HYGIENIC DESIGN ASPECTS OF PASTEURIZER TO PREVENT CROSS CONTAMINATION OF PASTEURIZED MILK

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Abstract

Design aspects of the pasteurizer shall be able to address effective pasteurization of each particle of milk as well as to prevent cross contamination of pasteurized milk.

To ensure effective pasteurization of each particle of milk the design shall address: holding coil design, flow monitoring and control, flow diversion valve (FDV) design, placement, safe mode installation, temperature sensors response time and fail safe connection.

The design shall also address prevention of pasteurized milk cross contamination like, balance tank design, holding coil contamination during every diversion, re-infection through back growth of microorganism from return line, cross-contamination due to pin hole/ hair line cracks in PHE plates/gasket, siphonage of raw milk into pasteurized line due to vacuum creation during diversion.

This article reviews various international standards on pasteurization process design aspects to prevent cross-contamination by raw milk/heat exchanging medias’ due to pin-hole, leak/ hair line cracks in plates and gaskets during production, diversion as well as power failures. This can be achieved by maintaining pasteurized milk at higher pressure than raw milk/heat exchanging medias’ at all times.

Hygienic regeneration bypass assembly helps to maintain positive pressure in the pasteurized milk side during low temperature diversion and power failures. Regeneration bypass assembly also helps to optimize the time taken to regain the required pasteurization temperatures at holding tube outlet within 3 minutes compared to 12-15 minutes in pasteurizers without regeneration bypass assembly.

Key Words: Diversion, regeneration by-pass (RBS), stuffing pump, deflator plate, vacuum breaker, positive pressure.

1. Introduction

This article reviews the advanced hygienic design aspects of pasteurizer which have evolved in the last decade. In the most of the developed countries the design is regulated in the way that provides effective implementation. Also the heat treatment equipment must be approved or authorized by the competent authority for operation and controls, which assures food safety of the valued consumers.

Temperature and time requirements for milk pasteurization are based on thermal death time studies for the key pathogenic microbes generally found in raw milk like Bacillus cereus, Listeria monocytogenes, Yersinia enterocolitica, Salmonella spp., Escherichia coli O157:H7, Campylobacter jejuni [1].

A heat exchanger used for pasteurization in dairy industry [2], is usually a piece of equipment that continually transfers heat from one medium to another. There are two main types of heat exchangers or:

a) Direct heat exchanger, where both media are in direct contact with each other. It is taken for granted that the media are not inter-mixing (e.g. cooling tower) and

b) Indirect heat exchanger, where both media are separated by a wall through which heat is transferred (e.g. plate heat exchanger).

2. General hygienic aspects of pasteurization process

Pasteurization process shall be able to kill all pathogens and improve milk keeping quality. Pasteurizer design shall address both issues, or effective pasteurization of each milk particle and prevention of various cross-contamination between raw milk, heating and cooling medium.
2.1 Pre-requisites to ensure effective pasteurization of each milk particle:

To ensure effective pasteurization of each milk particle, the design shall address holding coil design like continuous upward slope of min 2.1 cm/m and suitable length based on rheological properties of the product, milk flow monitoring and control, flow diversion valve (FDV) design (combination of primary and secondary valves or mix proof valve) [4, 7] which has to assure: bacterium tightness, FDV placement and safe mode installation, temperature sensors response time and fail safe connection.

2.2 Possibilities of cross-contamination of pasteurized milk in the pasteurizer:

Pasteurized milk can be easily cross-contaminated if:

a) The raw milk from balance tank will be syphoned into the pasteurized milk lines, if the balance tank overflow level is higher than the level of return lines. This happens in case of malfunction of FDVs or failure of FDV "O" ring.

b) Holding coil is contaminated during every diversion by inadequately pasteurized milk;

c) There is re-infection through back growth of microorganism from return line;

d) PHE plates/gasket contains pin hole/hair line cracks;

e) Raw milk is being sucked into pasteurized line due to vacuum creation in the downstream cooling and regeneration zone during diversion

f) Only one FDV, located at cooling zone outlet, is used for diverting the inadequately pasteurized milk as well as inadequately cooled milk. During every diversion, inadequately pasteurized milk contaminates downstream regeneration section and cooling sections. The solution of interlocking FDV to take care of the contaminated part is not practiced, due to very long duration of recirculation affecting productivity.

g) Pinholes, hairline cracks in heat exchange plates or gaskets, leading to contamination of pasteurized milk by raw milk/heat exchanging medias'.

This can be eliminated by maintaining pasteurized milk at higher pressure than raw milk/heat exchanging medias'. We have taken an approach hygienic engineering solution to address the above.

In plate heat exchangers, regeneration zones are used. When the milk enters the heat exchanger, it is warmed by milk that has already been heated and this, in turn, is at the same time cooled by the milk coming in. The latter is subsequently heated further by hot water (or steam). It is then flow through a holder section to achieve a sufficient heating time. After being cooled by the incoming milk, it is cooled further by means of cooling medium. Milk being heated and cooled is always in counter flow (Fig. 1) and the temperature difference between the two remains constant [8].

In general, thickness of the plate in plate-pack arrangement is about only 0.6 mm. To prevent cross-contamination (Fig. 1) from raw milk/heat exchanging medias’, positive pressure MUST be maintained in the pasteurized milk side always. This includes start-up, production, diversion, clarifier/seperator auto-desludging as well as power failure. In general, equipment is designed to maintain positive pressure only during production. However it is also equally important to maintain positive pressure of 1 to 2 psi more in pasteurized milk side vs raw milk/heat exchanging medias’ at all the time. This requirement is widely covered in various international standards like: EHEDG Doc. 1, 3-A Standard, PMO 2011, AS 3993-2003 [7], Canadian Food Inspection Agency Requirement [4] and British Columbia [5].

Developing countries are yet to have standards for equipment design to achieve the above. In the absence of national standards each equipment supplier is supplying pasteurizers of their own design, which leads to partial compliance with the key hygienic design aspects.

![Figure 1. Microbiological Hazards in the Regeneration Sections](image-url)
2.3 Current challenges in dairy industry on cross contaminations during pasteurization

2.3.1 General

According to few international standards and practices, during pasteurization process, if the temperature at holding coil outlet drops below pasteurization temperature, pasteurizer has to be emptied and pasteurizer cleaning and sanitation has to be carried out before production is re-started. However, in developing countries, frequency of diversion is very high due to frequent power failure (four to eight times daily) and other insufficient utilities support. In such cases, it is highly impractical to perform CIP after every temperature failure during processing. Hence, unpasteurized milk is diverted back to balance tank, and circulated through pasteurizer. When temperatures at holding coil outlet and cooling zone outlet reached to pasteurization conditions, milk is forwarded into pasteurized milk silos.

Being Critical Control Point of the process, milk pasteurization temperature is automatically controlled through Flow Diversion Valve (FDV) located at holding coil outlet. Whenever milk temperature drops from the set value (critical limit), milk is diverted by FDV back to balance tank/constant level tank. During diversion, positive pressure situation in pasteurizer get disturbed. Higher raw milk pressure in regenerator section may results in unacceptable cross-contamination of pasteurized milk side due to plate cracks and gasket failure.

During such process disturbance to prevent cross-contamination, raw milk shall be allowed to travel through the regeneration bypass system. During regeneration bypass, regeneration zones shall be connected to stuffing pump suction line. This will create sub-atmospheric pressure in the raw milk side of regeneration zones. Vacuum breaker shall be placed before flow diversion valve at cooling zone outlet. The pasteurized milk line containing vacuum breaker shall be elevated 30.5 centimeters (12 inches) above any raw milk contained in the pasteurizer system. Vacuum breaker will open during diversion and prevent generation of vacuum in pasteurized milk side.

According to dairy processing plants code for HTST pasteurization [5], raw milk in the regeneration zone shall drain freely to balance tank when the feed pump is shut down and the raw line is disconnected at the regenerator outlet. This may be accomplished by drilling a two (2) mm (Fig. 2) hole in raw milk channel deflector plates, and feeding the raw milk into the bottom of the regeneration section.

Also design of balance tank shall include return lines (divert, leak detect), CIP and water lines connections to prevent the siphonage of raw milk into the pasteurized milk or water lines. This is accomplished by ensuring that the lines break to atmosphere at a distance equal to or greater than two times the diameter of the largest return line above the maximum flood level of the constant level tank. When product to product regeneration is employed, the overflow point shall be lower than the bottom of the raw regenerator. The constant level tank shall have a lid (Fig. 3).

During diversion, pasteurized milk in the regeneration zones is held under sub-atmospheric pressure due to volumetric contraction of milk. This suction may be gradually relieved by possible entrance. Vacuum breakers [3], are installed on pasteurizers to help maintain proper pressure relationships in milk-to-milk regenerator sections, or to prevent a negative pressure development.
between the FDV and any downstream flow-promoting device. The use of vacuum breakers is allowed provided vacuum breakers must open to the atmosphere when subject to a negative pressure. The pasteurized milk, between its outlet from the regenerator and the nearest point downstream open to the atmosphere, shall rise to a vertical elevation of 30.5 centimeters (12 inches) above the highest raw milk level, downstream from the balance tank, and shall be open to the atmosphere at this or a higher elevation. Vacuum breaker shall make of hygienic design. The drain line connecting regeneration zone and balance tank shall not have free drainage back to the balance tank when diversion/shutdown occurs.

According to 3-A Sanitary Standards [6], raw milk shall bypass the regenerator during startup, when the raw product stuffing pump is in operation or during processing to modify product temperatures. The bypass system permits cold product to be drawn directly to stuffing pump from the balance tank. After achieving pasteurization temperature at holding coil outlet, feed pump starts to operate feeding raw milk into regeneration zones. The bypass pipeline shall be manually or automatically controlled by a valve. Entrapment of product in the bypass pipeline during period when the feed pump is in operation shall be precluded by close coupled bypass connections, or by design of the manually or automatically-controlled valve which will permits/low of product through the bypass pipeline. The function of regenerator or pressure controller system shall not be defeated through use of this bypass. The manufacturer shall have a current diagram available showing the plate and port arrangement in the correct operating sequence, and with the correct location of drain holes.

In this article two different scenarios are discussed as follows.

2.4 Creating pressure differential in pasteurizer during foreword flow

The purpose of the differential pressure in pasteurizer is to ensure the maintenance of higher pressure on the of the pasteurized milk in comparison to:

a) unpasteurized/raw milk,

b) cooling medium in the cooling section

c) heating medium in the heating section.

This is achieved by maintaining the following pressure differentials (Fig. 5):

- Under stable process conditions, when the milk is in forward-flow, the pressure on the pasteurized milk side of the regeneration and raw milk/heat exchanging medias’ zones shall not be less than 10 kPa above the pressure on the raw milk/heat exchanging medias’ side of any common heat exchange surface.

- The pressure drop (0.2 to 0.3 bar) across regeneration zones rises, so the product pressure before the heat exchanger must be increased to force the product through the plates of heat exchangers. It is necessary to install a booster pump at heating zone inlet. Back pressure valve (installed at chilling zone outlet) throttles the flow of milk, resulting in pressurized pasteurized milk line. This increased milk pressure will be uniformly distributed in pasteurized milk zones in the regenerators (approximately 3.5 Bar).

Figure 3. Feeding raw milk into the bottom of regeneration section & keeping the balance tank overflow line below the raw milk level in the REG Zones
2.5 Creating pressure differential in pasteurizer during diversion flow

a) During diversion, milk is diverted back to balance tank by flow diversion valve (Fig. 4). Thus pasteurized milk will not enter in the regeneration zones. Raw milk pressure in regeneration zones increases vs pasteurized milk. This may lead to possible cross-contamination of pasteurized milk due to hair line cracks or gasket failure.

b) Hygienic bypass assembly is used to aid during start-up of high capacity HTST systems. Their purpose is to bypass raw milk going in the Regeneration Zones. This will help to maintain differential pressure in regeneration section as well as to achieve pasteurization temperature at holding coil outlet in short time.

2.5.1 Components of Hygienic bypass:

2.5.1.1 Feed Pump
This pump shall be installed between the balance tank and the raw regeneration zone (Fig. 4) and operate only when ALL of the following conditions are met:

a) The feed pump is inter-wired with booster pump and shall only operate when the booster pump is running.

b) The feed pump is inter-wired with the flow diversion valve and only operates when the valve is in forward flow.

c) The feed pump must be wired through an automatic pressure control device that shall only permit the feed pump to operate when the pressure in the pasteurized side of the regeneration zone exceeds by at least 1 pound per square inch the pressure generated by the feed pump.

d) In the magnetic flow timing systems, centrifugal pumps are used as the timing pump.

2.5.1.2 Booster pump
This term is used for centrifugal pumps placed before heating zone in the pasteurizer. Sometimes, booster pumps used as timing pumps (to feed Milk to homogenizer). In these installations, the Booster Pump shall always be inter-wired with the homogenizer to prohibit operation unless the homogenizer is operating. In fact, all flow promoters in the HTST system are only allowed to operate in conjunction with the timing pump.

2.5.1.3 Stuffing pump
This term is used for a centrifugal pump placed between two successive Regeneration zones (Regeneration no. 1 & 2) of Pasteurizer. Stuffing pump will operate in case of diversion. Stuffing Pump will directly draw Raw Milk from balance tank and feed to clarifier by bypassing the Regeneration Zone no.1.

2.5.1.4 Regeneration bypass assembly pipework:

a) These lines and the associated valves allow cold raw milk from the balance tank to by-pass the raw regeneration zones and feed directly to the stuffing pump. Often when the homogenizer is used as the timing pump, a centrifugal booster pump will feed the inlet side of the homogenizer.

Figure 4. Schematic showing positive pressure in pasteurized milk side during diversion mode
b) The by-pass line valves may be automatically or manually controlled. This line shall not use when the feed pump is in operation. The by-pass line and valves must be designed, installed and operated to prevent product from being trapped in the dead end of blocked line for extended periods of time. This may be achieved by having the line and valve close-coupled or by having the valve designed to permit a small amount of product to flow through the line during normal product runs in forward flow.

2.5.1.5 Operating conditions:

a) Close coupled regeneration bypass assembly, with “ZERO” or “Dead end less than 1D (diameter of pipe)” shall be installed in each regeneration zone in raw side. While diversion, raw product in the regeneration shall drain freely to balance tank, by drilling a two (2) mm hole in the raw product channel deflector plates, and feeding the raw milk into the bottom of the REG section.

b) Balance tank is connected to feed pump. Feed pump is kept “OFF” & stuffing pump shall be “ON”. In regeneration zone no. 2, raw product shall get drained freely to the balance tank through drain valve.

c) Elevate the milk line at cooling zone outlet by 30.5 centimeters & install vacuum breaker, open to atmosphere at this elevation. Cooling medium circulation in cooling zone shall be stopped automatically during diversion.

d) To maintain positive pressure in the pasteurized milk side, during power failures:
   - Stuffing pump and PLC are to be connected through battery back-up
   - Regeneration bypass as well as clarifier/separator bypass shall be activated.
   - Vacuum breaker will be automatically opened to allow atmospheric pressure to come in regeneration zones.

3. Conclusions

- Hygienic regeneration bypass assembly helps to maintain positive pressure in the pasteurized milk side during start-up, low temperature diversion and power failures. This also prevents contamination of pasteurized milk by raw milk as well as heat transfer medias.'
- Hygienic regeneration bypass assembly is able to achieve pasteurization parameters (temperature at holding coil outlet and cooling zone outlet, pressure differential relationship) within optimal time.
- Alternate option for maintaining positive pressure during diversion and start-up is FDV placement at cooling zone outlet instead at holding coil outlet. During every diversion inadequately pasteurized milk contaminates downstream regeneration section and cooling sections. Hence the FDV is to be interlocked for circulation of hot milk to ensure the

![Fig 5: Schematic showing positive pressure in pasteurized milk side during forward flow](image-url)
coldest part (FDV located at cooling zone outlet) is heated to and remain at pasteurization temperature continuously and simultaneously for atleast required pasteurization time to destroy all relevant microorganisms. However, time taken to achieve desired pasteurization temperatures at holding coil outlet and cooling zone outlet, are three times more than regeneration bypass assembly.

- Hygienic regenerator bypass assembly also supports to minimize steam and energy consumption during start-up/diversion mode.

4. References


