RESEARCH PAPER
Visit us: *www.researchjournal.co.in*

Research Journal of Animal Husbandry and Dairy Science
Volume 6 | Issue 2 | Dec., 2015 | 130-134
⇨ e ISSN-2231-6442
■ DOI: 10.15740/HAS/RJAHDS/6.2/130-134

Performance evaluation of a plate type (HTST) milk pasteurizer

D.A. CHAUDHARY AND A.G. CHAUDHARI

ABSTRACT : The performance of plate type (HTST) milk pasteurizer was analyzed in a commercial dairy plant having installed capacity of 1.0 lakh lit./day. The purpose of the analysis was to determine the regeneration efficiency and utility usage includes steam, chilled water and electrical energy, in the milk pasteurization processing line. In this dairy plant, the experiment was carried out and results in 89.34 per cent regeneration efficiency achieved. Theoretical and actual steam consumption was determined at rate of 155.72 kg/hr and 156.48 kg/hr, respectively. Chilled water utilization was found to be 25.11 m^3 /hr *i.e.* 2.36 times than milk flow rate. Power consumption for milk pasteurization was found to be 16.09 kWh per hour.

KEY WORDS : Milk pasteurizer, HTST, Steam, Chilled water, Electrical energy

HOW TO CITE THIS PAPER : Chaudhary, D.A. and Chaudhari, A.G. (2015). Performance evaluation of a plate type (HTST) milk pasteurizer. *Res. J. Animal Hus. & Dairy Sci.,* **6**(2) : 130-134.

INTRODUCTION

One of the most important requirements of modern dairy industry is to be able to control the temperature of products at every stage in the process. Heating and cooling are therefore very common operations in the dairy processing operations. Pasteurization of milk is one of most common heat treatment process in dairy industry and is performed by heating of every particle of milk to at least 61^0 C and holding it at that temperature for 30 minutes, or heating the milk to 72^0 C and holding it at 72^0 C for 15 seconds and subsequent immediately cooled at temperature lower than 5^0 C. The primary purpose of heat treatment is to kill all micro organisms capable of causing disease (Ahmad, 1985).

There are two general type of pasteurizer, one is the batch type and another is continuous type or HTST. Plate heat exchangers (PHE) are one of the most widely used heat exchanger for a variety of purposes in dairy industry include pasteurization (for milk, cheese-milk, ice cream), raw milk cooling, and heating and cooling for by-product (yogurt, cream). They are highly efficient, compact, low in cost, versatile, sanitary and easily cleaned. It is made up of a frame or press, a number of gasketed plates which are arranged to form flow passages for the product and for the heating or cooling medium, and terminals which form the head or end of the plate stack and provide for piping connections (Sahay, and Singh, 2001).

The performance of HTST pasteurizer *i.e.* regeneration efficiency, heating and cooling medium requirement, directly affects the overall performance of plate type heat exchanger and it reduce with time, due to heat transfer fouling and poor operation and maintenance. Some methods are used to improve the efficiency of PHE by removal of the additional heat resistance of the fouling

MEMBERS OF RESEARCH FORUM

Address for correspondence :
D.A. Chaudhary, Department of Dairy Engineering, SMC College of Dairy Science, ANAND (GUJARAT) INDIA
Email : dchaudhary89@gmail.com

Associated Authors' :
A.G. Chaudhari, Department of Dairy Engineering, SMC College of Dairy Science, ANAND (GUJARAT) INDIA

layer and reduction of pressure drop in the process plant. This can be accomplished by incorporation of necessary compact design and their excellent heat transfer coefficient characteristics required for pasteurization purposes. The current study puts forward a performance evaluation of Plate type (HTST) Milk pasteurizer.

Process description :

In HTST Milk pasteurizer, the milk is pasteurized through plate heat exchangers which usually comprise four stages, i) pre heating or regeneration ii) heating, iii) holding and iv) cooling.

Regeneration section:

The milk at 5^0 C is fed into regeneration unit by a centrifugal pump. The cold milk is heated in the regeneration section by outgoing pasteurized milk. In this section, the cold incoming milk is heated to 55^0 C from 5^0 C by outgoing pasteurized milk, which is simultaneously pre-cooled to 18^0 C by incoming cold milk at 5^0 C. This saves heating and refrigeration energy. The process takes place in a heat exchanger and is called regenerative heat exchange or, more commonly, heat recovery. As much as 90 – 92 per cent of the heat content of the pasteurized milk can be recycled.

Heating section:

From regeneration unit, the warm milk is pumped by using booster pump, to plate heater where milk is heated at pasteurization temperature of 72^0 C by a heating medium. Hot water, vacuum steam or saturated steam at 100^0 C can be used as heating media. In HTST pasteurizer, hot steam, however is not used because of high differential temperature. The most commonly used heating media are therefore hot water or vacuum steam, although practically no vacuum system are delivered today.

Hot water system:

Steam is delivered from boiler at pressure of 6- 7 bar. This steam is used to heat water which heats the product to the pasteurization temperature.

Holding tube:

From heating section, the milk is then passed to holding tube where there is no any heat exchange take place.

Cooling section:

From regenerative cooling, the pasteurized milk is then pumped directly into cooling section where it is cooled at 4^0 C for final packaging. Generally 1^0 C chilled water or brine is circulated in the cooling section. Selection of holding tube is mainly depends on the capacity of pasteurizer and holding time.

The electrical energy is mainly utilized by centrifugal pump for transferring the milk from one place to another. The prime mover electric motors are employed for proper operation of the agitator by converting electrical energy into mechanical energy.

Design aspect of HTST pasteurizer :

The necessary size and configuration of a HTST pasteurizer depend on many factors includes i) Product flow rate, ii) Physical properties of the milk, iii) Temperature program, iv) Permitted pressure drops, v) Cleanability requirements and vi) Required running times.

MATERIAL AND METHODS

The Regeneration efficiency (RE) of a HTST pasteurizer is defined as ratio of the amount of heat supplied by regeneration to total heat load assuming no regeneration. Regeneration efficiency was calculated by (Gosta, 1995) using the following formula :

$$RE = \frac{W \times C(\theta_2 - \theta_1)}{W \times C(\theta_3 - \theta_1)} \times 100$$

where W-Mass flow rate of milk in m^3/ hour

C-Specific heat of milk in Kcal / kg ^{0}C

θ_1 - Inlet temperature in ^{0}C

θ_2 - Temperature leaving regeneration section in ^{0}C

θ_3 - Pasteurization temperature in ^{0}C

Steam consumption during pasteurization is calculated both theoretically and practically as follows.

Theoretical calculation:

Steam requirement is calculated from heating load of milk and is ratio of heat duty and enthalpy of steam corresponding to its pressure.

Heat duty (Q) of milk is the product of mass flow rate, specific heat and temperature difference.

$Q_{milk} = W_{milk}$ x ° x C (¯$_P$-¯$_2$)

where Q_{milk} - Heat duty of milk in Kcal / hour

W_{milk} - Mass flow rate of milk in m^3/ hour

ρ_{milk} -Density of milk in kg/m^3

C_{milk} - Specific heat of milk in Kcal / kg ^{0}C (For milk is C_p 3.89 kJ/kg ^{0}C).

θ_1-Temperature leaving regeneration section in ^{0}C

θ_2 -Pasteurization temperature in ^{0}C

Steam requirement is calculated by using following equation as given below.

$$W_{steam} = \frac{Q_{milk}}{\lambda_s}$$

where W_{steam} -Mass flow rate of steam required in kg/hour.

Q_{milk} - Heat duty of milk in Kcal / hour

λ_s-Enthalpy of steam corresponding to its pressure

Enthalpy of steam was taken from steam tables corresponding to the steam pressure.

Practical calculation :

– Condensate was collected at regular intervals in insulated container whose volume was pre-determined.

– Time required to fill up the container was noted.

Then steam consumption per hour was calculated.

– Daily steam consumption was calculated by multiplying average steam consumption with processing time.

– Daily milk processed was noted by the flow meter and also checked by scale provided inside the silos.

Cooling media requirement is calculated by using energy balance. Chilled water requirement is therefore calculated by using following equation.

$$W_{cw} = \frac{W_{milk}\ x\ \rho_{milk}\ x\ C_{milk}\ (\theta_4 - \theta_5)}{\rho_{CW}\ x\ C_{CW}\ (\theta_{cwr} - \theta_{cws})}$$

where W_{cw} – mass flow rate of chilled water in m^3/ hour

ρ_{cw} - Density of water in kg/ m^3

C_{cw}-Specific heat of water in Kcal / kg ^{0}C

θ_4 - Pasteurized milk temperature leaving regeneration section in ^{0}C

Table 1 : Performance study of milk pasteurization

Sr. No.	Time Hr:Min	Milk flow rate in LPH	Milk temperature in (^{o}C)					Utility parameter			
			θ_1	θ_2	θ_3	θ_4	θ_5	Steam pressure (kg/cm^2) Abs	θ_{Cond} (^{o}C)	θ_{cws}	θ_{cwr}
1.	00.00	10592	2.20	69.0	78.0	13.5	3.30	2.21	71.0	2.0	6.30
2.	01:00	10800	2.80	70.0	78.0	14.5	3.50	2.31	73.0	1.9	6.25
3.	02:00	10560	3.20	70.0	78.0	14.0	3.20	2.21	71.0	1.9	6.25
4.	03:00	10500	3.30	70.5	78.0	13.8	3.30	2.25	72.5	2.0	6.30
5.	04:00	10700	3.20	70.5	78.0	14.0	3.40	2.30	72.0	2.0	6.20
Avg.		10630	2.94	70.0	78.0	13.9	3.34	2.25	71.9	1.96	6.25

Table 2 : Electrical energy consumption in milk pasteurization section

Equipments	Running time/day (h:min)	Rated data		Actual electrical energy consumption/day					
		Power (kW)	Motor Eff. (%)	Voltage (V)	Current (A)	Cos ϕ	Power (kW)	Motor Load (%)	kWh Energy
Milk PHE pump	10 : 20	2.2	85.0	411.0	3.89	0.92	2.54	98.01	26.23
Booster pump	10 : 20	3.5	85.0	412.0	6.15	0.92	4.03	98.00	41.63
Chilled water pump	10 : 20	5.5	85.7	413.5	9.27	0.86	5.68	88.61	58.67
Hot water circulation pump	10 : 20	3.5	87.0	412.0	7.87	0.66	3.84	95.43	39.66
Total		14.7					16.09		166.19

Table 3 : Specific steam and electrical energy consumption per 100 kg milk processed

Sr. No.	Processing Time Hr:Min	Milk processed in kg	Steam consumption (kg)		Electrical energy consumption (kWh)		Specific utility consumption per 100 kg milk	
			Hourly	Total	Hourly	Total	Steam (kg)	Power (kWh)
1.	10:00	105920	150.27	1502	16.10	161.00	1.41	0.150
2.	10:10	109720	153.33	1557	16.05	163.06	1.42	0.146
3.	10:30	110880	160.00	1623	16.13	169.36	1.46	0.152
4.	10:50	114030	166.59	1809	15.98	173.54	1.58	0.152
5.	10:10	108712	152.23	1546	16.20	164.59	1.42	0.151
Avg.	10:20	109852	156.48	1616	16.09	166.20	1.47	0.151

θ_5 - Final cooling temperature in ^{0}C

θ_{cws} - chilled water supply temperature in ^{0}C

θ_{cwr} - chilled water return temperature in ^{0}C

The electrical energy consumption is determined by following procedure.

– Rated data mentioned on the electrical equipment were noted *i.e.* the rated power in hp (kW), voltage (v), current (A), efficiency (%) and power factor.

– Average running hours of all electrical equipment during processing were observed.

– Current, voltage and power factor of electric equipment were measured using power analyzer or digital clamp meter.

– Power consumption was calculated using the formula

3 phase AC wire equipment : $P = \sqrt{3}\, VI \cos\phi$

Single phase AC wire equipment : $P = VI \cos\phi$

where P, V, I and $\cos\phi$ are actual power consumption, voltage, current and power factor, respectively.

The actual load of motor was calculated using the formula given by Bureau of energy efficiency.

$$P_{ir} = \frac{\text{Name plate full rated kW}}{\eta_{fl}} \times 100$$

Where, p_{ir} = Input power at full-rated load (kW)

η_{fl} = Efficiency at full-rated load (%)

$$\text{Load}\,(\%) = \frac{P_i}{P_{ir}} \times 100$$

During experiment study, various instruments were used for measuring different parameters.

– Pressure gauge was used for measurement of steam pressure which provides the hot water for the purpose of milk heating up to pasteurization temperature.

– RTD is temperature sensing element and was used for measurement of temperature includes θ_1, θ_2, θ_3, θ_4, θ_5, θ_{cws}, θ_{cwr} and $\theta_{cond.}$. These all temperature are mentioned in above equations.

– Energy analyzer was utilized for measurement of mainly four electrical parameter *i.e.* Voltage, current, power and power factor, for the centrifugal pump and other electrical appliance.

Performance calculation :

The dairy plant selected for the study had milk pasteurization handling capacity of 1, 00,000 liters per day. During experiment, some of the milk as well as utility parameters observed and recorded are given in Table 1 and similarly name plate data and measured parameter for centrifugal pumps used in milk pasteurization units are illustrated in Table 2. These observation data's are employed for performance evaluation of milk pasteurizer having 10,000 LPH capacities and details calculation are as follows.

Regeneration efficiency:

For milk, Specific heat is 0.93 Kcal/kg ^{0}C

$$RE = \frac{W \times C\,(\theta_2 - \theta_1)}{W \times C\,(\theta_3 - \theta_1)} \times 100$$

$$= \frac{10630 \times 0.93\ (70 - 2.94)}{10630 \times 0.93\ (78 - 2.94)} \times 100$$

$$= \frac{67.06}{75.06} \times 100 = 89.34\%$$

Theoretical steam requirement is :

For milk, density value was obtained as 1032kg/m^3 by measurement using pycnomenter.

$$Q_{milk} = W_{milk} \times ° \times C\ (¯_P - ¯_2)$$

$$= 10.63 \times 1032 \times 0.93\ (78\text{-}70)$$

$$= 81617.99\ \frac{kcal}{hr}$$

Steam requirement is calculated by using following equation as given below.

For steam, Enthalpy = 524.13 kcal /kg at 2.25 kg/ cm^2

$$W_{steam} = \frac{Q_{milk}}{\lambda_s}$$

$$= \frac{81617.99}{524.13} = 155.72\ \frac{kg}{hr}$$

Actual Steam consumption per hourly in respective of milk processes is determined by practical method and observed data is illustrated in Table 3.Average steam consumption per hour is obtained as 156.48 kg / hr.

Theoretical chilled water requirement:

For chilled water, assumed that density and specific heat value is 1000 kg/m^3 and 1kcal/ kg ^{0}C, respectively.

$$W_{cw} = \frac{W_{milk} \times \rho_{milk} \times C_{milk}\ (\theta_4 - \theta_5)}{\rho_{CW} \times C_{CW}\ (\theta_{cwr} - \theta_{cws})}$$

$$= \frac{10.63 \times 1032 \times 0.93\ (13.9 - 3.34)}{1000 \times 1\ (6.25 - 1.96)} = \frac{107735.75}{4290} = 25.11\ \frac{m^2}{hr}$$

It means that 2.36 time chilled water flow rate is required to achieved our task.

Electrical energy calculation:

For milk PHE feed pump, rated power and efficiency is 2.2 kW and 85 per cent, respectively.

Power $=\sqrt{3}$ VI cos ϕ

$=1.732 \times 411 \times 3.89 \times 0.92$

$= 2547.57$ W = 2.55 kW.

$$\text{Load \%} = \frac{\text{Measured power x Efficiency}}{\text{Rated power}} \times 100$$

$$= \frac{2.55 \times 0.85}{2.2} \times 100$$

$$= \frac{2.167}{2.2} \times 100 = 98.52\%$$

Utility saving calculation :

$$\text{Refrigeration load} = W_{milk} \times \rho_{milk} \times C_{milk} (\theta_3 - \theta_4)$$

$= 10.63 \times 1032 \times 0.93 \; (78\text{-}13.9)$

$= 653964.14$ Kcal/hr

$= 653964.14 / 3000 = 217.98$ TR per hour

$$\text{Steam saving} = W_{milk} \times \rho_{milk} \times C_{milk} (\theta_2 - \theta_1)$$

$= 10.63 \times 1032 \times 0.93 \; (70\text{-}2.94)$

$= 684162.80$ Kcal/hr

$= 684162.80 / 524.13 = 1305.33$ kg/hr@ 2.25 kg/cm^2 pressure

Specific utility consumption :

Specific steam and electrical energy consumed per 100 kg milk processed are shown in Table 3. The steam consumption per 100 kg milk processed was found to be 1.47 kg. While the electrical energy consumption per 100 kg of milk was found to be 0.151 kWh. The similar finding was observed by Kanth (2003). They found that with a pasteurizer capacity of 11000 litres/hour and steam consumption and electrical energy consumption was reported as 1.6 kg and 0.20 kWh per 100 lit of milk, respectively.

Conclusion :

Keeping this in view performance evaluation of plate type (HTST) milk pasteurizer has been conducted in a commercial dairy plant having one lakh litre per day milk handling capacity. The experiment is carried out and results in pasteurizer having 89.34 regeneration capacity *i.e.* only 10.66 per cent energy required for achieving our task. Theoretical and actual steam consumption was determined at rate of 155.72 kg/hr and 156.48 kg/hr, respectively. Chilled water utilization was found to be 25.11 m^3 /hr *i.e.* 2.36 times than milk flow rate. Power consumption for milk pasteurization was found to be 16.09 kWh per hour. The average steam and power consumption per 100 kg of milk processed was calculated as 1.47 kg and 0.151 kWh.

LITERATURE CITED

Ahmad, Tufail (1985). *Dairy plant engineering and management*. Kitab Mahal Chapter 8,pp. 198-207.

Gosta, Bylund (1995). *Dairy processing handbook. Tetra Pak Processing Systems* AB. Chapter -6.1, pp:84-86.

Sahay, K.M. and Singh, K.K. (2001). *Unit operations of Agricultural process engineering*."Vikas Publishing House Pvt. Ltd., Chapter -7 pp: 316-318.

Received : *01.11.2015;* ***Revised:*** *08.11.2015;* ***Accepted :*** *22.11.2015*