PASTEURIZATION OF GRADE "A" MILK AND MILK PRODUCTS BY STEAM INJECTION

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(Received for publication January 26, 1973)

ABSTRACT

Steam injection systems are in common use in some parts of the United States. They have not been recognized, however, as a satisfactory method for pasteurizing milk and milk products because of possible poor mixing of steam and product, vapor formation in the holding tube, and inadequate public health controls. Recent research has solved these problems and steam injectors may be used to pasteurize milk products when the steam and product flows are isolated from the pressure fluctuations in the injection chamber, when no vapor is formed in the holding tube, and when non-condensable gases are eliminated from the steam supply. The injection chamber is isolated by installing supplementary orifices of a proper size at the injector ports to maintain a product pressure drop of 10 psi across the injector. Vapor formation is prevented by maintaining a holding tube pressure 10 psi above the boiling pressure of the liquid product. Non-condensable gases are eliminated from the steam supply by installing an approved deaerator in the boiler system.

Ultra-High Temperature (UHT) processes by plate heat exchange have been identified for milk and milk products *(9)*; however, the commercial application of these processes has been limited to cream and flavored products that are relatively heat stable. During pasteurization, the total heat treatment given the product is the sum of that received during heating, holding, and cooling, and in plate heat exchangers, the heating and cooling phases represent a significant portion of the total heat treatment. Conversely, in steam injection systems, heating and cooling are virtually instantaneous, and as a result, the total heat treatment is only slightly greater than that received in the holding tube. Because of this, steam injection systems appear useful in minimizing organoleptic damage caused by the high temperatures of UHT processes.

Steam injection systems are used routinely in southern and central parts of the United States for flavor control of milk products, and adequate controls are supplied with these systems to prevent dilution of product with water. Such systems have not been used for pasteurization, however, because of possible inadequate mixing of steam and product *(7)*, reduced residence times in the holding tube due to vapor formation, and inadequate controls for the instantaneous temperature drop that occurs with a loss of steam *(8)*.

Recent research has yielded solutions to these problems. Temperature variations in product leaving the injector are negligible when the steam and product flows are isolated from the pressure fluctuations in the injection chamber *(11)*. Residence times in the holding tube are constant when the pressure of product in the holding tube is held 10 psi above the boiling pressure of the liquid *(3)*; and adequate controls have been developed for steam injection systems *(12)*. These research accomplishments have enabled the identification of satisfactory processes for pasteurization of milk and milk products by steam injection.

TIME-TEMPERATURE STANDARDS

The recommended time-temperature standards are identical to those specified for ultra-high temperature pasteurization by plate heat exchange *(9)*. These are: *(a)* 1 sec hold at 191 F, *(b)* 0.5 sec hold at 194 F, *(c)* 0.1 sec hold at 201 F, *(d)* 0.05 sec hold at 204 F, and *(e)* 0.01 sec hold at 212 F.

These combinations of time and temperature are minimum requirements, and actual processing conditions may exceed these requirements in either time or temperature. The time and temperatures are applicable to all milk and milk products which are now being pasteurized in plate-type pasteurizers (whole milk including Vitamin D and fortified, skim milk, low fat milk, chocolate milk and drink, cream, frozen dessert mix, eggnog, and concentrated milk).

EQUIPMENT

The equipment is similar to that now used for conventional pasteurization and flavor control, where a plate heat exchanger, holding tube, and flow diversion valve are used to pasteurize the product before steam injection. For steam injection pasteurization, however, the product is preheated in a plate heat exchanger, heated to pasteurization temperature in the steam injector, pasteurized in the holding tube, precooled in the vacuum tank, cooled to storage temperature by the plate heat exchanger, and then controlled by the flow diversion valve (Fig. 1).

INSTALLING THE INJECTOR

Of all the problems associated with steam injectors,

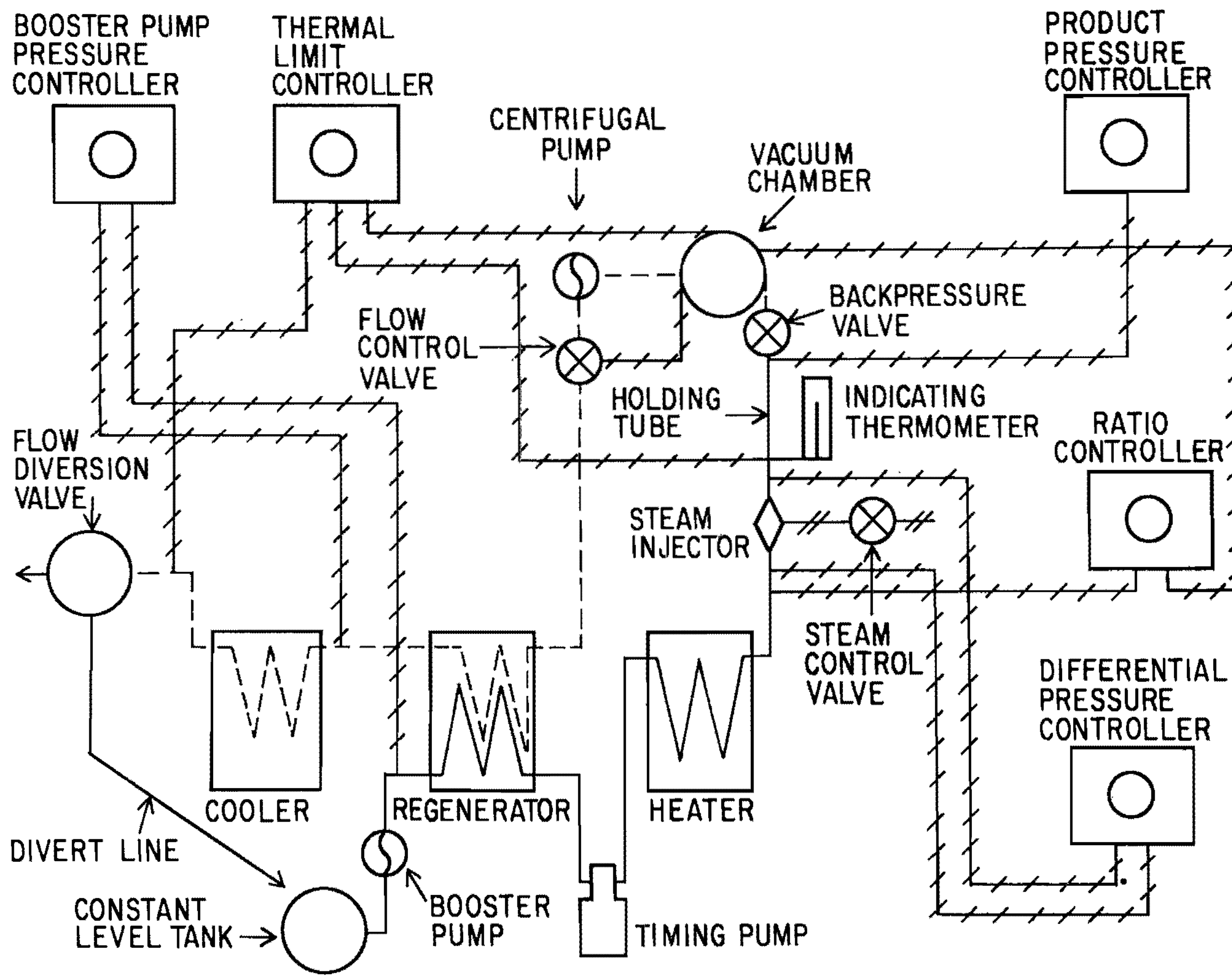

Figure 1. Flow diagram and controls for steam injection pasteurizers.

inadequate mixing of steam and product is the most serious. Unless the injector is installed properly, temperature fluctuations of ± 28 F may occur *(11)*, and these fluctuations may persist for significant distances into the holding tube *(7, 11)*. Under some conditions, the temperature variations can be large enough to prevent normal operation of the temperature controller. Roberts and Dill *(10)* reported this problem in 1962 and minimized the temperature variations by installing an orifice at the injector exit.

To ensure proper operation, steam and product flows must be isolated from the pressure fluctuations in the injection chamber *(11)*. This is done by placing supplementary orifices at the product inlet and heated product outlet ports of the steam injector. A pressure drop of 10 psi across the injector is needed to ensure proper operation *(11)*. Since this pressure drop will vary with flow rate and product, a differential pressure control diverts flow whenever the pressure drop across the injector is less than 10 psi. Diagrams of several steam injectors are available elsewhere *(6, 11)*.

Vapor formation in the holding tube is prevented by maintaining injection pressure 15 psi higher than the boiling pressure of the liquid in the holding tube *(3)*. Since the pressure drop across the orifice at the injector exit is at least 5 psi, the above requirement is met by maintaining product pressure in the holding tube at least 10 psi above the boiling pressure of the liquid in the holding tube *(11)*. An absolute pressure control diverts flow when this condition is not met.

TIMING THE HOLDING TUBE

Since the flow of some dairy products is characterized as laminar and under these conditions the residence time of the fastest product can never be less than one-half that of the average of all particles *(2)*, holding time is computed in a manner similar to that developed for UHT pasteurization by plate heat exchange *(1)*. The procedure was modified to reflect a 12% flow increase by steam injection. Not all processes will require the injection of this much steam, so a small margin of safety exists for most processes. A steam addition rate of 12% (12 lb. of steam per 100 lb. of product) yields a temperature rise across the injector of 120 F, and is adequate to cover most operations.

CONTROLS

Most UHT pasteurizers have the flow diversion valve located at the end of the cooling section. This obviates two major problems. When the flow diversion valve is located at the end of the holding tube, it diverts unpasteurized product to the raw product supply tank, and stops flow of product to the pasteurized side of the regenerator. Any product at a temperature above 212 F, however, will boil when diverted to atmospheric pressure. From the plant operator's viewpoint, stopping the flow of product at the inlet to the pasteurized side of the regenerator causes more serious problems. At UHT temperatures, product quickly burns on to the heat exchange surfaces, and any significant flow stoppage requires a shutdown and a cleaning operation. The fluid in the raw product side of the regenerator continues to recirculate without cooling, but even a brief period of diverted flow can cause extensive flavor damage to the recirculating product *(4)*.

With steam injection systems, there is the additional problem of control response times. A complete loss of steam pressure causes a precipitous drop in temperature, and conventional controls do not have the speed of response required to prevent the forward flow of unpasteurized product *(8)*. However, by locating the flow diversion valve at the end of the cooling section rather than at the end of the holding tube, the conventional controls are sufficiently fast to prevent the forward flow of unpasteurized product after a complete loss of steam pressure. Consequently, for steam injection systems, the recommended location for the flow diversion valve is at the end of the cooling section. The controls required for steam injection systems are as follows:

Temperature controllers. The safety thermal limit recorder-controller controls the flow diversion valve to prevent mixing of raw and pasteurized products, and it can do this unassisted, only when the flow diversion valve is located at the end of the holding tube. When there is a diversion with the flow diversion valve located after the cooler, the vacuum chamber, the pasteurized side of the regenerator, and the cooler become contaminated with raw product, and forward flow must not occur until all product surfaces downstream from the holding tube have been sanitized. This is accomplished by installing two additional temperature controllers in the system. The sensing element of the safety thermal limit recorder-controller is installed in the product at the beginning of the holding tube. The sensing element of one auxiliary controller is installed in the steam vapors in the top of the vacuum chamber, and the other is installed in the product at the common port of the flow diversion valve. The three temperature controllers are interwired to prevent forward flow until the three temperature sensing elements have been exposed to fluid at pasteurization temperature, continuously and simultaneously for pasteurization time. This ensures that all product surfaces between the three sensing elements have been sanitized. To do this, the cooling water must be turned off and this is usually done automatically.

When the pasteurized lines have been sanitized by the above procedure, the sensing elements at the vacuum chamber and the flow-diversion valve are automatically dropped from the control circuit, the cooling water is turned on, and forward flow is permitted for as long as pasteurization requirements are met in the holding tube. If the temperature of product in the holding tube drops below that required for pasteurization, the flow-diversion valve is moved to the divert position, the sensing elements at the vacuum chamber and the flow-diversion valve are automatically returned to the control circuit, and forward flow is prevented until all of the product surfaces downstream from the holding tube have been sanitized.

Differential pressure controller. A differential pressure control is installed across the steam injector with sensors in the product flows entering and leaving the injector (Fig. 1). When the pressure differential across the injector is less than 10 psi, the controller moves the flow diversion valve to the divert position. Forward flow is prevented until the product surfaces downstream from the holding tube have been sanitized as described above.

Absolute pressure controller. An absolute pressure control is installed in the holding tube and is adjusted to move the flow diversion valve to the divert position whenever product pressure is less than 10 psi above the boiling pressure of the liquid in the holding tube (Fig. 1). Forward flow is prevented until the product surfaces downstream from the holding tube have been sanitized as described above.

Ratio controller. As with all steam injection systems, a ratio controller is required to prevent dilution of product (Fig. 1). The ratio controller and the steam supply will be interlocked in the same manner as for the high-temperature, short-time processes.

STEAM SUPPLY

The steam supply must be the same as that specified for existing flavor control systems *(13)*, with one additional provision: non-condensable gases must be removed. Non-condensable gases in the steam supply are injected into the product, and, although they are removed in the vacuum tank, they reduce the effectiveness of pasteurization.

Using a glass holding tube, Peterson and Jordan *(6)* photographed non-condensed gases after steam injection. Since the non-condensable gases enter the product downstream from the metering pump, they displace product in the holding tube and cause a reduction in holding time. Non-condensed gases also reduce the effectiveness of the mixing process between steam and product *(3, 5, 11)*.

To prevent the introduction of non-condensable gases through the steam injector, the steam boiler must be supplied with a deaerator and must be installed in accordance with the requirements of a qualified boiler feed water treatment authority.

When used in conjunction with approved and properly operated ancillary equipment, and when installed, and operated as described herein, steam injectors are acceptable for pasteurization of milk and milk products under that portion of definition S of the Grade "A" Pasteurized Milk Ordinance *(13)* which provides for other pasteurization processes recognized by the Food and Drug Administration to be equally efficient. More detailed information on methods and procedures for the inspection of equipment as well as the necessary wiring diagrams used for pasteurization by steam injection will be provided upon request.

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