. The detergent is metered into the plant's supply circuit. After cleaning, the solution is discarded. In most cases a water treatment plant is required for microfiltration processes. Prior to production start, the pipes and the membranes in the microfiltration plant are sterilised with steam.

A filtration plant can be integrated into an existing milk heat exchanger line. The investment costs for a microfiltration plant are almost identical with those for a direct heating plant if a pasteuriser, separator and standardisation unit are already available.

The advantage of the membrane processes is the low thermal stress for the product. The milk is heated to 74° C, while the cream is heated to 90°–110° C together with the retentate. In comparison with the thermal process concepts, the filtration process yields

Microfiltration plant

Ceramic membranes

a lower lactulose value of 17 mg/kg and a higher β-lactoglobulin value of approx. 2,500mg/l.

The product has a consistently good taste from immediately after production until the expiry day, which can virtually not be distinguished from conventional fresh milk.

Deep-bed Filtration

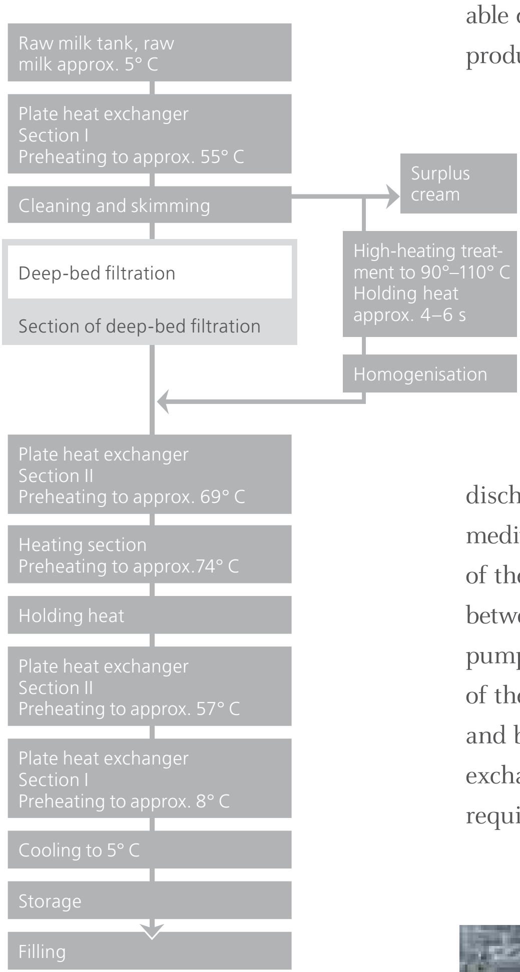
The deep-bed filtration process for the production of ESL milk has been developed and patented by the companies E. Begerow and GEA TDS.

The process was originally used in the beverage industry but also achieves bacteria removal rates of over 99 percent in the dairy industry. As this is a "dead end" deep-bed filtration process, no retentate (bacteria concentrate) is produced.

Deep-bed filtration process sequence
As shown in the schematic process diagram, the raw milk is preheated in the first heat transfer section of the heat exchanger and is then cleaned and skimmed in a separator. The cream required for fat content standardisation is high-heat treated and homogenised. The skim milk is filtered downstream of the separator and then standardised. The product is then further preheated in heat exchanger 2 and finally heated to 74° C. The medium passes through the holding tube in about 15–30 seconds. The milk is cooled in the return circuit of the plate heat exchanger and is buffered at 5° C in a tank farm prior to filling.

In contrast to membrane filtration the particles do not deposit on the membrane surface but are retained by the filter.

Schematic process diagram of deep-bed filtration



A pre-filter unit and a final filter unit are used for deep-bed filtration. Each filter unit consists of several polypropylene filter cartridges. The prefilter has a nominal separation limit of 0.3 µm and the final filter of 0.2 µm. Experience has shown that approx. 80 percent of the microorganisms are removed by the prefilter. The prefilter also retains suspended matter that could lead to more serious clogging of the final filter.

The filters do not retain any milk constituents that would cause a detectable change in dry mass in the final product. A filter unit consists of the housing dome, the medium inlet and outlet and the distributor plate which holds the individual filter elements.

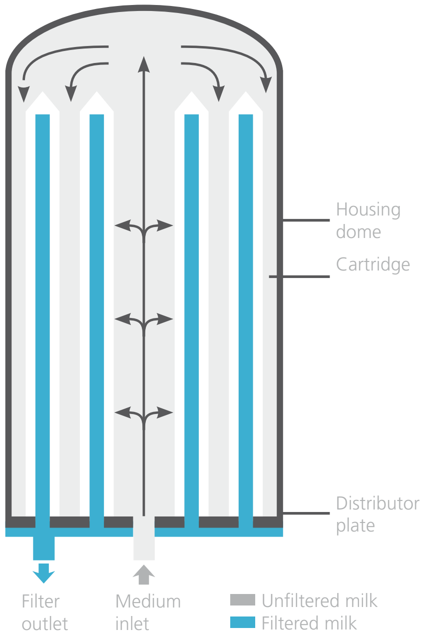
The product enters the housing dome via the medium inlet, flows through the filter cartridges and is discharged as filtrated milk via the medium outlet. The pressure drop of the medium per filter unit ranges between 0.10–0.45 bar. A booster pump between the skim milk outlet of the separator and the filter unit and between the filter unit and heat exchanger section 2 is therefore not required.


Deep-bed filtration plant

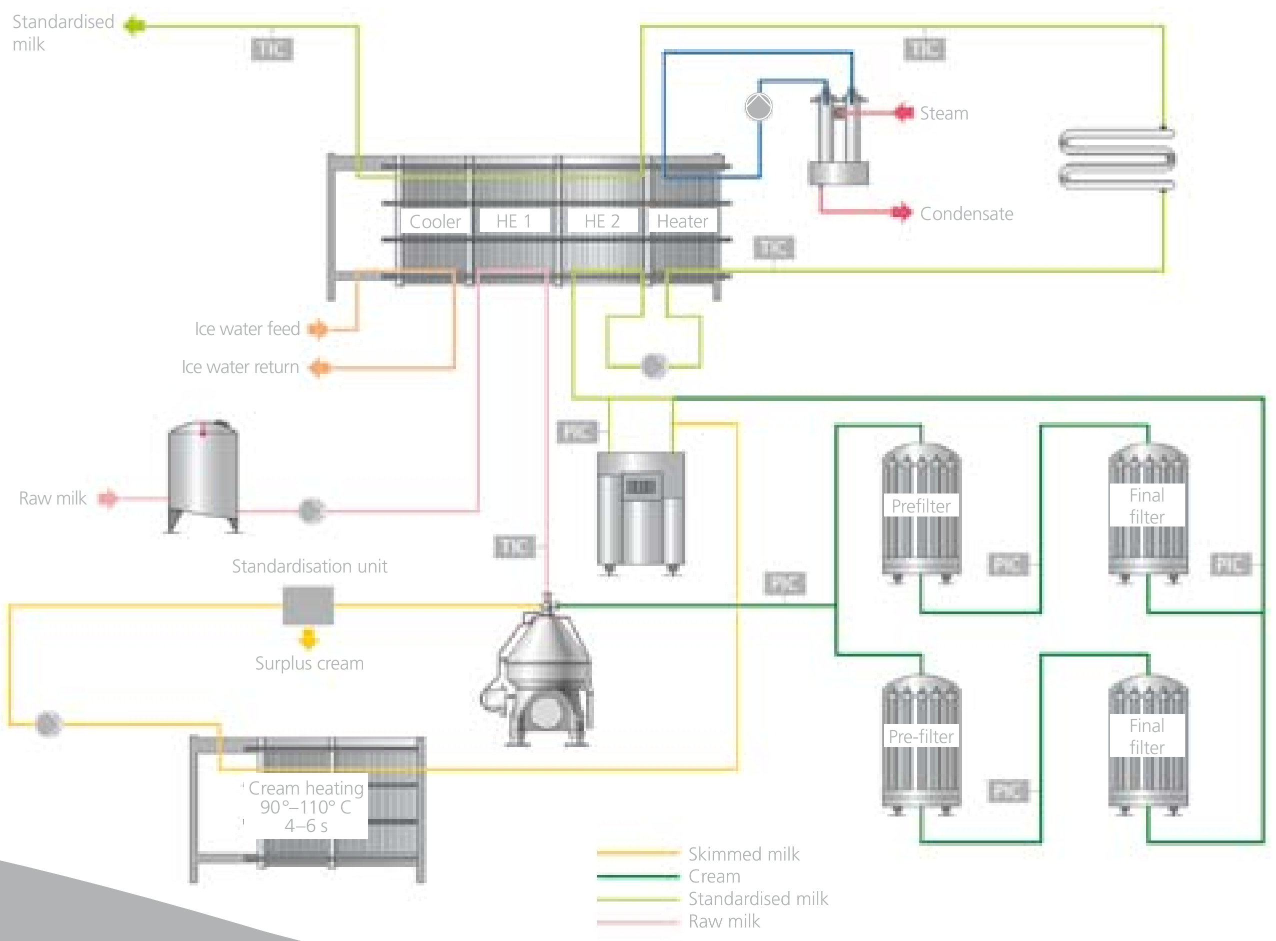
The filter plant is cleaned by its own CIP system. The cleaning system consists of a tank, a supply pump and the connections to the filter plant. Cartridge filters with a pore width of 0.1 µm are used for water treatment in order to retain suspended matter. A ready-made caustic solution and nitric or phosphoric acid are used as CIP medium. After cleaning, the housing domes are pushed out with compressed air and sterilised with steam together with the pipes. In comparison with a direct heating plant the investment costs for a deep-filtration plant are almost identical if a milk heat exchanger line with separator and standardisation unit already exists. Production times of up to 8 hours are achieved.

It should particularly be emphasised that the thermal and mechanical stress for the product in deep-bed filtration processes is the lowest compared with the other process concepts described. Product taste tests have shown that the product has a consistently good taste from immediately after production until the expiry day, which cannot be distinguished from traditional fresh milk.

Housing dome and filter cartridge



Schematic diagram of a deep-bed filtration plant



Technology with bacteria-removing separators

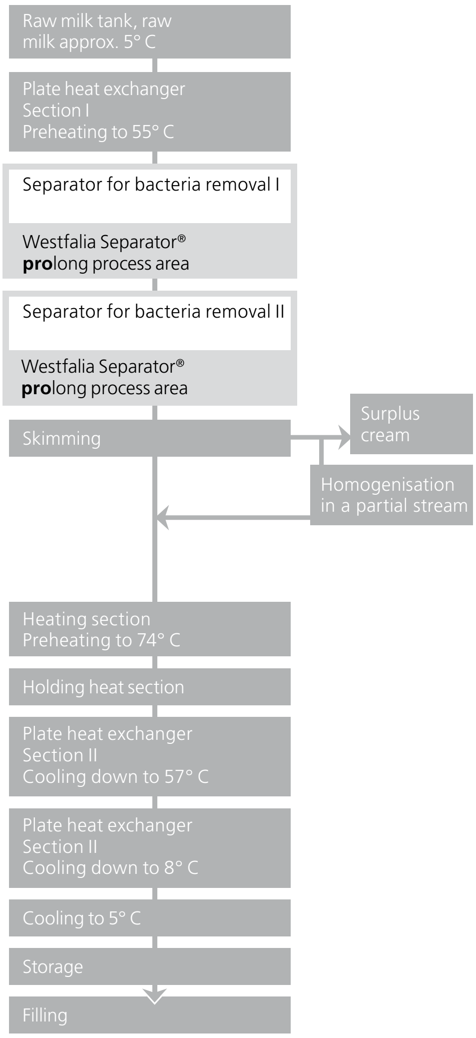
Two additional bacteria removing separators are installed in a conventional milk pasteuriser line.

These separators remove approx. 99.9% of bacteria from the milk. The milk is then treated in a conventional flash pasteuriser as usual. The thermal load of this process corresponds to the load of a conventional pasteuriser line; native ß-lactoglobulin values of approx. 3100 mg/l are attained. It allows average product shelf lives of at least 20 days. The bacteria count of bacillus cereus, a spore-forming bacterium which is not sensitive to heat and is therefore critical for the production of drinking milk, can be reduced to a level of less than one spore in 10 ml of milk by Westfalia Separator® **pro**long.

Westfalia Separator® prolong process description

The raw milk is pumped from the raw milk tank to the milk heat exchanger. It flows through heat exchanger section I, where it is warmed up to approx. 55° C, and is then passed on to separator I. Here, the overall bacteria count is reduced by approx. 96–97%. After the first bacteria removal stage, the milk continues to separator II, where the overall bacteria count is further reduced to approx. 99.9%. The bacteria removed are discharged from the solids space by partial ejection operations. The treated milk is conveyed to the skimming separator, where the incoming milk is separated

Block diagram of the Westfalia Separator® **pro**long process sequence



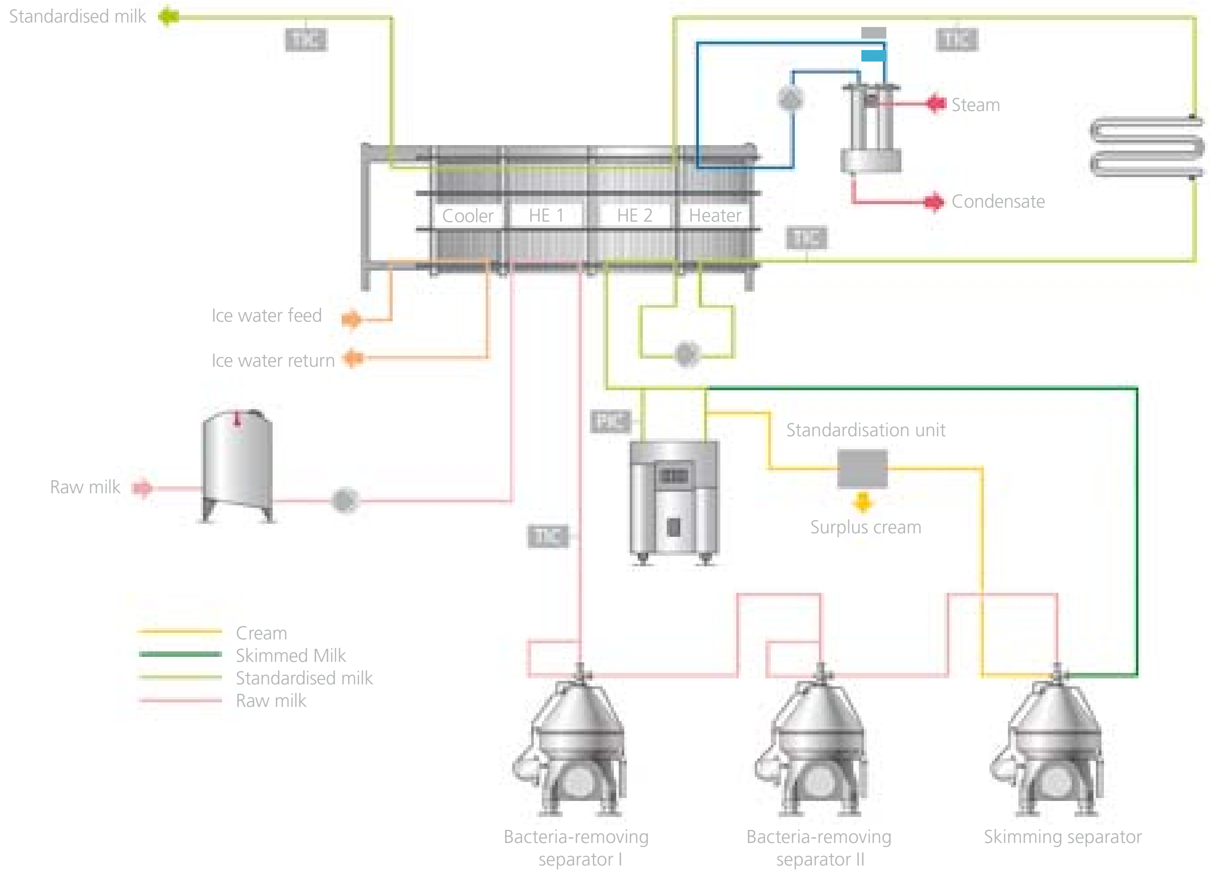
into skim milk and cream. In a standardisation unit, the fat content in the skim milk is regulated to the required value and is then homogenised in a partial stream. The surplus cream produced is discharged and can be used for other applications.

The milk is further heated in heat exchanger section II, passes through the flash pasteuriser and is finally cooled down to approx. 4–5° C in the return flows of heat exchangers II + I and in the cooler. It is buffered in storage tanks and made available for filling.

An existing flash pasteuriser line can easily be converted to include Wesfalia Separator® **pro**long. Apart from the fact that total operating costs are generally lower than for microfiltration lines, the ease of integrating Westfalia Separator® **pro**long into existing processes also helps to reduce investment costs. A further advantage of this process is that it is suitable for use both in cheese-making operations and the production of fresh milk products.

Skimming and bacteria-removing separators

Flow diagram of the Westfalia Separator® **pro**long process



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To find out more about GEA TDS process technology, see www.gea-tds.com.

GEA Process Engineering

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