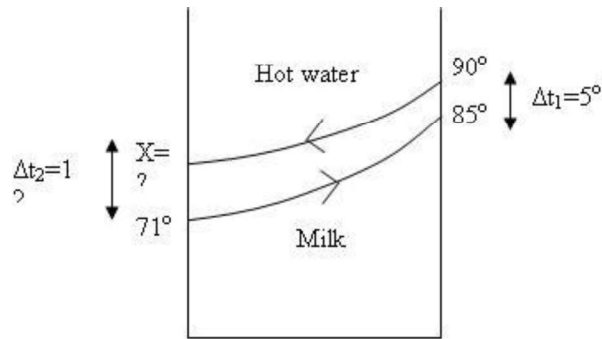




Applying heat balance X is calculated (temperature drop in hot water)

$$24000 \times 1 \times (90 - X) = 12000 \times 1 \times (85 - 71)$$

$$X = 83$$

Equation for LMTD (Log Mean Temperature Difference)

Equation for LMTD (Log Mean Temperature Difference)

$$t_{LMTD} = \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}}$$

$$t_{LMTD} = \frac{12 - 5}{\ln \frac{12}{5}}$$

$$= 8^\circ$$

The LMTD diagram can be represented as:

$$12 \left(\frac{71 - 85}{90 - 90} \right) 5 \quad t = 8^\circ\text{C}$$

For heat exchangers heat transfer rate is given as:

For heat exchangers heat transfer rate is given as:

$$Q = UA t_{LMTD}$$

Where,

Q = rate of heat transfer

A = Area of heat transfer

t_{LMTD} = Log mean temperature difference

Or

$$Q = UaN t_{LMTD} \dots\dots\dots(1)$$

Where,

A = area of one plate

N = number of plates

And since,

$$Q = m s \Delta t \dots (2)$$

From equations 1 and 2

$$UaN = m s \Delta t$$

$$N = 12000 \times 1 \times 14 = 24$$

$$0.375 \times 2320 \times 8$$

Arrangement $3 \times 5 / 2 \times 8 = 32$ plates.

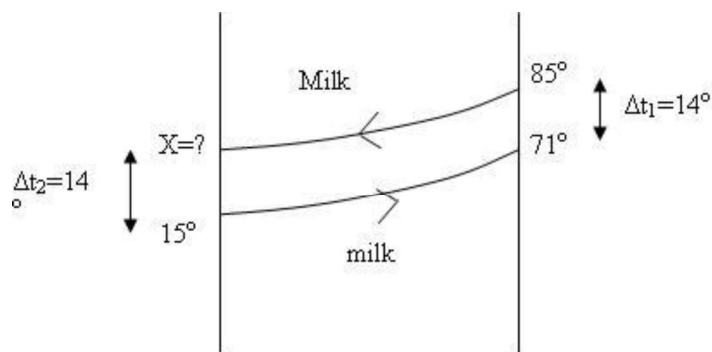
Here,

3×5 is for milk (3 passes and 5 channels)

2×8 is for hot water (2 passes and 5 channels)

Regenerating Section

The LMTD calculations are given below:



We know,

$$t_{LMTD} = \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}}$$

Since, $\Delta t_2 - \Delta t_1 = 14$ therefore we take the average value,

$$t_{LMTD} = \frac{\Delta t_2 + \Delta t_1}{2}$$

$$t_{LMTD} = \frac{14 + 14}{2} = 14$$

LMTD diagram can be represented as

$$1 \left(\frac{15 - 71}{29 - 85} \right) 14 \quad t = 14^\circ$$

We know,

$$UaN t_{LMTD} = m s \Delta t$$

$$N = 12000 \times 56 \times 1 = 56$$

$$0.375 \times 2290 \times 14$$

$$\text{Arrangement } 6 \times 5 / 6 \times 5 = 61$$

However, in the entering range 15 - 71 a branch to the centrifuge has to be provided as close as possible to 45 °C.

Each group means a rise in temperature of $71-15/6 = 9.3^\circ\text{C}$

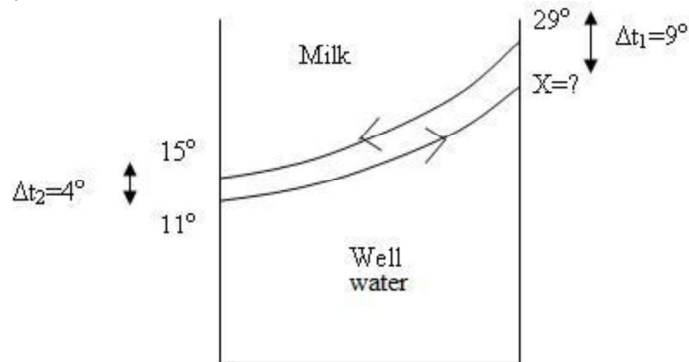
If we make a branch after 3 groups the temperature there will be approximately 43°C.

Arrangement reg. section I: $3 \times 5 / 3 \times 5 = 31$ plates

Reg. section II: $3 \times 5 / 3 \times 5 = 31$ plates

Cooling

By means of 18.000 l t r / h well water of 11 °C.



$$M_w S_w \Delta t = M_m S_m \Delta$$

$$18000 \times 1 \times (11-X) = 12000 \times 1 \times (29-15)$$

$$X = 20^\circ$$

$$M_w S_w \Delta t = M_m S_m \Delta$$

$$18000 \times 1 \times (11-X) = 12000 \times 1 \times (29-15)$$

$$X = 20^\circ$$

$$\Delta t_1 = 15 - 11 = 4$$

$$\Delta t_2 = 29 - 20 = 9$$

$$t_{LMTD} = \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}} = 6.1^\circ$$

LMTD diagram can be represented as:

$$9 \left(\frac{29-15}{20-11} \right)^4$$

$$t = 6.1^\circ \text{C}$$

We Know,

$$UaN t_{LMTD} = m s \Delta t$$

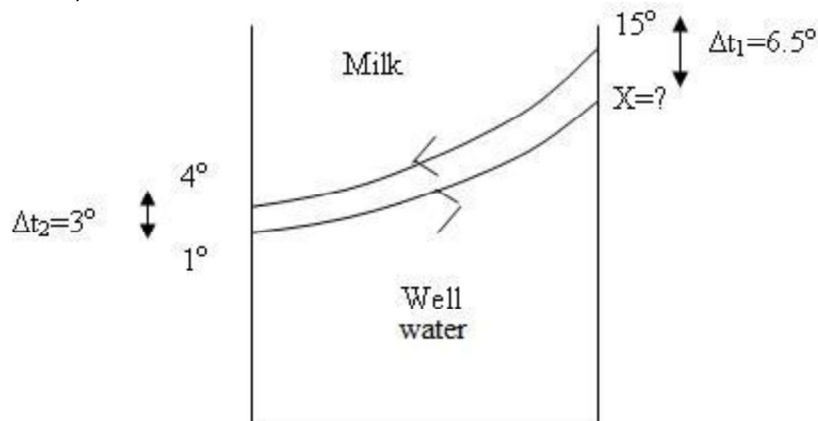
$$N = 12000 \times 14 \times 1 = 35$$

$$0.375 \times 2100 \times 6.1$$

$$\text{Arrangement } 3 \times 6 / 3 \times 6 = 37$$

Deep Cooling

By means of 24.000 l t r / h chilled water of 1°C.



$$M_m S_m \Delta t = M_c S_c \Delta$$

$$12000 \times 1 \times (15-4) = 24000 \times 1 \times (X-1)$$

$$X = 6.5^\circ$$

$$M_m S_m \Delta t = M_c S_c \Delta$$

$$12000 \times 1 \times (15-4) = 24000 \times 1 \times (X-1)$$

$$X = 6.5^\circ$$

$$\Delta t_1 = 4 \quad 1 = 3$$

$$\Delta t_2 = 15 - 6.5 = 8.5$$

$$t_{LMTD} = \frac{\Delta t_2 - \Delta t_1}{\ln \frac{\Delta t_2}{\Delta t_1}} = 5.25^\circ$$

LMTD diagram can be represented as:

$$8.5 \left(\frac{15-4}{6.5-1} \right)^3 \quad t = 5.25^\circ\text{C}$$

$$N = \frac{12000 \times 11 \times 1}{0.375 \times 1800 \times 5.25} = 36$$

$$\text{Arrangement } 3 \times 6 / 3 \times 6 = 37$$

$$= 5.25^\circ$$

$$\text{Arrangement } 3 \times 6 / 3 \times 6 = 37$$

Pressure Drops

Milk $15 \times 1.12 + 6 \times 0.78 + 28 \times 0.1 + 3$ (holding section) = 27.3 mwc

Hot water $2 \times 1.75 + 3 \times 0.19 = 4.1$ mwc

Well water $3 \times 1.75 + 4 \times 0.11 = 5.7$ mwc

Chilled water $3 \times 3.00 + 4 \times 0.19 = 9.8$ mwc

20.2 PROBLEM :

Calculate the number of plates in each section of HTST pasteurizer, for the following data:

Milk Hot water Chilled water

1. Flow Rate 10,000 lph 30,000 lph 30,000 lph

2. Inlet temperature 4°C 85°C 1°C

3. Outlet temperature 4°C

4. Overall heat

Transfer coefficient

'U' k.cal/m² hr $^\circ\text{C}$ 2320 2290 1800

Area of each plate is 0.375 m²; Regeneration Efficiency: 80%; Past. Temperature: 75°C

Soln:

Regeneration Section

$$\text{Regeneration } \frac{80}{100} = \frac{(x - 4)}{75 - 4}$$

$$X = 60.8$$

Heat balance between raw milk and heated milk

$$10,000 \times 0.93 \times (60.8 - 4) = 10,000 \times 0.93 \times (75 - x)$$

$$X = 18.2^\circ\text{C}$$

Note: Remember that rate of heat is different than the heat balance

Heating Section:

Heat gained by milk = Heat lost by hot water

$$10,000 \times 0.93 \times (75-60.8) = 30,000 \times 1 \times (85-X)$$

Chilling Section:

Heat lost by milk = Heat gained by chilled water

$$10,000 \times 0.93 \times (18.2-4) = 30,000 \times 1 \times (X-1)$$

$$X=5.7$$

Heat gained by raw milk in Regeneration section is rate of transfer in that section

$$10,000 \times 0.93 \times (60.8-4) = UA\Delta T_{LMTD}$$

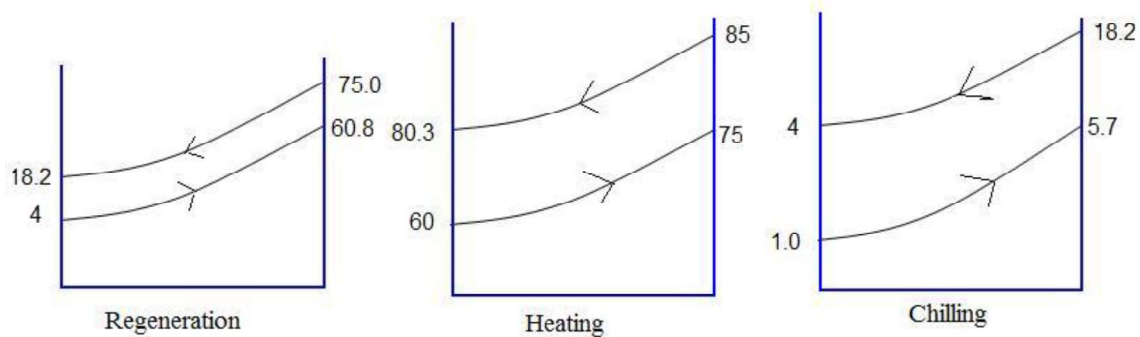


Fig.20.1 Temperature profiles in various section of pasteurizer

$$\begin{aligned} \Delta T_{LMTD} &= \frac{(18.2-4)-(75.0-60.8)}{\ln \frac{(18.2-4)}{(75-60.8)}} = \frac{(80.6-60)-(85-75)}{\ln \frac{(80.6-60)}{(85-75)}} = \frac{(4-1)-(18.2-5.7)}{\ln \frac{(3)}{(18.2-5.7)}} \\ &= \frac{(19.4-10)}{\ln \frac{(19.4)}{(10)}} = \frac{(12.5-3)}{\ln \frac{(12.5)}{(3)}} \\ &= \frac{9.4}{\ln(1.94)} = \frac{9.5}{\ln(4.16)} \\ &= \frac{9.4}{0.66} = \frac{9.8}{1.42} \\ &= 14.2 = 14.24 = 6.75 \end{aligned}$$

Balancing the heat exchanged to the Rate of heat transfer equation,

Regeneration Section: Chilling section Heating section

Balancing the heat exchanged to the Rate of heat transfer equation,

$$n = \frac{10,000 \times 0.93 \times (60.8 - 4)}{2290 \times 0.375 \times 14.3} = \frac{10,000 \times 0.93 \times (75 - 60)}{2320 \times 0.375 \times 11.24} = \frac{10,000 \times 0.93 \times (18.2 - 4)}{1800 \times 0.375 \times 6.75}$$

= 43.3 or 44 plates = 11.26 or 12 = 29

Answer: The number of plates required in Regeneration, heating and chilling sections are 44, 12 and 29 respectively.

Role of Correction Factor

The above calculations using LMTD, may not be the true representative of counter current flow, as the milk and service fluid are differing in the flow rates. To control the pressures on both sides to be equal, the flow in the channels is made unequal. When the milk and service fluid flow is in the ratio of the range of 0.66 to 1.5, it is possible to have equal number of passes on both sides of the exchangers making the flow to be counter current. When it becomes necessary to go for unequal passes due to large differences in flow rates, it becomes necessary to apply significant correction factor to take into account the non-counter current flow situation.

The extent of LMTD correction depends upon several factors, including the number of NTU/pass and number of channels per pass. Correction factor is required also because, in the end zones of plates, heat is transferred only on one side, and with even number of plates, one fluid has an extra stream or passage over the other.

$$F \text{ T LMTD cross flow} = F \times F \text{ LMTD}$$

$$F = \frac{\log_e \left(\frac{1-P}{1-P.R} \right)}{(R+1) \log_e \left(\frac{R}{R+1} \right) + \log_e (1-P.R.)}$$

$$\text{Where, } R = \frac{T_{hi} - T_{ho}}{T_{co} - T_{ci}}$$

$$P = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}}$$