# Chapter 4

# Technical Analysis

In this chapter will describe and the theory of heat transfers in each type, the theory of homogenization, the meaning of tubular heat exchanger, and the process diagram which is as a process model of this project. After that, will be the equipment requirement and cost estimation of equipment.

## 4.1 Heat transfer theory

Two substances must have different temperatures in order to transfer heat from one substance to another. Heat always flows from the warmer substance to colder. The heat flow is rapid when the temperature difference is great. During heat transfer, the difference in temperature is gradually reduced and he rate of transfer slows down, ceasing altogether when the temperatures are equalized.

Heat can be transferred in three ways, by conduction, convection and radiation.

### Conduction

Conduction means transfer of thermal energy through solid bodies and through layers of liquid at rest (without physical flow or mixing in the direction of heat transfer). Heat transferred by conduction to the handle, which becomes warmer

### Convection

Convection is a form of heat transfer that occurs when particles with high heat content are mixed with cold particles and transfer their heat to the latter by conduction. If the teaspoon is rinsed with running cold water, heat is transferred from the spoon to the water, which is heated in the process. The heated water is replaced by cold water, which in turn absorbs heat from the spoon. Heat transfer by convection continues until the spoon and the running water have the same temperature.

### Radiation

Radiation is the emission of heat from a body, which has accumulated thermal energy. The thermal energy is converted into radiant energy, emitted from the body and absorbed by other bodies, which it strikes. Almost all substances emit radiant energy.

## 4.2 Heat transfer principles

All heat transfer in dairies takes place in the form of convection and conduction. Two principles are used, direct and indirect heating.

### 4.2.1 Directed heating

Direct heating means that the heating medium is mixed with the product. This technique is used

- To heat water. Steam is injected directly into the water and transfers heat to the water by both convection and conduction.
- To heat products such as curd in the manufacture of certain types of cheese (by mixing hot water with the curd) and to sterilize milk by the direct method (steam injection or infusion of milk into steam).

The direct method of heat transfer is efficient for rapid heating. It offers certain advantages, which will be considered on long life milk production. It does, however, involve mixing the product with the heating medium, and this necessitates certain steps in the subsequent process. It also makes strict demands on the quality of the heating medium.

### 4.2.2 Indirect heating

Indirect heat transfer is therefore the most commonly used method in dairy. In this method a partition is placed between the product and the heating or cooling medium. Heat is then transferred from the medium through the partition into the product.

We assume that the heating medium is hot water, flowing on one side of the partition, and cold milk on the other. The partition is consequently heated on the heating-medium side and cooled on the product side. In a plate heat exchanger the plate is the partition.

There is a boundary layer on each side of the partition. The velocity of the liquids is slowed down by friction to almost zero at the boundary layer in contact with the partition. The layer immediately outside the boundary layer is only slowed down by the liquid in the boundary layer and therefore has a low velocity. The velocity increases progressively, and is highest at the center of the channel.

Similarly, the temperature of the hot water is highest in the middles of the channel. The closer the water is to the partition, the more the cold milk on the other side cools it. Convection and conduction, to the boundary layer transfer heat. Transfer from the boundary layer through the wall to the boundary layer on the other side is almost entirely by conduction, while both conduction and convection accomplish further transfer to the milk in the central zone of the channel

## 4.3 Heat exchanger

A heat exchanger is used to transfer heat by the indirect method. It is possible to simplify heat transfer by representing the heat exchanger symbolically as two channels separated by a tubular partition.

Hot water flows through one channel and milk through the other. Heat is transferred through the partition. The hot water enters the channel at a higher temperature is cooled to a lower temperature of at the outlet. Milk enters the heat exchanger at a lower temperature and is heated by the hot water to an exit temperature. The temperature changes during passage through the heat exchanger.

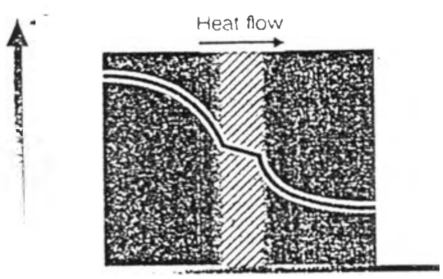


Figure 6: The direction of heat transfer.
Source: Diary processing handbook, Tetra Pak.

### 4.3.1 Holding tube

Correct heat treatment requires that the milk be held for a specified time at pasteurization temperature. This is done in an external holding cell. A holding cell usually consists of a pipe arranged in a spiral or zigzag patter. The length of the pipe and flow rate are calculated so that the time in the holding cell is equal to required holding time.

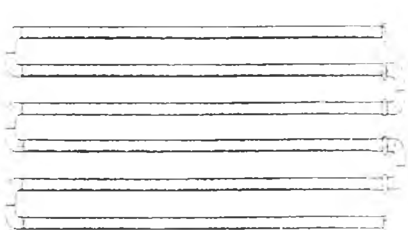

Figure 7: Holding tubes
Source: Diary processing handbook, Tetra Pak.

### 4.3.2 Tubular heat exchangers

Tubular heat exchangers are in some cases used for pasteurization 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.

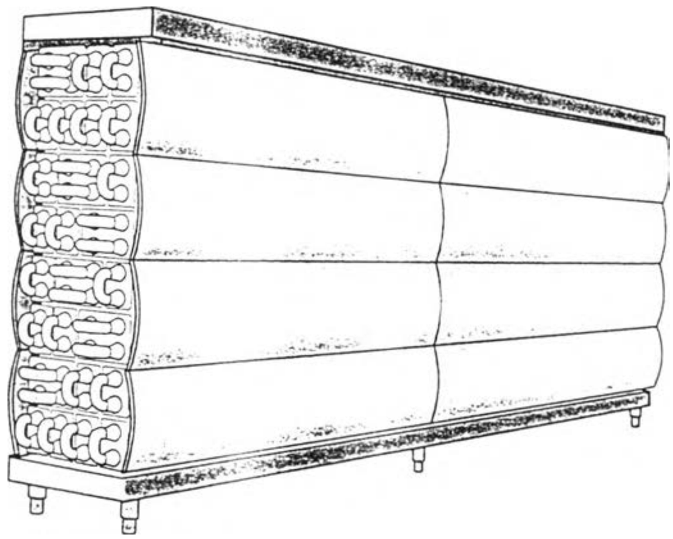

Figure 8: Tubular Heat Exchanger
Source: Diary processing handbook, Tetra Pak.

### 4.4 Introduction to Homogenizes

Homogenization has become a standard industrial process, universally practiced as a means of stabilizing the fat emulsion against gravity separation. Homogenization primarily causes disruption of fat globules into much smaller ones. Consequently, it diminishes creaming and may also diminish the tendency of globules to clump or coalesce. Essentially all homogenized milk is produced by mechanical means. Milk is force though a small passage at high velocity. The net result reduces the fat globules to approximately 1μm in diameter.

### Homogenization theories

Many theories of the mechanism of high-pressure homogenization have been presented over the year. For an oil-in-water dispersion like milk, where most of the droplets are less than one μm diameter, two theories have survived. Both of them give a good explanation of the influence of different parameters on the homogenization effect. The theory of globule disruption by turbulent eddies is based on the fact that a lot of small eddies are created in a liquid traveling at high velocity. Higher velocity gives smaller eddies. If an eddy hits an oil droplet of its own size, the droplet will break up.

## 4.5 Process model and equipment

The picture of process model below will be used as a model for calculation.

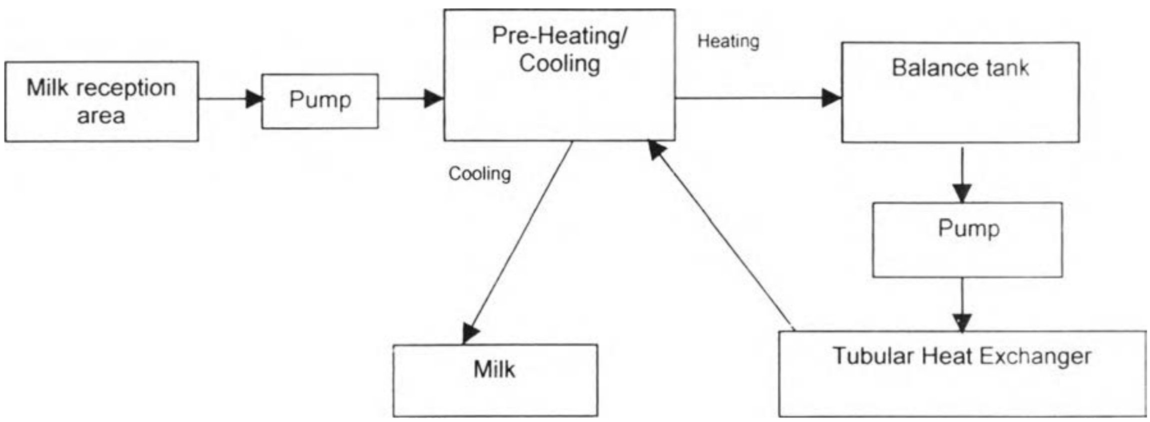


Figure 9: Process diagram of fresh milk pasteurization

According to the process model above, the beginning of the process is milk reception. The fresh milk will arrive factory in tank car, 5000 – 12000 Kg/car, and will be loaded to storage tank. After that, fresh milk will be sent to coffee processing area, distance is 200 meter.

- **Pipe**

The distance from fresh milk reception to processing line of liquid coffee is around 200 meter. It is necessary to have 2 pipes, one is used to transfer and the other is for cleaning chemical forward purpose, cleaning in place (CIP). So, length of pipe will be 400 meter with diameter 2 inches according to the existing pipe diameter.

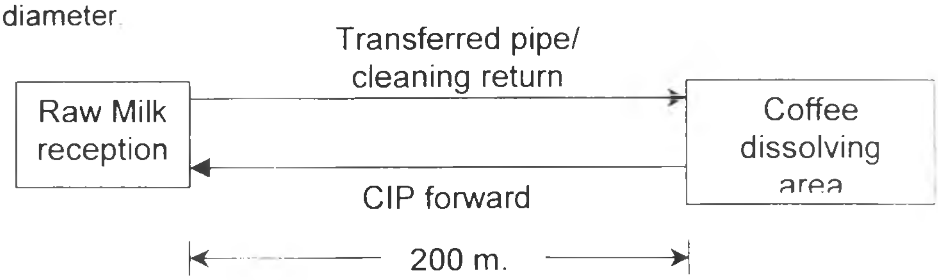


Figure 10: The distance from milk reception area to coffee processing area.

- **Bends**

The pipeline has 20 points, which need to use bends, in order to reverse the flow back, install pipe fit to the building. The diameter is 2 inches.

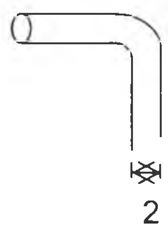

Figure 11: Bend

- **Valve**

Valve used to open or close to control the flow of liquid, normally, it is recommend to use hygienic type. With this purpose it will use the valve which has a control unit on the top, automatic valve. It will use 3 units for transferring and 3 for CIP purpose. All 6 units are 2 ways valve.

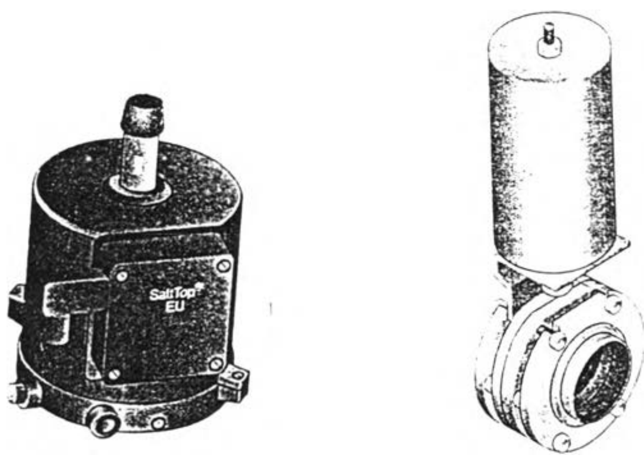

Figure 12: Automatic valve
Source: Diary processing handbook, Tetra Pak.

- **Pipe support and clamps**

Normally, it is recommend having clamps and supports at every 8 meters pipe length and every angle pipe. So, it will be around 70 pieces.

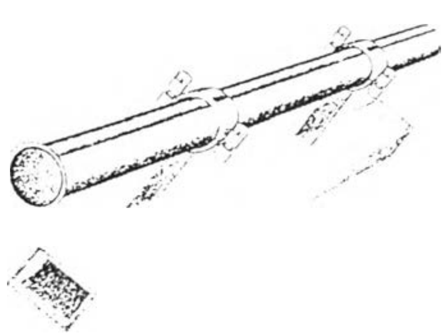

Figure 13: Pipe support and clamp
Source: Diary processing handbook, Tetra Pak.

For the hygienic reasons, all product-wetted parts of dairy equipment, which are mentioned above, are made of stainless steel. The material grades are used is AISI 316, which often called acidproof steel.

- **Small balance tank**

The small balance tank will use for buffering the milk in order to have a continue dosing to colloid mill. The size is 500 liters with the level control unit and stainless steel material, minimal standard unit.

- **Regenerate plate exchanger**

It is used to heat up and cool down the product in the processing. The purpose of heating section is to prepare milk for oil dosing, the condition of dosing is around 45 °C. The function of cooling section is making heat treatment milk back to normal temperature, around 30 °C. The flow rate, which passed is also 10,00 liter/hour. The information give to supplier, we got the pressure drop from plate exchanger at 0.5 bar. In the heating section, the supplier will sell including the circulated pump in order to fit to his design.

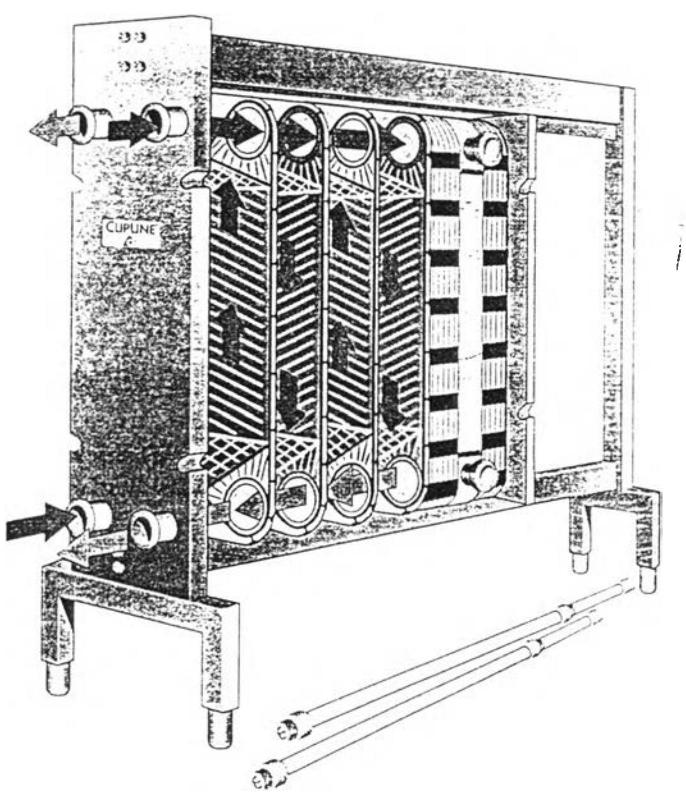

Figure 14: Regenerate plate heat exchanger
Source: Diary processing handbook, Tetra Pak.

- **Automation**

To fit to the existing design, it should be operated with the same standard. so automation is applied with this purpose. The advantage of using automation to control the processing are more safety, better product quality, reliability, flexible production and standard production control. With this part, the contract supplier will be handled designs, installation and instrument based on existing instruments. Moreover, the wiring cable is including with this job.

- **Pump**

The pump is required for 2 units in order to transfer milk from milk reception area to liquid coffee processing area and supply milk to colloid mill. The capacity of pump for transferring milk is 10,000 liter/hour, same as supply pump to colloid mill. The calculation of friction loss from pipe, distance and valve of transferred line are

- Friction loss from distance; 2 inches diameter with capacity 10,000 l/hr at velocity 1.5 m/sec.

From the capacity, friction loss and velocity flow stainless steel pipe, we got loss at 5.5 m./100 m. of pipe. So

200 meter pipe length loss = 11 m.

- Friction loss from bend, 2 inches or 51mm. diameter

From the friction loss equipment in meter straight stainless steel pipe for one fitting table

We got loss 1m straight line/bend. If 20 bend, it is equal to 20 m straight pipe. So, the friction loss will be

$$\frac{20}{100} \times 5.5 = 1.1 \text{ m.}$$

- Friction loss from 2 ways valve, 2 inches or 51 mm. Diameter

From the friction loss equipment in meter straight stainless steel pipe for one fitting table

We got loss 8m straight pipe/valve. If 2 units, it is equal to 16 m straight pipe. So, the friction loss will be

$$\frac{16}{100} \times 5.5 = 0.88 \text{ m}$$

The total loss from pipe, bends and valves is 12.98 m. The friction loss 10 m is equal to 1 bar, if 12.98 m it will equal to

$$\frac{12.98}{10} = 1.298 \text{ approximate } 1.3 \text{ bar}$$

The pressure drop from plate exchanger is 0.5 bar, so the operating pressure of transfer milk pump will be 2 bar.

For the colloid mill, the requirement of supply pressure is 1 bar at 10,000 liter/ hour, so the operating pressure supply mill to colloid mill is 1 bar.

**Friction loss equivalent in meter straight stainless steel pipe**

| | Diameter of pipe | | | | | |
|---|---|---|---|---|---|---|
| | 25 mm | 38 mm | 51 mm | 63.5 mm | 76 mm | 101.6 mm |
| **Fitting** | | | | | | |
| Two-way valve | 6 | 8 | 8 | 9 | 10 | 10 |
| Three-way valve | 7 | 9 | 9 | 10 | 12 | 12 |
| Elbow(bend) | 0.8 | 1 | 1 | 1 | 1.5 | 1.5 |
| Tee | 2 | 3 | 3 | 4 | 5 | 5 |

Table 5: The friction loss at each equipment type
Source: Fluid Handling component book, APV 2001.

- **Tubular Heat Exchanger**

The Tubular Heat Exchanger is required at fit to the flow rate of supply pump, that is 10,000 l/hr. The temperature is required at pasteurize temperature 85 °C and holding for 30 second (from the study of Nestle, it depend on microorganism loaded). This specification will be sent to contract supplier for calculation of size and model. This unit will be included of steam control unit.

## 4.6 Cost estimation of project

The investment cost is coming from the cost of equipment and labor cost. The supervisory cost does not include because of use the company's engineer to control work.

- Pipe cost

The cost of pipe with diameter 2 inches is 6 meter/5,000 Baht. So, the cost of pipe will be

$$\frac{400}{6} \times 5000 = 333,333 \text{ Baht}$$

- Bend cost (elbow)

The cost per unit is 300 Baht. So, the cost of bend will be

20 x 300 = 6,000 Baht

- Support and clamp

The cost of support and clamp is 500 Baht /set. It uses 70 set, the cost will be

70 x 500 = 35,000 Baht

- Pump

The specification of pump, 10,000 liter/hour, 2 bar operating pressure with sanitary material type. The cost from contract supplier is 150,000 Baht not include VAT 7% and discount 5%, include shipment cost. So, the cost will be

Pump : 150,000 x 0.95 = 142,500 Baht
VAT 7% : 142,500 x 0.07 = 9,975 Baht

The total cost of pump (centrifugal pump) will be 152,475 Baht/unit. So, 2 units the cost will be

152,475 x 2 = 304,950 Baht

- Small balance tank

Small balance tank can supply by local supplier, the cost of tank is 45,000 Baht and the control unit is 120,000 Baht. So, the total cost of balance tank is 165,000 Baht.

- Automatic valve

Automatic valve composed with 3 units, actuator, top unit, and valve body. These 3 components has been sold separately, the cost of each part are below;

| | |
|---|---|
| Actuator | 10,000 Baht |
| Top unit | 11,000 Baht |
| Valve body | 4,300 Baht |

The estimate number of valve is 6 complete units, so we will multiply 6 in each unit. The estimation cost of valve will be

| | |
|---|---|
| Actuator | 10,000 x 6 = 60,000 Baht |
| Top unit | 11,000 x 6 = 66,000 Baht |
| Valve body | 4,300 x 6 = 25,800 Baht |
| Total | 151,800 Baht |
| Vat 7% | 10,626 Baht |
| | 162,426 Baht |

- Automation

The cost of Automation part is 2,200,000 Baht. It doesn't include VAT 7%. The automation cost will be

VAT 7%: 2,200,000 x 0.07 = 154,000 Baht

Total cost include VAT : 2,354,000 Baht

- The generate plate exchanger

The cost is 720,000 Baht, not including VAT 7%, including shipment cost. So, the cost after VAT will be

VAT: 720,000 x 0.07 = 50,400 Baht
Cost include VAT : 770,400 Baht

- Tubular Heat Exchanger

The cost from supplier is at 4,000,000 Baht. It doesn't include VAT 7%, so the price of Tubular will be

VAT 7% : 3,000,000 x 0.07 = 210,000 Baht

Total cost of Tubular Heat Exchanger will be 3,210.000 Baht.

- Installation

The cost from welding, pipe work, industrial utility and installation is 300,000 Baht as a contract supplier.

From the above estimation cost of investment will be

| | |
|---|---|
| 1. Pipe cost | 333.333 Baht |
| 2. Bend cost | 6.000 Baht |
| 3. Pipe support and clamp cost | 35,000 Baht |
| 4. Pump cost | 304.950 Baht |
| 5. Valve cost | 162.426 Baht |
| 5. Small balance tank | 165.000 Baht |
| 6. Automation and installation | 2,354.000 Baht |
| 7. The generate plate exchanger cost | 770,400 Baht |
| 8. Tubular Heat Exchanger | 3,210.000 Baht |
| 9. Installation cost | 300.000 Baht |
| **Total** | **7,641,109 Baht** |