Application note AG/FB115-EN Rev. D

Reliable measurement and automation in the milk-processing industry

Customized instrumentation as a complete solution

Measurement made easy

Introduction

Milk is an important food for us. It is a natural product and consists primarily of water, fat, protein, milk sugar (lactose) and mineral compounds. It also contains enzymes, vitamins and trace elements. As with every natural product, the composition of milk varies. When it comes to food for human consumption, we also use milk in the production of various products such as butter, cream, cheese, yogurt etc. Milk is processed in this respect in various systems in closed process lines.

In larger dairies, treatment is largely automated and therefore also requires a range of measuring devices for monitoring, regulating and controlling processes. All measuring devices should comply with hygienic design principles and be designed such that the impact on the valuable foodstuff is as minimal as possible during production. It is not possible to describe all of the processes and associated measuring technology in this document. The scope of this document is therefore limited to the description of the milk line.

Reliable measurement and automation in the milk-processing industry

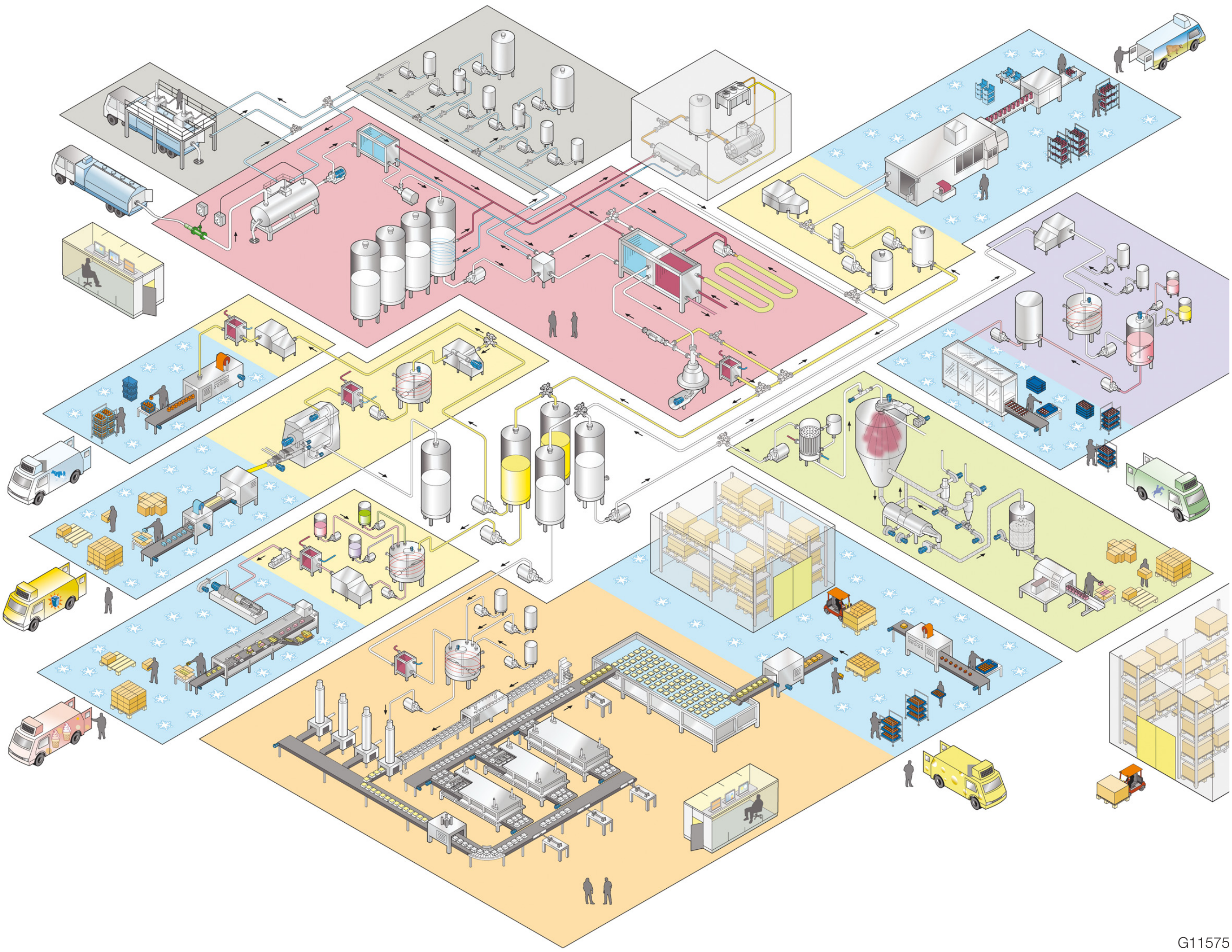

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Fig. 1: Example schema of a dairy with various production lines

Pasteurizing line

The pasteurizing line is the centerpiece in any dairy. It is here that raw milk is processed into fresh milk for consumption or into a base product for the production of other dairy products.

During the pasteurization process of milk, which involves heating to 72 to 75 °C for 15 to 30 seconds with immediate subsequent recooling, disease-promoting (pathogenic) microorganisms in the milk are killed off. Discussion of the measuring technology to be used focuses on dairywork-based application.

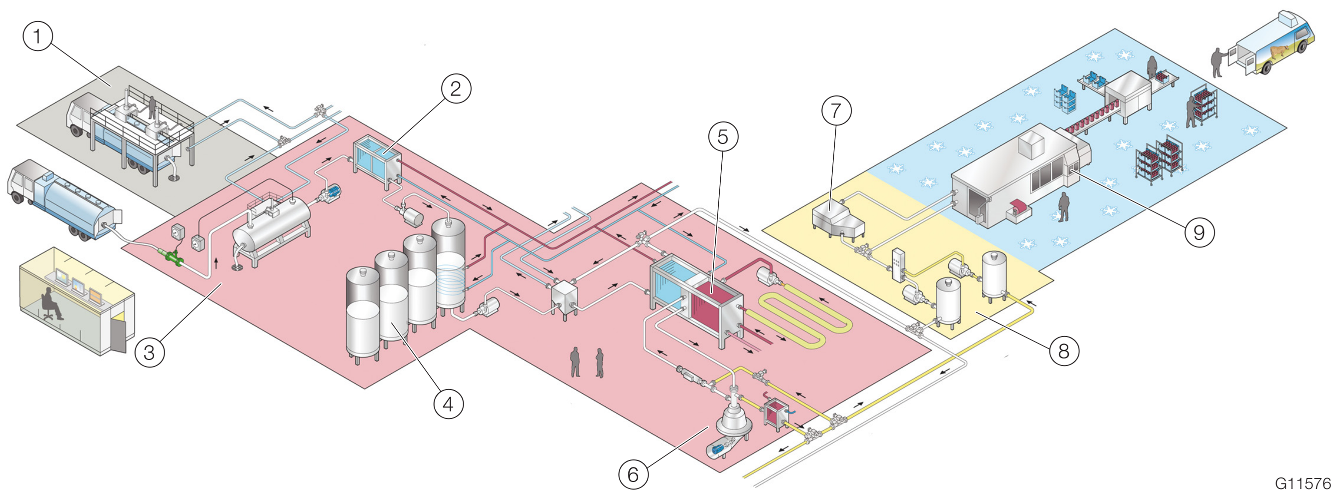

Fig. 2: Pasteurizing line schema
(1) Milk collection (2) Raw milk cooling (3) Quality assurance (4) Storage (5) Heat treatment (6) Separation (7) Homogenization (8) Standardization (9) Filling

Milk collection

Raw milk is delivered in tank trucks. From this raw milk, samples are analyzed for germs or other residues. The milk is then unloaded via suitable volume measurement systems, with possible temporary storage in buffer tanks. Volume measurement systems can include truck scales, weighing tanks mounted on pressure cells or flow measuring systems such as electromagnetic flowmeters or mass flowmeters. Official verification capability is often required for flow measurements. For purely volumetric flowmeters, the possibility of eliminating air content must be considered.
If the milk heats up to over 5 °C in the tanker, it is cooled down via heat exchangers and then temporarily stored in stacked storage tanks.
To prevent the milk from creaming in the tanks, a forced circulation mechanism with stirrer is often installed in the stacked storage tanks.

To control the stirrer mechanism, level limit switches or hydrostatic level measuring devices are installed on the tank at the very least.

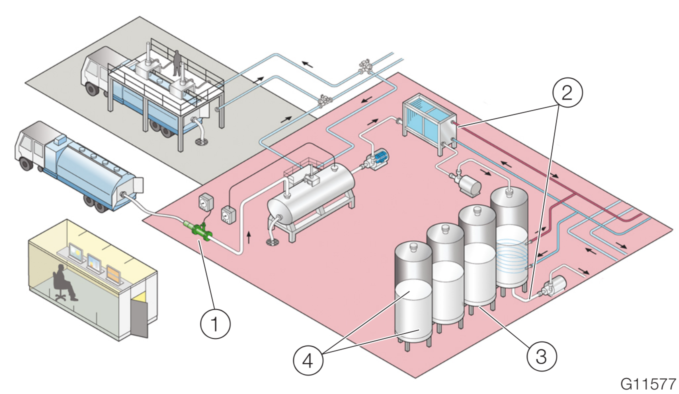

Fig. 3: Measuring technology used for milk collection
(1) Flow measurement (2) Temperature measurement (3) Pressure measurement, level measurement (4) Level monitoring

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Products used

Electromagnetic flowmeter HygienicMaster FEH		Flow measurement
	Nominal diameter DN: in accordance with specification Liner: PFA Material used for measuring electrodes: stainless steel 1.4571 (AISI 316Ti) Material used for sensor: stainless steel Flow measurement of conductive liquids 5 µS or higher, also for fat-containing media FDA-approved materials, EHEDG Media temperature up to 130 °C (180 °C at flanged connection) Measuring accuracy up to 0.2 %	Recording of the delivered quantity of raw milk. Official verification capability-approved version of flowmeter preferably to be used.

Coriolis mass flowmeter CoriolisMaster FCH100 / FCH400		Flow measurement
	No conductivity of the measuring medium is necessary High measuring accuracy up to 0.15 % Material conformity in accordance with EHEDG and FDA MID / OIML approval for billing	Recording of the delivered quantity of raw milk.

Temperature sensor TSHY and temperature transmitter TTH300		Temperature measurement
 	Pt100 with single or double measuring inset Entirely made from stainless steel With thermowell or hygienic welded spud Fast-acting, half-life period < 2.5 s Long-term stability and vibration resistant due to mineral-insulated cable Head-mount transmitter Redundant connection of two temperature sensors is possible Temperature-linear output With sensor break and drift detection	Recording of the raw milk temperature. Temperature monitoring in stacked storage tanks.

Transmitter 261GG/AG for pressure or absolute pressure / level		Pressure measurement
	Stainless steel housing Adjustable measuring range Process connection via DRD flange or other hygienic connection High operating temperature range Pressures up to 40 bar with hygienic connection Accuracy up to 0.1 % Turndown ratio: 1:20	Continuous fill-level monitoring on stacked storage tanks.

Heat treatment

Milk must be heat-treated in order to kill off disease-promoting germs. This objective is usually achieved by means of short-term heating. The short-term heater is an essential system component within the process line and is especially important for quality assurance. The milk is heated to 75 °C for 15 to 30 s. In doing so, it is run out of the raw milk tank into a supply tank and then heated usually by means of a plate apparatus with heat exchangers (heat recovery). A wound pipe section (heat retainer), at the end of which the heating temperature is measured, ensures that the heating duration is maintained. The heated milk is then directed via the heat exchanger further, releasing a large amount of its energy in the process.

In the final cooling stage, the milk is cooled down to 5 to 8 °C. It can then be forced into process tanks, where it is temporarily stored for further processing. A special monitoring mechanism ensures that only correctly treated milk reaches the temporary storage tanks. In the event of an error, the mechanism switches to circulation and the milk is again conducted to the supply tank or the system is purged.

Pressure transmitters monitor the pressure drops occurring via the heat exchangers, in which product is directed against product. A booster pump ensures that in case of leakage only heated milk can pass over to untreated milk and not vice versa.

Fig. 4: Heat treatment system image

In addition to short-term heating, the following additional procedures are common:

Long-term heating

A pasteurization process in which the milk is heated to 62 to 65 °C in a container and then kept at the heating temperature for 30 to 32 minutes. This process is still only used in exceptional cases, specifically when involving small volumes for processing.

High heating

A pasteurization process in which the milk is heated to 85 to 127 °C in a continuous flow, with a heat holding time of at least 4 seconds at 85 °C. This process is preferred for the production of process milk or for the heat treating of cream. Milk with a longer shelf life also undergoes this process.

Ultra-high heating

A process in which milk is heated to 135 °C in a continuous flow and then kept at this temperature for approx. 1 second. It is then cooled off abruptly and finally filled into sterile, light-protected packages under aseptic conditions. This process, which is the most costly in terms of apparatus, is used to produce non-perishable milk (H-milk) and non-perishable dairy products.

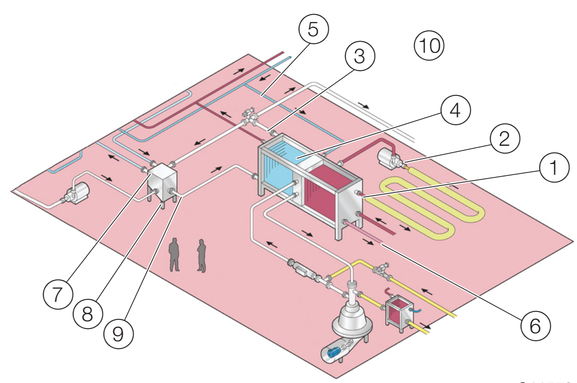

Fig. 5: Measuring technology used for heat treatment
① ② ③ Temperature measurement ④ Pressure measurement ⑤ ⑥ Control valve with positioner ⑦ Level measurement ⑧ Level monitoring ⑨ Flow measurement ⑩ Measured value recording

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Products used

Temperature sensor TSHY and temperature transmitter TTH300		Temperature measurement
 	Pt100 with single or double measuring inset Entirely made from stainless steel With thermowell or hygienic welded spud Fast-acting, half-life period < 2.5 s Long-term stability and vibration resistant due to mineral-insulated cable Head-mount transmitter Redundant connection of two temperature sensors is possible Temperature-linear output With sensor break and drift detection	Recording of the temperature before heat holding. Recording of the temperature after heat holding. Recording of the outflow temperature.

Transmitter 261GG/AG for pressure or absolute pressure / level		Pressure measurement
	Stainless steel housing Adjustable measuring range Process connection via DRD flange or other hygienic connection High operating temperature range Pressures up to 40 bar with hygienic connection Accuracy up to 0.1 % Turndown ratio: 1:20	Recording of the pressure drop via heat exchanger.

Control valve 23/24 with digital positioner TZIDC		Control valve
	Straight-way valve with cast steel housing Stainless steel internal fitting With maintenance-free, self-adjusting packed gland Process connection via flange in accordance with DIN Seat can be changed or rotated without special tools Positioner with robust nozzle flapper system Wide temperature range High vibration resistance Installed integrated, without external piping	Setting of the heating (steam) and cooling medium.

Electromagnetic flowmeter HygienicMaster FEH		Flow measurement
	Nominal diameter DN: in accordance with specification Liner: PFA Material used for measuring electrodes: stainless steel 1.4571 (AISI 316Ti) Material used for sensor: stainless steel Flow measurement of conductive liquids 5 µS or higher, also for fat-containing media FDA-approved materials, EHEDG Media temperature up to 130 °C (180 °C at flanged connection) Measuring accuracy up to 0.2 %	Recording of the delivered quantity of raw milk. Official verification capability-approved version of flowmeter preferably to be used.

Videographic recorder SM500F / RVG200		Measured value recording
	Control panel or on-site installation Optionally with mathematical, logic and totalizing function With SD drive Inputs 4 … 20 mA, voltage, resistance thermometer, thermocouples Potential-free contacts	Monitoring and documentation of the heating process.

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Separating

There are various reasons for separating milk. Purification may be one reason, separation of cream from skimmed milk another. For quark or cheese production, separation of dry matter from the whey is a necessary step.
The quality or separation effect can be regulated and controlled via the feed flow and the counter pressure.

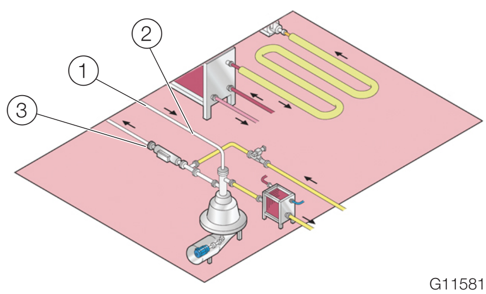

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Fig. 6: Measuring technology used for separation
① Flow measurement ② ③ Control valve with positioner

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Fig. 7: Image of separation system

Products used

Electromagnetic flowmeter HygienicMaster FEH		Flow measurement
	Nominal diameter DN: in accordance with specification Liner: PFA Material used for measuring electrodes: stainless steel 1.4571 (AISI 316Ti) Material used for sensor: stainless steel Flow measurement of conductive liquids 5 μS or higher, also for fat-containing media FDA-approved materials, EHEDG Media temperature up to 130 °C (180 °C at flanged connection) Measuring accuracy up to 0.2 %	Recording of the delivered quantity of raw milk. Official verification capability-approved version of flowmeter preferably to be used.

Control valve 23/26 with digital positioner TZIDC		Control valve
	As an angle or straight-way valve Entirely made from stainless steel Process connection via welded spud or round thread process connection Optionally with steam lock Positioner with robust nozzle flapper system Wide temperature range High vibration resistance Installed integrated, without external piping	Setting of the separator feed volume

Standardization

Milk is a natural product with variable fat content. Raw milk often has a fat content of over 4.2 %. The law specifies that milk for consumption on the conventional market must have a fat content of 3.5 % or 1.5 %. A separation process is therefore used to initially separate the cream from the skimmed milk and then re-add it on a measured basis to achieve the desired fat content.
If milk processing is terminated immediately after separation, there is no need for the temporary storage of the cream and skimmed milk.
Fat is a valuable constituent of milk that is also needed to produce other dairy products such as butter or cheese. Manufacturers therefore may not use more than the prescribed 3.5 % for consumable milk, and the law does not permit any less in any case. The "blending procedure" therefore must be very precise.
For blending, dairies use a precise Blendline control method with error correction and very precise flowmeters. Fluctuations in the cream concentration are simultaneously recorded and corrected via a density measurement.

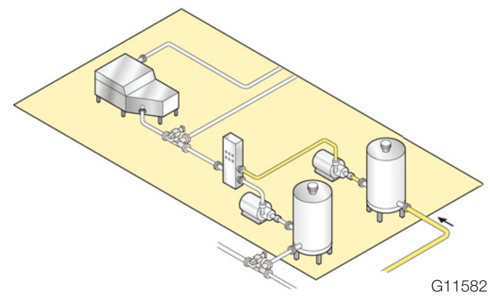

Fig. 8: Standardization schema

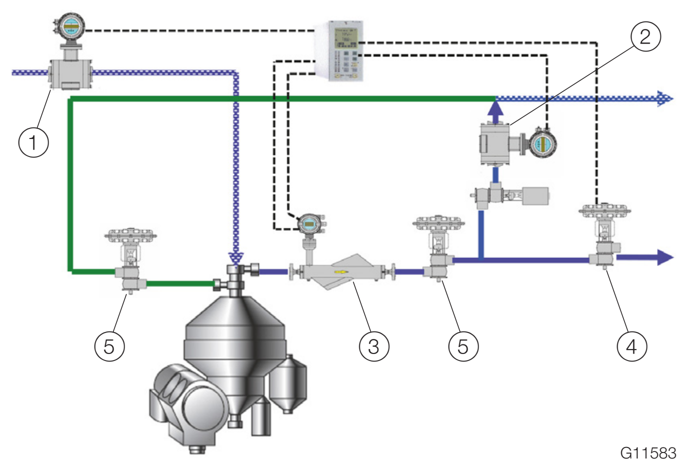

Fig. 9: Control schema and measuring technology standardization used

(1) Flow measurement separator intake
(2) Flow measurement for added cream (3) Overall flow measurement (4) Control valve (5) Pressure-sustaining valve

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Products used

Electromagnetic flowmeter HygienicMaster FEH		Flow measurement
	Nominal diameter DN: in accordance with specification Liner: PFA Material used for measuring electrodes: stainless steel 1.4571 (AISI 316Ti) Material used for sensor: stainless steel Flow measurement of conductive liquids 5 µS or higher, also for fat-containing media FDA-approved materials, EHEDG Media temperature up to 130 °C (180 °C at flanged connection) Measuring accuracy up to 0.2 %	Flow measurement on the separator intake.

Electromagnetic flowmeter HygienicMaster FEH with pointed electrode		Flow measurement
	Nominal diameter DN: in accordance with specification Liner: PFA Material used for measuring electrodes: stainless steel 1.4571 (AISI 316Ti) Material used for sensor: stainless steel Flow measurement of conductive liquids 5 µS or higher, also for fat-containing media FDA-approved materials, EHEDG Media temperature up to 130 °C (180 °C at flanged connection) Measuring accuracy up to 0.2 %	Flow measurement of added cream.

Coriolis mass flowmeter CoriolisMaster FCH100 / FCH400		Flow measurement
	Simultaneous measurement of mass flow and density / concentration No medium conductivity required High accuracy of density measurements up to 1 g/l High flow-rate accuracy Stainless steel wetted parts and housing EHEDG, short installation length Lower pressure drop Self-draining	Measurement of the total cream flow rate. Cream concentration measurement.

Control valve 23/26 with digital positioner TZIDC		Control valve
	As an angle or straight-way valve Entirely made from stainless steel Process connection via welded spud or round thread process connection Optionally with steam lock Positioner with robust nozzle flapper system Wide temperature range High vibration resistance Installed integrated, without external piping	Added cream setting.

Homogenization

Natural, non-homogenized milk tends toward creaming. Fat in the milk is distributed in spheres that are lighter than the proportion of water and therefore rise to the top over time and float on the remaining liquid.
During homogenization, the milk is pressed through sieves with very fine holes at 100 … 400 bar using a high pressure pump. During this process, larger fat spheres are broken up by shearing forces, and due to acceleration of the milk in the small passages, the pressure in the medium is reduced such that cavitation occurs, further breaking apart these spheres. A great number of smaller fat globules are created as a result, which are homogeneously distributed in the milk and cream much more slowly.

Minimal measuring technology is used in this process step. If pressure transmitters are used, they must have a high pressure rating yet be hygienically designed.

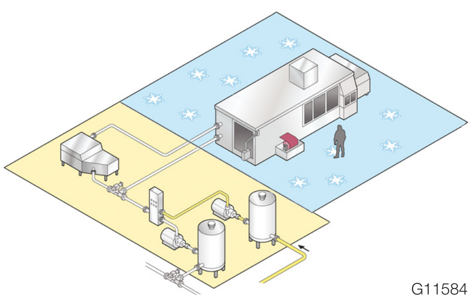

Fig. 10: Homogenization schema

Filling

After homogenization, the final process stage in the milk production line is the filling of consumable milk into consumer-specific packing. Weighing systems or even fast and reproducible batch-suited electromagnetic flowmeters in many cases are used in this respect. They must be capable of recording overrun quantities and to correct them independently. Highly consistent conditions upstream of the filling valve are a condition for accurate, reproducible filling. The level and the pressure in the supply tank therefore are recorded and constantly adjusted.

When filling containers that have a filling time of more than 3.5 seconds, the electromagnetic flowmeter FEH500 can be used as a measuring device. The device is equipped with an internal presetting counter with precontact and main contact, enabling it to switch a valve initially from full throughput to reduced throughput and then to close it completely. Additionally, it is equipped with an overrun correction mechanism, which independently records the overrun quantity after the close command and retroactively corrects the time for the close command.

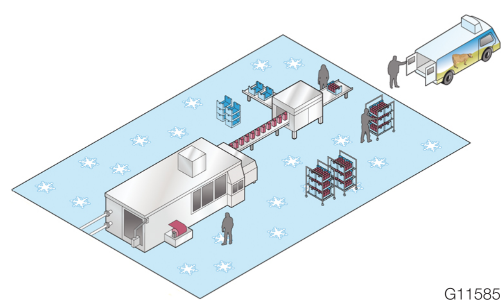

Fig. 11: Filling schema

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Products used

Transmitter 261GG/AG for pressure or absolute pressure / level		Pressure measurement
	Stainless steel housing Adjustable measuring range Process connection via DRD flange or other hygienic connection High operating temperature range Pressures up to 40 bar with hygienic connection Accuracy up to 0.1 % Turndown ratio: 1:20	Measurement of the level on the supply tank. A conductive tester can also be used for this. Recording of the overlay pressure on the supply tank.

Control valve 23/26 with digital positioner TZIDC		Control valve
	As an angle or straight-way valve Entirely made from stainless steel Process connection via welded spud or round thread process connection Optionally with steam lock Positioner with robust nozzle flapper system Wide temperature range High vibration resistance Installed integrated, without external piping	Setting of the milk feed flow

Electromagnetic flowmeter HygienicMaster FEH500		Flow measurement
	Suited for batch operation with internal presetting counter Nominal diameter DN: in accordance with specification Liner: PFA Material used for measuring electrodes: stainless steel 1.4571 (AISI 316Ti) Material used for sensor: stainless steel Flow measurement of conductive liquids 5 µS or higher, also for fat-containing media FDA-approved materials, EHEDG Media temperature up to 130 °C (180 °C at flanged connection) Measuring accuracy up to 0.2 %	Recording of the fill quantity and control of the fill valve.

CIP (clean-in-place) cleaning

Hygiene is vital in the milk-processing industry. Therefore tankers, temporary storage tanks, stacked storage tanks, piping etc. must be cleaned daily and in some cases even sterilized. The cleaning media are provided in the CIP system. After production, a mostly automated procedure for 5-stage CIP cleaning is started:

1. Initial purging with hot water
2. Cleaning with hot lye
3. Intermediate purging with (lukewarm) water
4. Cleaning with hot acid
5. Rinsing with cold water

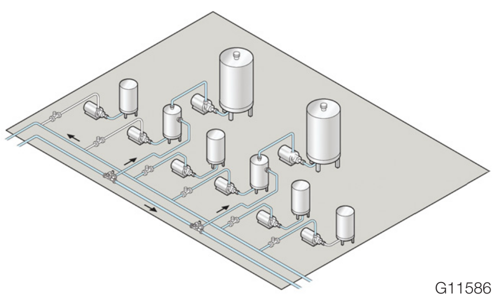

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Fig. 12: CIP cleaning schema

Temperature sensors are used to adjust the cleaning temperatures. Flowmeters can be used to monitor whether all paths are open and whether cleaning medium also flows through the system. Using conductivity measurements, it is possible to detect whether the cleaning solution has absorbed dirt and if cleaning agents that are fed back must be concentrated. Additionally, the individual cleaning agent phases can be separated by recording the conductance value. Via turbidity sensors, product residues are detected during initial purging and, if necessary, collected in a purged milk tank. The burden on waste water treatment is consequently reduced and product residues can be supplied for further processing (animal feed for agriculture).

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Fig. 13: CIP cleaning system images

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Special aspects for using and selecting measuring devices

Electromagnetic flowmeter

With sufficient electrical conductivity, the electromagnetic flowmeter is the most commonly used measuring device for flow measurements. Possible air content in the medium is measured as a volume fraction. In case of high fat content in the medium, which could result in isolation of the electrodes, pointed electrodes should be used. For low conductivities, for example for media with high Brix content, it is possible to switch to devices with alternating field excitation with preamplifier. For two-phase measuring media, the use of an alternating field device is also frequently recommended; the same applies in case of pulsating conveyance of the medium.

Coriolis mass flowmeter

The Coriolis mass flowmeter is suited to both conductive and non-conductive media. The pressure drop, specifically for higher viscosities, is higher than with an electromagnetic flowmeter; in another respect higher viscosities do not cause further disruption. Because the mass flow is recorded directly, limited air pockets do not influence the accuracy of the measurement. However, large air pockets may mean that the device is no longer suitable. As the density is also recorded simultaneously, it is also possible to determine fat concentrations. However, this requires a device with highly accurate density calibration. In case of pulsating conveyance, the pulsation frequency of the medium should be as far from the device’s excitation frequency as possible.

Vortex and Swirl flowmeters

Vortex and swirl flowmeters can be used for conductive and non-conductive liquids with water-like viscosity, though also for gases and vapors. While the vortex flowmeter requires similar inlet/outlet sections to a differential pressure element, the swirl flowmeter manages virtually without steadying lengths. Up to DN 200, the use of this flowmeter is often less laborious than a differential pressure flow measurement. Additionally, significantly greater measuring range dynamics are obtained in this respect. However, these devices are less suited to hygienic applications.

Temperature Sensors

In milk processing, outside of steam generation, Pt100 temperature sensors in hygienic design are usually used with single, fixed-head transmitters. However, for particularly important measuring points, temperature sensors can also be equipped with double Pt100 sensors. In this case, transmitters with two inputs are used, which on the one hand monitor the redundancy and on the other hand switch to the remaining sensor if one of the sensors breaks. Additionally, monitoring is performed for a possible drift between the two sensors. An alarm is triggered, thus preventing incorrect measurements.

Additional process steps

As the schema at the beginning of the application description illustrates, many other products are derived from milk. Cream, butter, yogurt, quark, desserts, cheese, whey products and milk powder are some examples. Not all of the associated processing procedures can be described in detail in this document. However, they are composed of similar basic process steps such as thermization, separating, filtering, dosing, mixing and storing. The same or very similar measuring devices to those in the milk line are used.

Service Delivery

In addition to the supply of measuring devices, plant operators often also require measuring arrangement to be installed and handed over ready for operation, and to be kept maintained. ABB Service offers maintenance tasks for upkeep and periodic measuring point checking. When constructing large-scale systems, these services are generally assumed by the supplier of the overall system. For smaller reconstruction schemes, ABB works together with competent regional partners, who also take over small and medium-sized projects and implement a complete solution for the end user.

These partners not only have thorough knowledge of the applications and management of ABB devices and direct lines of contact to ABB Sales, they also possess a high degree of expert knowledge in the area of process engineering for the food industry and energy management.

Projects can be managed jointly, from isolated applications, e.g. a heat treatment system or a mixing system, through to complete production lines. Offerings to end customers include services such as consulting, project management, providing expert process knowledge, mechanical engineering, electrical and automation technology planning, installing and commissioning of entire applications as well as delivery of partial or complete turnkey systems that are furnished with ABB equipment.

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Fig. 14

Contact us

ABB Limited
Process Automation
Howard Road, St. Neots
Cambridgeshire, PE19 8EU
UK
Tel: +44 (0)870 600 6122
Fax: +44 (0)1480 213 339
Mail: enquiries.mp.uk@gb.abb.com

ABB Inc.
Process Automation
125 E. County Line Road
Warminster, PA 18974
USA
Tel: +1 215 674 6000
Fax: +1 215 674 7183

ABB Automation Products GmbH
Process Automation
Dransfelder Str. 2
37079 Goettingen
Germany
Tel: +49 551 905-0
Fax: +49 551 905-777

www.abb.com/flow

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