Faculty of Engineering Alexandria University

Electrical Engineering Department 3rd year Power

Milk to cheese Process

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Tradition and basic knowledge:

Cheese is a milk concentrate, the basic solids of which consist mainly of protein (actually casein) and fat. The residual liquid is called whey.

There are different kinds of cheese

- Cured or ripened cheese is cheese that is not ready for consumption shortly after manufacture, but which must be held for such time, at such temperature, and under such other conditions as will result in the necessary biochemical and physical changes characterizing the cheese.
- Uncured, unripened or fresh cheese is cheese that is ready for consumption shortly after manufacture.

Milk treatment prior to cheese making:

The suitability of milk as a raw material for cheese production depends largely on conditions at the dairy farm. Quite apart from the general demand for strict hygienic conditions, *milk from sick cows or animals undergoing treatment with antibiotics must not be used for cheese making, or any other milk product.* Feeding animals on badly prepared silage can adversely affect the quality of several varieties of cheese.

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Milk Collection:

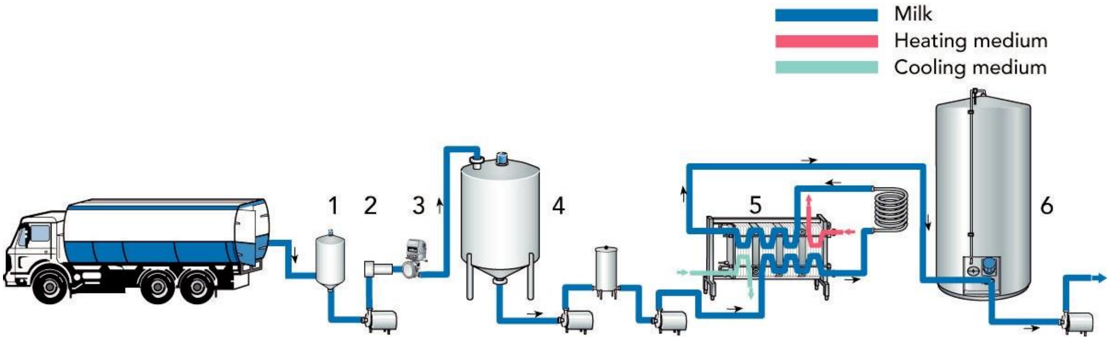
With the traditional method of milk reception, i.e. morning delivery of milk in churns to the dairy in the course of a few hours of all milk needed for the day's production, the milk was treated almost immediately after being weighed in. The fat content was then standardized in conjunction with separation and pasteurization and, after regenerative cooling to renneting temperature; the milk was pumped to the cheese making tanks. The practice of collecting milk from farms at intervals of two or three days is widespread. This means that particularly stringent requirements must be met regarding the way the milk is treated by the producers. Especially a quick cooling of the collected milk to 4 °C is essential.

Heat treatment and mechanical reduction of bacteria – thermization:

When collection of milk on alternate days was introduced, cheese producers who had to use such milk noticed that the quality of the cheese frequently deteriorated. This tendency was particularly noticeable when the milk had to be stored a further day after reception, even when it was chilled to 4 °C in conjunction with transfer from road tanker to storage tank. Even longer storage times may be expected when working weeks are limited to six or even five days. During cold storage, the milk protein and milk salts change character, which tends to impair cheese making properties. It has been shown that about 25 % of the calcium precipitates as phosphate after 24 hours storage at +5 °C. This reduction, however, is temporary. When the milk is pasteurized, the calcium redissolves and the coagulating properties of the milk are almost completely restored. b-casein also leaves the complex casein micelle system during cold storage, which further contributes to reducing the cheese making properties. However, this reduction too is almost completely restored by pasteurization.

Thermization moderate heat treatment at 65 °C for 15 S, which is often given to cheese milk.

The figure below shows reception arrangements for cheese milk.



1. Air eliminator.
2. Filter.
3. Milk Meter.
4. Intermediate storage tank.
5. Thermization and cooling or cooling only.
6. Silo tank.

General manufacturing Procedure:

The temperatures, times, and target pH for different steps, the sequence of processing steps, the use of salting or brining, block formation, and aging vary considerably between cheese types. The following flow chart provides a very general outline of cheese making steps. The general processing steps for Cheddar cheese are used for illustration.

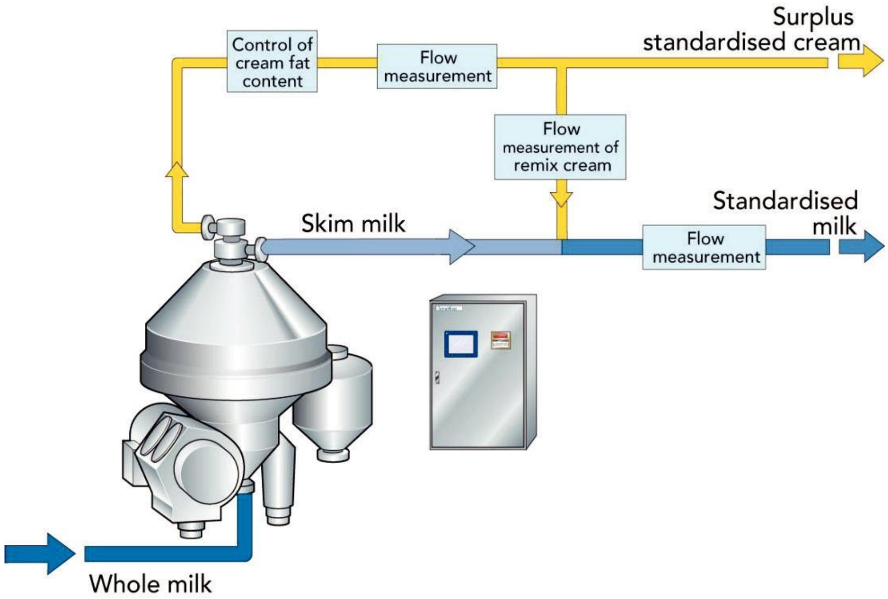
General Cheese Processing Steps:

- Milk standardization.
- Pasteurization/Heat treatment milk.
- Milk Cooling.
- Inoculating with starter and non-starter bacteria and ripen.
- Adding rennet and forming curd.
- Cutting curd and heating.
- Whey draining.
- Texture Curd.
- Dry salt or brine.
- Forming cheese into blocks.
- Storage and aging.
- Packaging.

The times, temperatures, and target pH values used for cheddar cheese will depend on individual formulations and the intended end use of the cheese. These conditions can be adjusted to optimize the properties of Cheddar cheese for shredding, melting, or for cheese that is meant to be aged for several years.

1- Milk Standardization:

Refers to the adjustment which means rising or lowering of fat and solids not fat levels of milk. The standardization of milk is commonly done in case of market milk supply and also in case of milk products.



2- Pasteurization:

Before the actual cheese making begins, the milk usually undergoes pre-treatment designed to create optimum conditions for production. Milk intended for cheese that requires more than one month of ripening needs not necessarily be pasteurized, but usually is.

you can see that milk intended for unripened cheese (fresh cheese) must be pasteurized. This implies that cheese milk for types needing a ripening period of at least one month need not be pasteurized.

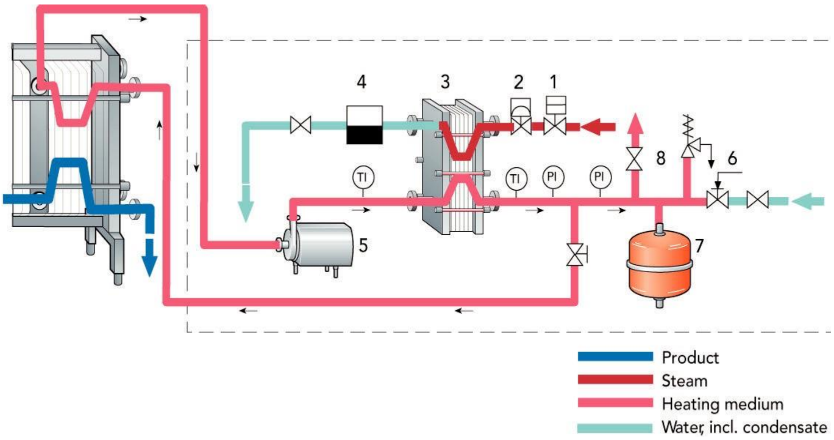
Pasteurization equalizes the bacterial composition of the milk from one day to the next, eliminating disturbances in an automatic or time-controlled process. Pasteurization must be sufficient to kill bacteria capable of affecting the quality of the cheese.

It must also kill most of the natural bacteria. pasteurization at 72 – 73 °C for 15 – 20 seconds is therefore most commonly applied.

Hot water heating systems

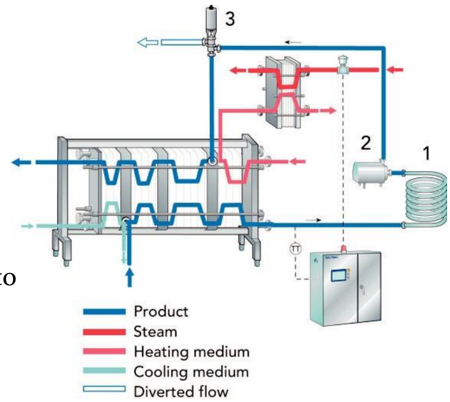
1. Steam shut-off valve
2. Steam regulating valve
3. Heat exchanger
4. Steam trap
5. Centrifugal pump
6. Water regulating valve
7. Expansion vessel
8. Safety and ventilation valves

- **TI** Temperature indicator
- **PI** Pressure indicator



Temperature control

A constant pasteurization temperature is maintained by a temperature controller acting on the steam regulating valve. Any tendency for the product temperature to drop is immediately detected by a sensor in the product line before the holding tube. The sensor then changes the signal to the controller, which opens the steam-regulating valve to supply more steam to the water. This increases the temperature of the circulating water and stops the temperature drop in the product.



Holding

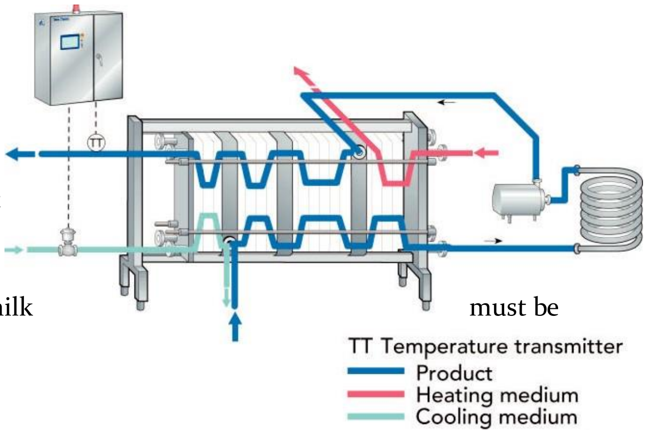
The length and size of the externally located holding tube are calculated according to the known holding time and hourly capacity of the plant and the pipe dimension, typically the same as for the pipes feeding the pasteurization plant. Typically, the holding tube is covered by a stainless steel hood to prevent people from being burnt when touching it and from radiation as well.

Pasteurization control

It is essential that the milk has been properly pasteurized before it leaves the plate heat exchanger. If the temperature drops below 72 °C, the unpasteurized milk must be kept apart from the already pasteurized product. To accomplish this, a temperature transmitter and flow diversion valve are fitted in the pipe downstream of the holding tube. A Valve returns unpasteurized milk to the balance tank if the temperature transmitter detects that the milk passing it has not been sufficiently heated.

3- Milk Cooling:

Milk is cooled after pasteurization or heat treatment to 32℃ to bring it to the temperature needed for the starter bacteria to grow. If raw milk is used the milk must be heated to 32℃.

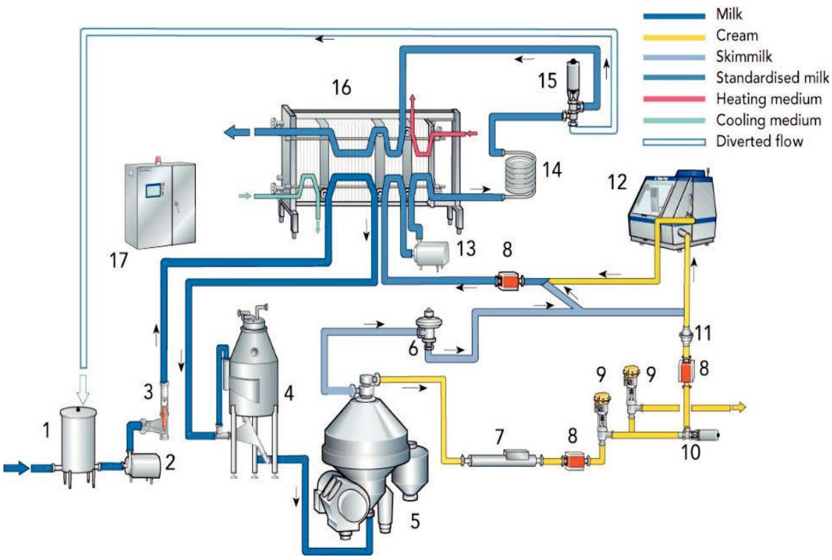


Pasteurizer cooling system

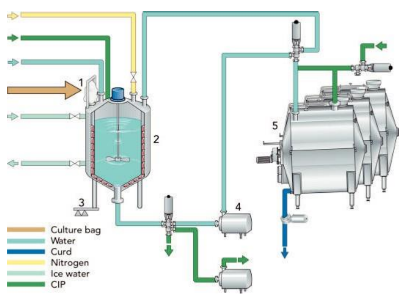
As already noted, the product is cooled mainly by regenerative heat exchange. The maximum practical efficiency of regeneration is about 94 – 95%, which means that the lowest temperature obtained by regenerative cooling is about 8 – 9 °C. Chilling the milk to 4 °C for storage therefore requires a cooling medium with a temperature of about 2 °C. Ice water can only be used if the final temperature is above 3 – 4 °C. For lower temperatures, it is necessary to use brine or alcohol solutions, to avoid the risk of freezing cooling media. The coolant is circulated from the dairy refrigeration plant to the point of use. The flow of coolant to the pasteurizer cooling section is controlled to maintain a constant product outlet temperature. This is done by a regulating circuit consisting of a temperature transmitter in the outgoing product line, a temperature controller in the control panel and a regulating valve in the coolant supply line. The position of the regulating valve is altered by the controller in response to signals from the transmitter. The signal from the transmitter is directly proportional to the temperature of the product leaving the pasteurizer. This signal is often connected to a temperature recorder in the control panel and recorded on a graph, together with the pasteurization temperature and the position of the flow diversion valve.

The complete pasteurizer

1-Balance tank
2-Product feed pump
3-Flow controller
4-Deaerator
5-Separator
6-Constant pressure valve
7-Density transmitter
8-Flow transmitter
9-Regulating valve
10-Shut-off valve
11-Check valve
12-Homogenisator
13-Booster pump
14-Holding tube
15-Flow diversion valve
16-Plate heat exchanger
17-Process control



4- Inoculating with starter and non-starter bacteria and ripen:



The essential additives in the cheese making process are the starter culture and the rennet. Under certain conditions it may also be necessary to supply other components such as calcium chloride. The starter culture is a very important factor in cheese making; it performs several duties.
The starter cultures and any non-starter adjunct bacteria are added to the milk and held at 32°C for 30 minutes to ripen. The

ripening step allows the bacteria to grow and begin fermentation, which lowers the pH and develops the flavor of the cheese.

5- Adding Rennet and forming Curd:

All cheese manufacture depends upon formation of curd by the action of rennet or similar enzymes. Coagulation of casein is the fundamental process in cheese making. It is generally done with rennet, but other proteolytic enzymes can be used, as well as acidification of the casein to the iso-electric point (pH 4.6 – 4.7).

6- Cutting Curd and heating:

Heat treatment is required during cheese making to regulate the size and acidification of the curd. The growth of acid-producing bacteria is limited by heat, which is thus used to regulate production of lactic acid. Apart from the bacteriological effect, the heat also promotes contraction of the curd accompanied by expulsion of whey.
This figure shows a cross-section of cutting and stirring tool blade:

7- Drain whey

The whey is drained from the vat and the curd forms a mat.

8- Texture curd

The curd mats are cut into sections and piled on top of each other and flipped periodically. This step is called **cheddarin**g. Cheddaring helps to expel more whey, allows the fermentation to continue until a pH of 5.1 to 5.5 is reached, and allows the mats to "knit" together and form a tighter matted structure. The curd mats are then milled (cut) into smaller pieces.

9- Dry Salt or Brine

For cheddar cheese, the smaller, milled curd pieces are put back in the vat and salted by sprinkling dry salt on the curd and mixing in the salt. In some cheese varieties, such as mozzarella, the curd is formed into loaves and then the loaves are placed in a brine (salt water solution).

10-Form Cheese into Blocks

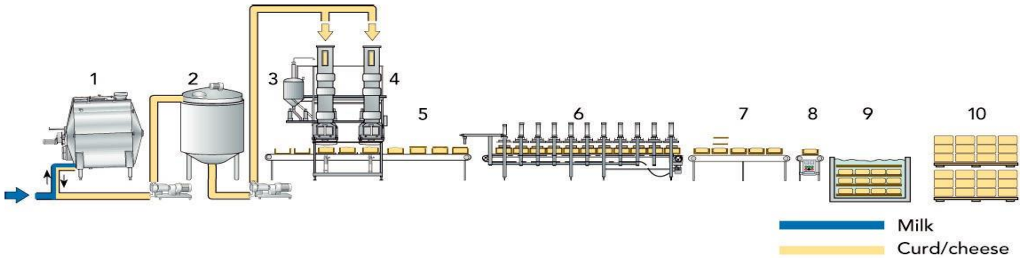
The salted curd pieces are placed in cheese hoops and pressed into blocks to form the cheese.

11- Store and Age

The cheese is stored in coolers until the desired age is reached. Depending on the variety, cheese can be aged from several months to several years.

12- Package

Cheese may be cut and packaged into blocks or it may be waxed.



So that was the milk's journey to become cheese.

The following chapter describes the frequently used components in dairy processing. It covers only those components that are used in liquid milk processing. Cheese making equipment.

1- Heat exchangers

The following three types of heat exchangers are the most widely used nowadays:

- Plate heat exchanger
- Tubular heat exchanger

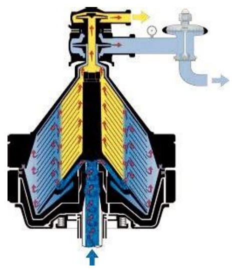
PLATE HEAT EXCHANGERS

Most heat treatment of dairy products is carried out in plate heat exchangers. consists of a pack of stainless steel plates clamped in a frame. The frame may contain several separate plate packs – sections – in which different stages of treatment, such as pre-heating, final heating and cooling take place. The heating medium is hot water, and the cooling medium cold water, ice-water or propyl glycol, depending on the required product outlet temperature.

TUBULAR HEAT EXCHANGERS

Tubular heat exchangers are in some cases used for pasteurization and UHT treatment of dairy products. The tubular heat exchanger unlike plate heat exchangers, has no contact points in the product channel and can thus handle products with particles up to a certain size. The maximum particle size depends on the diameter of the tube. The tubular heat exchanger can also run longer between cleanings than the plate heat exchanger in UHT treatment. Compared to a plate heat exchanger, a higher flow velocity is needed to create efficient heat transfer in a tubular heat exchanger.

2- Centrifugal separators



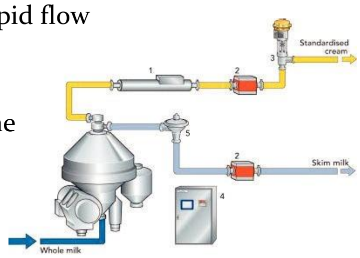
In modern milk processing plants with a diversified product range, direct in-line standardization is usually combined with separation. Control valves, flow and density meters and a computerized control loop are used to adjust the fat content of milk and cream to desired values. The pressure in the skim milk outlet must be kept constant in order to enable accurate standardization. This pressure must be maintained, regardless of variations in flow or pressure drop caused by the equipment after separation, and this is done with a constant-pressure valve located close to the skim milk outlet.

- **CREAM FAT CONTROL SYSTEM**

The fat content of the cream in the outlet from the separator is determined by the cream flow rate. The cream fat content is inversely proportional to the flow rate. Some standardization systems therefore use flow meters to control the fat content. This is the quickest method and as long as the temperature and fat content in the whole milk before separation are constant.

CASCADE CONTROL

A combination of accurate measurement of the fat content and rapid flow metering, known as cascade control, offers great advantages. The cascade control system thus results in fewer product losses and a more accurate result. The computer monitors the fat content of the cream, the flow rate of the cream and the setting of the cream regulating valve.



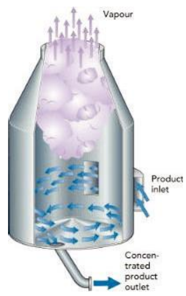
- **FAT CONTROL BY DENSITY MEASUREMENT**

Measurement of the cream fat content is based on the fixed relationship which exists between fat content and density. The fat content varies inversely with density because the fat in cream is lighter than the milk serum.

- **FLOW TRANSMITTER**

Flow control valves for cream and skim milk

3- Evaporators



Increase the concentration of the product

4- Pumps

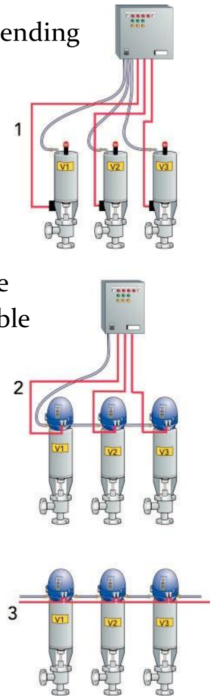
The centrifugal pump is commonly used in dairy production

5- Pipes

6- Valves

- **POSITION INDICATION AND CONTROL**

A valve can be fitted with various types of position indication. Depending on the control system of the plant. Different types of switches are **microswitches**, **inductive proximity switches** or **Hall elements.** The switches are used for feedback signals to the control system. When only switches are fitted to the valves, it is necessary to have one solenoid valve for each valve in a solenoid-valve cabinet. A solenoid valve supplies compressed air to the product valve when it receives a signal and releases the air pressure when the signal disappears. This system (1) requires one electric cable and one air hose for each valve. The combined unit (2) is a basic top unit, which is fitted on the top of the valve actuator. It includes activation stem, sensor system and solenoid valves. One air hose can supply many valves but one electric cable per valve is still required.



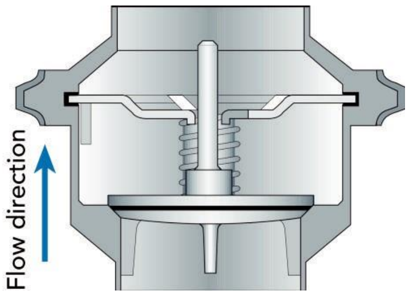
The following figure shows Valve position indication systems

1- Indication only
2- Indication with top unit
3- Indication and control system

- **CHECK AND CONTROL VALVES**

CHECK VALVES:

A check valve is fitted when it is necessary to prevent the product from flowing in the wrong direction. The valve is kept open by the liquid flow in the correct direction. If the flow stops, the valve plug is forced against its seat by the spring. The valve then closes against reversal of the flow.



CONTROL VALVES:

The control valve is used for accurate control of flows and pressures at various points in the system.

7- Tanks

Tanks in a dairy factory are used for number of purposes. The sizes range from 150 000 liters for the silo tanks in the reception department down to approximately 100 liters for the smallest tanks.

Tanks can generally be divided into two main categories according to function:

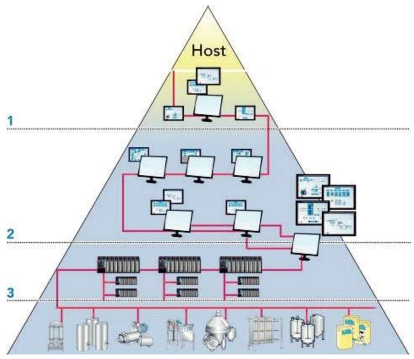
- Storage tanks

Automation role in the cheese process

PROCESS CONTROL

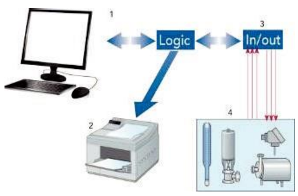
Shown a Schematic control system layout for a complete process line.

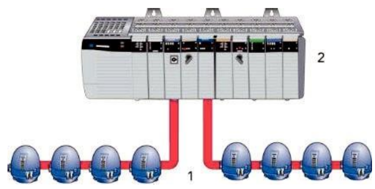
1- Business planning and logistics
2- Manufacturing operations and control
3- Production control



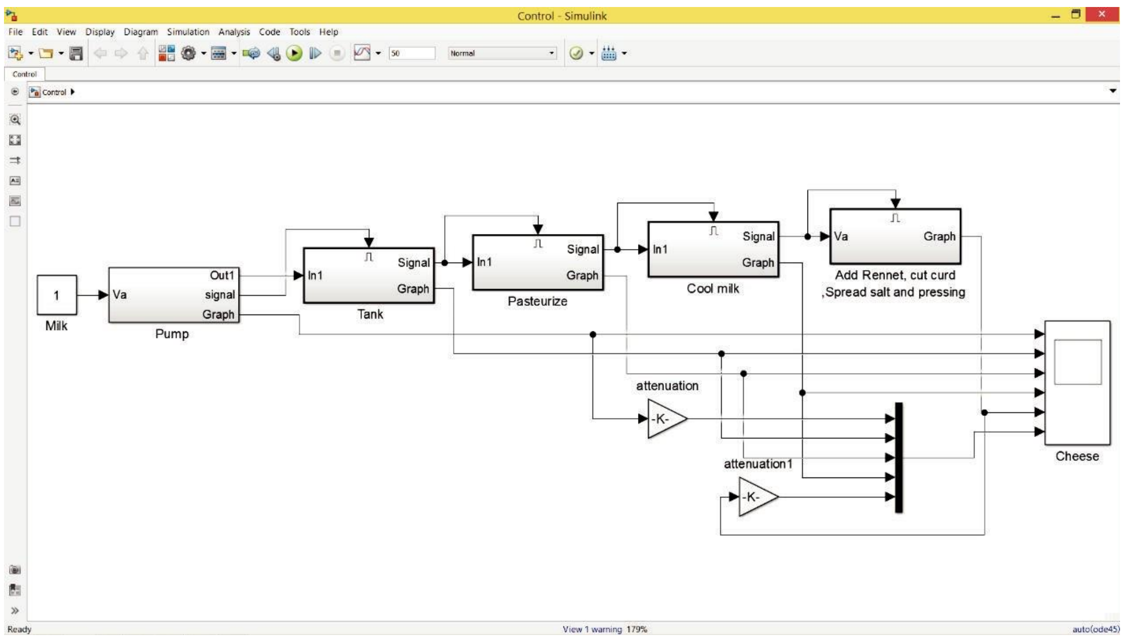
WHY DO WE NEED AUTOMATION?

- Food safety
- Consistent product quality
- Reliability
- Production economy
- Flexible production
- Production control
- Traceability



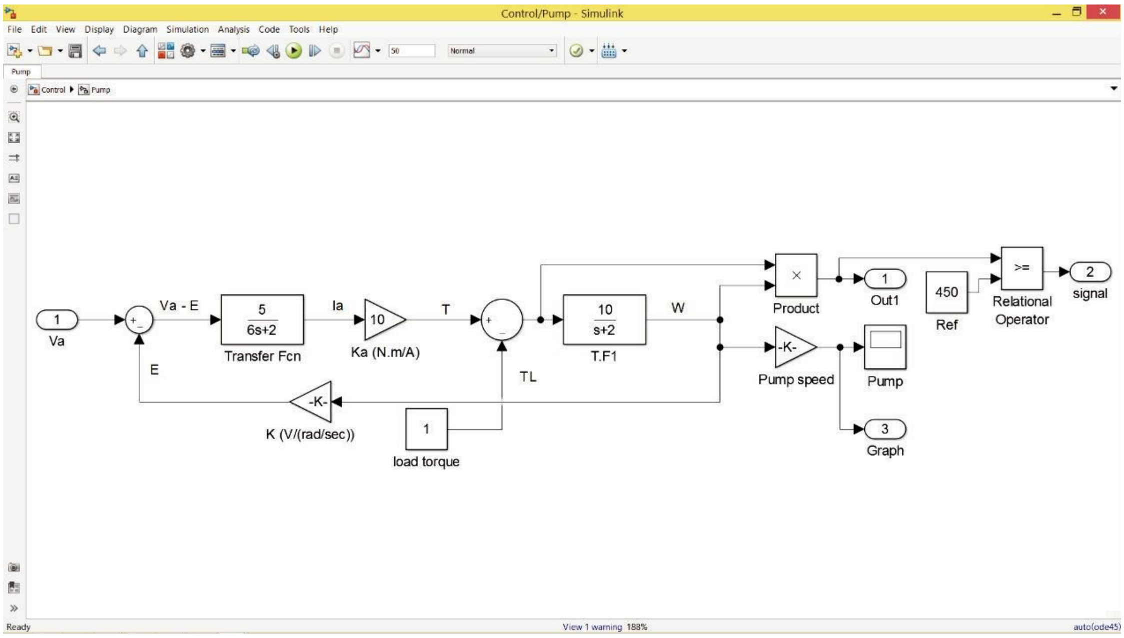


Simulation using MATLAB



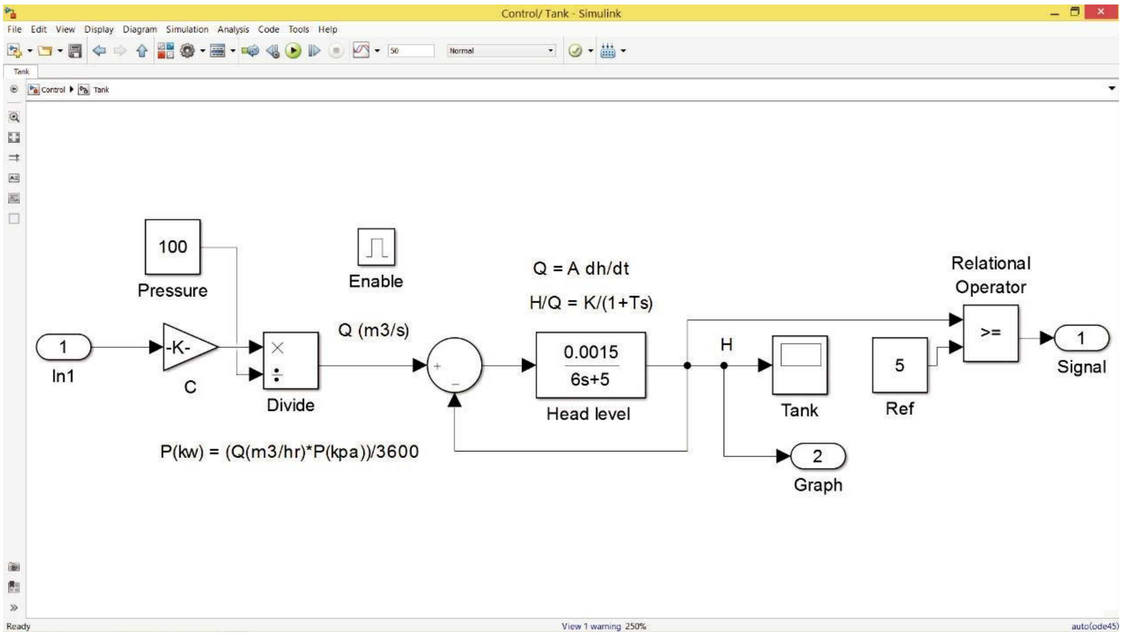
This the overall simulation for the process represented in 5 steps, all blocks represent the response of the system depending on the previous state.

1- Pump



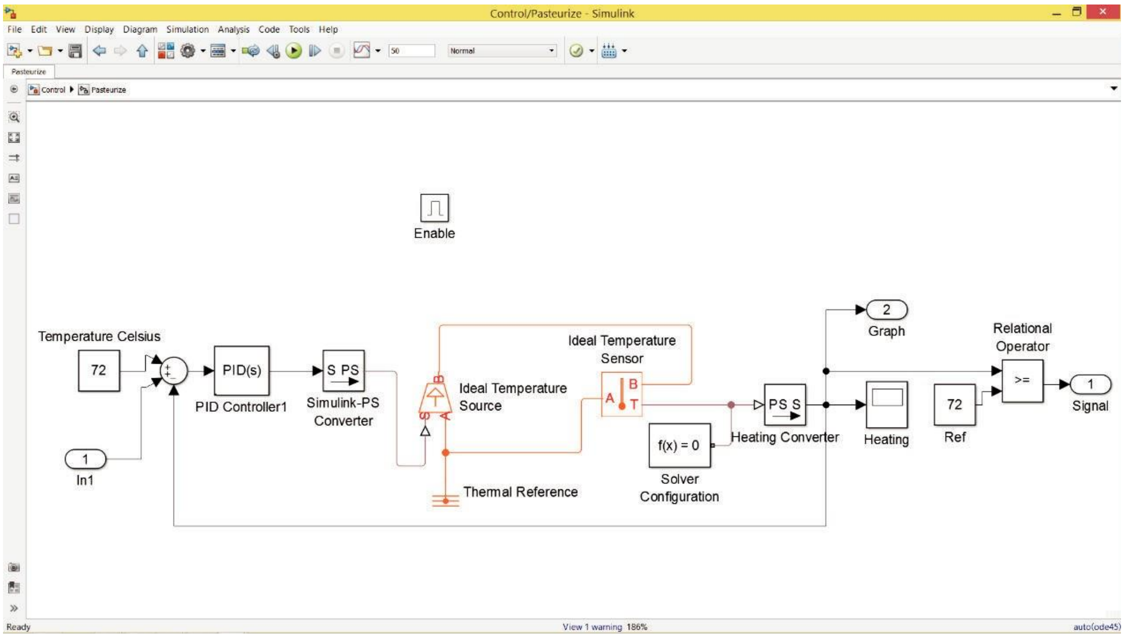
The pump input is the voltage V_a for the DC motor and the output is Power of the pump

2- Tank



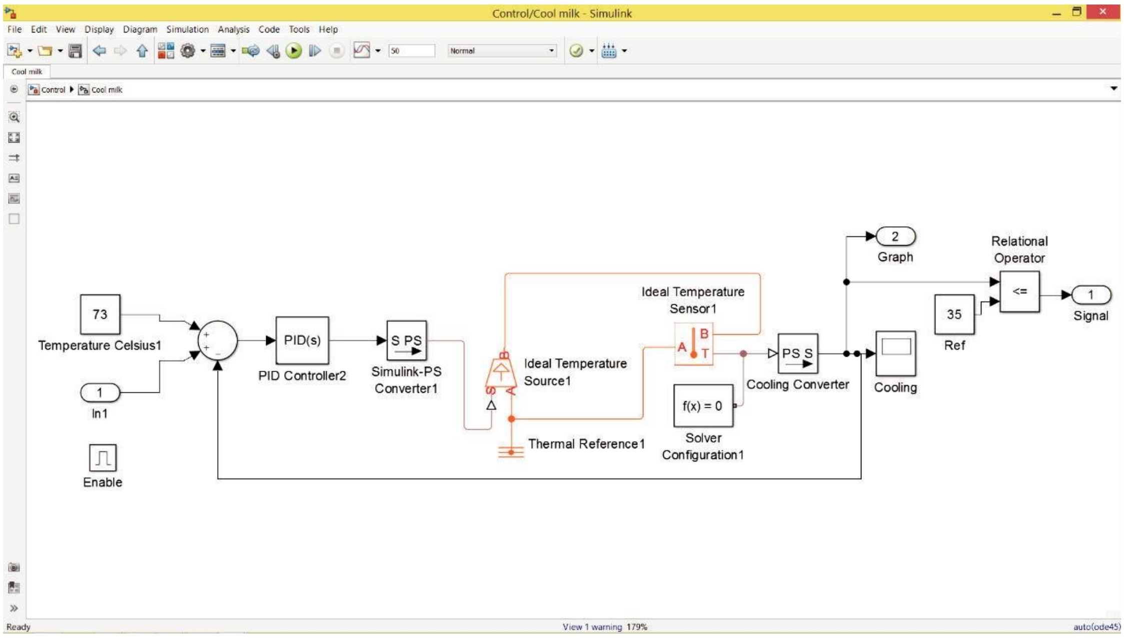
The tank input is the power of the pump and its output is the head level of milk

3- Pasteurize



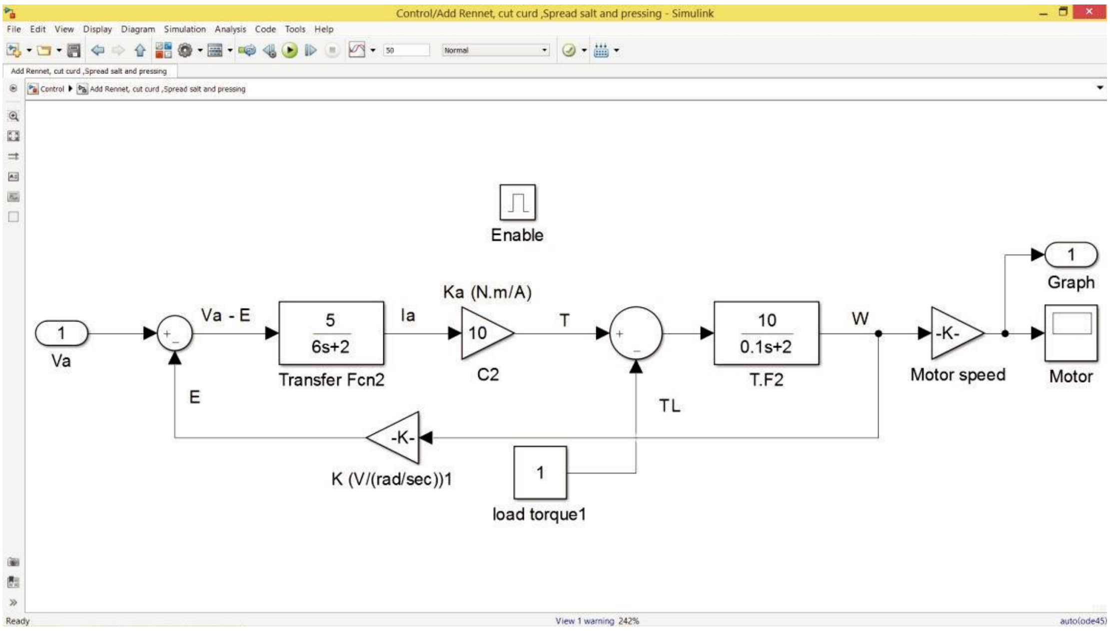
The pasteurization process is to heat the milk to 73ºC

4- Cooing milk



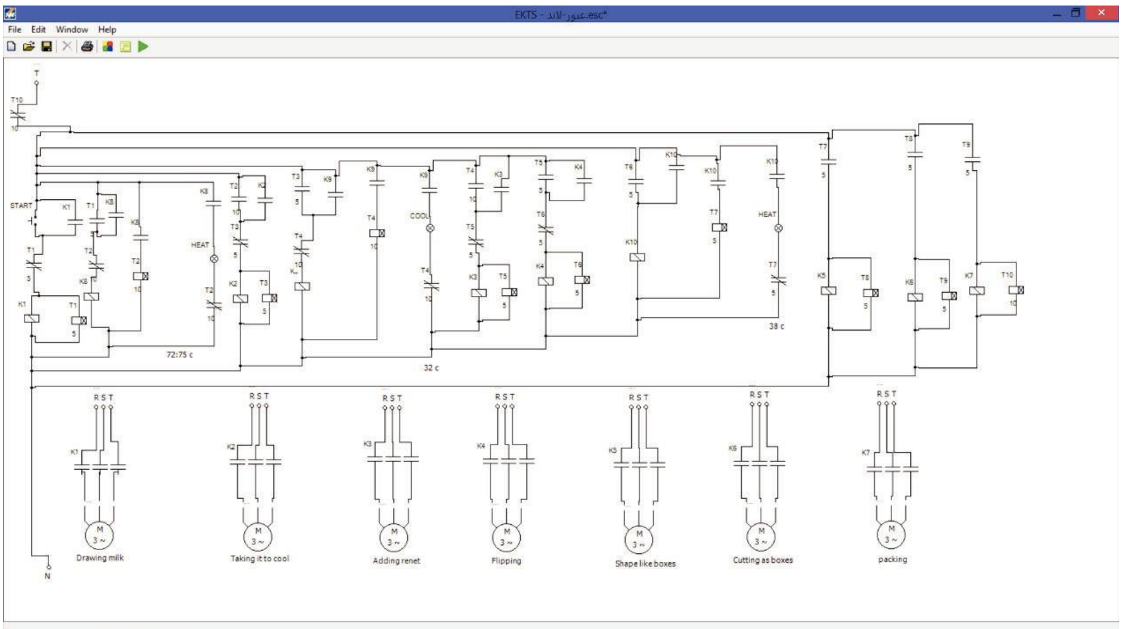
The cooling process is to cool the milk to 30ºC

5- Add Rennet, cut curd, spread salt and pressing



The rest of process is a simulation to DC motor for adding rennet, cutting, spreading and pressing

Simulation using EKTS



Reference

http://dairyprocessinghandbook.com/chapter/cheese

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