Pasteurization Process Energy Optimization For A Milk Dairy Plant By Energy Audit Approach

Modi. A., Prajapat R.

Abstract: The competition and quality aspect limited the profitability of the milk dairy plant. The milk dairy processes are fast growing business but high energy cost is a serious problem. In the current scenario to understand the problems related to high energy consumption of the milk processing and to suggest methods for their active reduction with the help of different approaches needed proper management of the all processes used in the plant. Major emphasis of the paper is to utilize the waste heat of the process which otherwise goes to the atmosphere and to control the pollution depending upon regulatory context. The major considerations are the product type and resource cost. By help of energy audit technique a most economical method is suggested for preservation of milk, with the lowest possible investment and energy expenditure and minimum performance variation.

Keywords: Pasteurization Process, Heat exchanger, Energy Optimization, Energy audit.

I. INTRODUCTION

Dairy industry is included in the one of the major food industries in India. In Milk dairy plant a better development prospect is available because in USA 85% milk product used and 48% in India. Currently India produces around 123.7 million tons of milk every year [1]. This represents 7.8% of world milk production [2]. In future demand of milk product will be increase. The world trade of dairy products, namely butter and butter oil, skim milk powder, whole milk powder, condensed milk and cheese, amounted to 58.2 million tones in milk equivalents (excluding trade within the European Union) in 2011 [3]. The dairy sector can play an important role in providing jobs for rural communities [4]. Dairy production and processing provide employment, not only to people who work on dairy farms or in dairy plants, but also to the whole communities, from upstream e.g. inputs and services providers to downstream e.g. marketing of finished products. Dairy cooperatives have played a very significant role in the procurement, processing and marketing of milk and dairy products and in representing farmers politically at both the state and national level [4]. The Pasteurization process is the main process which consumes a significant amount of energy [6]. The dairy processes performance variation causes the negative impact on product marketing [5]. The performance variations in dairy processes can be obtained by continuous energy audit of the plant.

- *Modi. A., Department of Industrial Production Engineering, Shri. G.S. Institute of Technology and Science, Indore -452003, (M.P.) India*
  Email- atul_123modi@yahoo.com
- *Prajapat R., Department of Industrial Production Engineering, Shri. G.S. Institute of Technology and Science, Indore -452003, (M.P.) India,*
  Email- reenaindia2210@gmail.com

II. Literature Review

World energy consumption is increasing day-by-day and it indicates the nation growth pattern also. The Dairy industry is going to grow in the future and has bright prospects; hence this is an industry which has a huge scope [2]. It's requires process heating, refrigeration cooling and electricity loads. The different type of wastes are developed in milk process of dairy plant such as water waste, steam waste, electrical energy waste etc [21]. The different methods can be used for energy saving in milk dairy plant [18]. The bigger problem in milk plant in pasteurization process high energy cost, as it consumes high electrical energy for complete process [13]. Milk Pasteurized process is an essential process for diary plant that contributes a large amount of energy mainly consisting of electricity and other fuels [16]. Losses of energy in pasteurization process are more in compare to other processes. The optimization of pasteurization process is also essential to reduce the milk processes performance variations and associated other losses like quality and preservation cost [17]. The Pasteurized Milk is now an essential process and its optimization by energy audit approach to minimize energy consumption will open a new way of loss reduction [20]. The improvements in pasteurization process by achieving better efficiency and associated product quality developed a confidence in milk dairy industry. The literature suggest many method for reducing loss in pasteurization process like CHP System , CIP process, solar energy application for heating and cooling, RAS network(connected to PC network) , written programs based on MATLAB software, application such as sequential quadratic programming, etc [15 & 19].

III. Layout of milk processing plant

The layout of a milk processing plant depends upon the operations carried such producing pasteurized Milk, cheese, curd, etc. A typical milk processing plant receives raw milk from a collecting station through trucks and is stored in large tanks at the industry. It is then clarified and homogenized and moved to pasteurization. Milk is chilled up to 4 degree Celsius and then packed into cartons and dispatched for transportation.

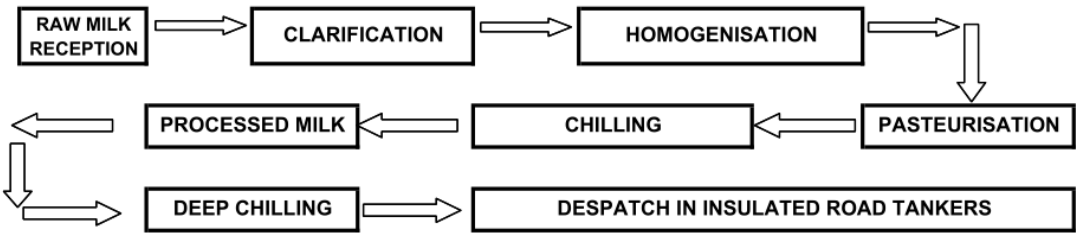

Fig. 1 Layout of milk processing plan

IV. Pasteurization Process

Pasteurization is the process of heating a liquid to below the boiling point to destroy microorganisms. It was developed by Louis Pasteur in 1864 to improve the keeping qualities of wine. Commercial pasteurization of milk began in the late 1800s in Europe and in the early 1900s in the United States. Pasteurization became mandatory for all milk sold within the city of Chicago in 1908, and in 1947 Michigan became the first state to require that all milk for sale within the state be pasteurized. Pasteurization is the process of the heating liquids for the purpose of destroying viruses and harmful organism. It was developed in 1864 to improve the keeping qualities of milk [17]. Pasteurization typically uses heating and cooling cycle at temperatures above the boiling point of milk and above the freezing point. As society industrialized around the turn of the 20th century, increased milk production and distribution led to outbreaks of milk borne diseases. These illnesses were virtually eliminated with the commercial implementation of pasteurization, in combination with improved management practices on dairy farms. In 1938, milk products were the source of 25% of all food and waterborne illnesses that were traced to sources, but now they account for far less than 1% of all food and waterborne illnesses. [3] Pasteurized milk process is a diary process that consumes large amount of energy consisting of electricity and fuel.

The Purpose of Pasteurization

- To increase milk safety for the consumer by destroying disease causing microorganisms (pathogens) that may be present in milk such as viruses and harmful organisms such as bacteria, protozoa, moulds and yeasts
- To increase keeping the quality of milk products by destroying spoilage microorganisms and enzymes that contributes to the reduced quality and shelf-life of milk. [23]

V. Batch pasteurization

Batch (or "vat") pasteurization is the simplest and oldest method for pasteurizing milk. Milk is heated to 154.4^0 Fahrenheit (63^0 Celsius) in a large container and held at that temperature for 30 minutes. This process can be carried out at home on the stovetop using a large pot or, for small-scale dairies, with steam-heated kettles and fancy temperature control equipment [7]. In batch processing, the milk has to be stirred constantly to make sure that each particle of milk is heated.

VI. High temperature/short time (HTST)

High-temperature short-time pasteurization (HTST), or flash pasteurization or continuous process, is the most common method now days, especially for higher volume of milk processing. In HTST process, milk is forced between metal plates or through pipes which are heated on the OD by hot water [8]. This method is faster and more energy efficient than batch pasteurization. The Pasteurized milk is a dairy product that has a shelf life of 8 to 10 days in the open and un-packed. Five steps of the pasteurization process of milk are required. Firstly, the raw milk is reserved in silo tank of huge capacity. Second step is carried out by the heat treatment. The objective of this process is to kill micro-organism of milk at more than 72℃ of heating temperature and than holds for some time for more than 16 seconds. Before heating the milk, the heated milk is homogenized so changing the fat globules into smaller ones for creaming. Next, the pasteurized milk is often cooled to a low temperature approximately up to 6℃ or lower. Lastly, the ijit-reena (autosaved)cooled milk is stored in large tanks before going to packing process. This method is faster and more energy efficient than batch pasteurization. The UHT processing holds the milk at a temperature of $138C^0$ (250^0F) for a fraction of a second. Milk simply labeled “pasteurized” is usually treated with the HTST method, whereas milk labeled “ultra-pasteurized” or simply “UHT” must be treated with UHD method [9].

VII. Methodology

There is no tailor made proposed methodology, as the energy audit role changes with the organization type [10]. The aim of .representing the methodology for milk dairy plant is to control the wastage and losses of the complete manufacturing cycle. The first step of methodology is the identification of main work center or functions of the dairy plant. The different types of energy used and equipment are listed for detail energy audit. The energy audit is conducted on selected function’s selected equipment only [12]. The data of energy consumption and energy related data are collected [13]. An audit team consisting of qualified and experienced electrical and mechanical engineers. However, it may be mentioned that each team was accompanied by an expert. The energy audit identifies the dairy plant areas where wastage of any type of energy found. To developed improved model of manufacturing system the audit approach determined the critical areas and energy wastage and the advanced manufacturing techniques improved them [3].The proposed alternative designs for heat treatment e.g. heating and cooling process during pasteurization process by help of

plate type heat exchanger. The existing system is then compared with the improved system on basis of various alternatives and on criterion of energy consumed, cost, noise generated and location feasibility [11].

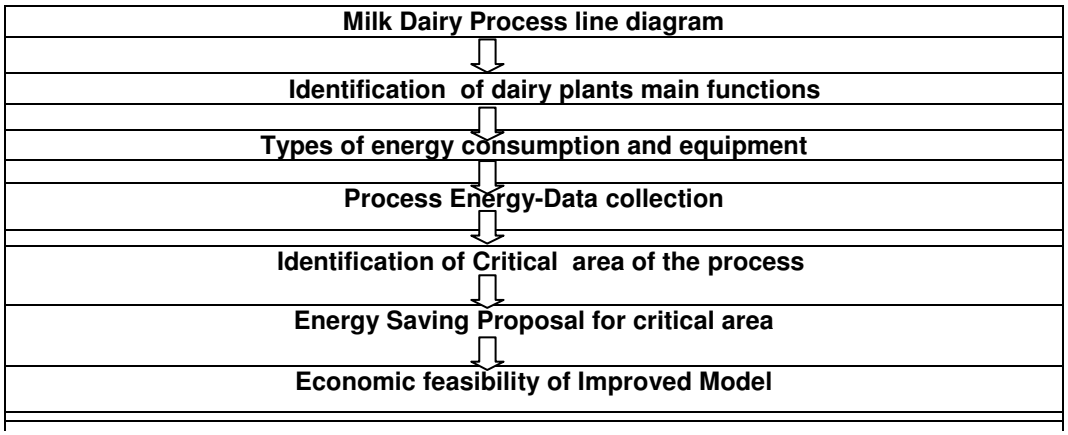

Fig-2 Methodology for milk dairy plant processes energy optimization

VIII. Energy optimization in Milk Dairy plant

The role of energy optimization changes from plant to plant. Saving of energy is as important as environment saving. In different industry different energy conversion system may be employed and every type of energy conversion system poses its own detrimental effect on the environment. Sometimes the harmful effluent developed by these system causes halt to these systems. For example the effluent of power station, industries, urban development's mining of coal or transportation of oil by sea etc. Each type of energy conversion system has its own limitation about effluent and pollution. Both air & water pollution causes environment losses in the form of animal and human life losses & agricultural crop and forest losses. The industrial and nuclear wastages pose a danger to ecological system. They destroy the earth atmosphere, which in turn result in change in wind pattern, rainfall, life in coastal area & temperature increase. The energy optimization when apply to modern milk dairy plant then it mean to develop a methodology for reducing energy different forms wastages and losses in a manufacturing system of dairy plant. It helps to develop capable manufacturing system with optimum energy efficiency for different products and grades [15]. The selection and performance control of any energy conversion system requires proper planning and energy audit provide information for energy wise use only. The each equipment appropriateness and correct way of operations is determined and implemented for efficient and judicious use of energy. No matter the plant is how well designed the day to day out put shows variation from unit to unit. The process on-line control is very important and essential and can be developed with continuous monitoring and improvement.

IX. Importance of Energy Audit approach

The Energy Audit approach is a key approach for systematic decision making in process management. It quantifies the energy uses according to its various functions. It attempts to balance the total energy inputs with the output or the uses. The role of energy audit changes from preliminary audit to detailed audit [13]. The detailed audit goes beyond quantitative estimates to the energy cost and saving and includes engineering applications and recommendations. The preliminary audit can be used as control tool to take feed-back of the implemented projects and form basis of next project of improvements [9]. The energy conservation and maximization strategies for a process industry like dairy plant are cost effective, which conserve the environment automatically [12].

X. Case study

A milk processing plant located at Indore Dugdh Sangh Maryadit, Indore India is considered for the case study. The plant has a capacity of processing 240000 liters of liquid milk a day using HTST milk pasteurization method. It takes 24 hours to process this quantity of milk. It uses electricity to meet heating and cooling energy needs for milk processing (pasteurization) as well as for plant lighting and other functions. For the chilling part of pasteurization, the plant is equipped with an ammonia based vapour compression refrigeration plant. Refrigeration capacity of the plant is 2.8 TR.

Limitation factor of milk dairy plant

The milk dairy plant main functional departments are milk processing area, electrical, chilling system, boilers, and packaging. The table represents the milk dairy plant limitation. The main limitation in pasteurization process is lower energy efficiency, more energy consumption and heat losses.

Table 1- Areas of considerations & limitations in milk dairy plant.

S. No.	Area	Limitations
1	Processing	High electricity and Energy consume
2	Electrical	Load factor ,Voltage fluctuation, High energy consumption, Power cut.
3	Chilling	Ammonia leakage and low temperature and high electricity
4	Boiling	High fuel consumption, High temperature of water
5	Packaging	High energy consumption and water waste

Existing System of milk dairy plant

The milk dairy plant is based on product layout and in current situation a profit making organization. The fig.3 represents the flow diagram and plant set-up. The Plant running Capacity is 240000 liters (10000 Liters /hour) for 24 hours working. Pasteurization Method: HTST pasteurization (Heating at 72℃ for 30 sec followed by cooling at 4℃)

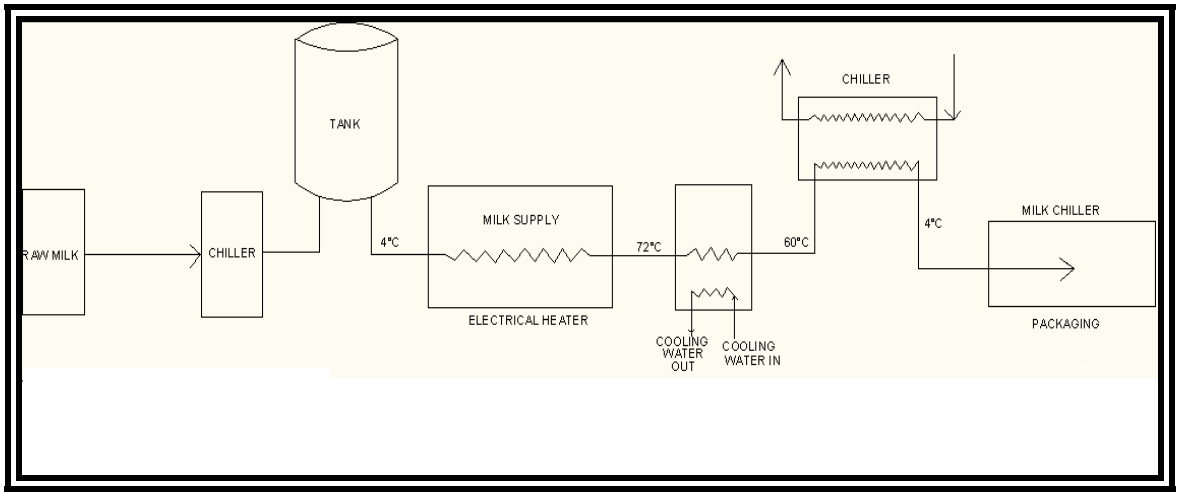

Fig.3. Existing System Plant Layout [Product lay-out]

Data Collection

First of all, baseline data was collected. Rated power consumption of electric motor of compressor is 120(4), 125(1) total 605hp (451.14 kW). Electric coils of rated power 295.96 kW are used to heat the milk to the desired temperature. Power requirements for running pumps for milk and water circulation is 141.68 kW. Another 57.03 kW is required for running fans and for lighting. A packaging machine is employed that consumes 78.4 kW of power. The total power requirement for the plant is thus 1080 kW. Except heating and cooling power requirements all other electricity loads are assumed to be approximately constant for each of the alternative plant designs that have been suggested below. Knowing the total production of milk to be 10000 liter/hour, the milk processing energy cost per liter is Rs. 2. In table 1 details of main equipments is mentioned & in table 2 the total power consumption of various process & man contribution percentage is mentioned.

Table 2. Details of existing equipments

S.N.	Equipments	Power Rating
1	Power of Motor of Compressor	451.14 kW
2	Heater: Power Consumed	285kW
3	Pumps	141.68kW
4	Packaging Machine:	78.4 kW

Table 3. Total energy consumption

Section	**Total KW**	**%**
Process	50818	34.49
Prepack	9547	6.48
Refrigeration	49128	33.35
Boiler	12763	8.66
E.T.P	7542	5.12
Pump house	3393	2.3
Product	1449	0.98
Lighting	7156	4.86
Canteen	1749	1.19
Tetrafino	3774	2.56
Total KWH	147319	100.00

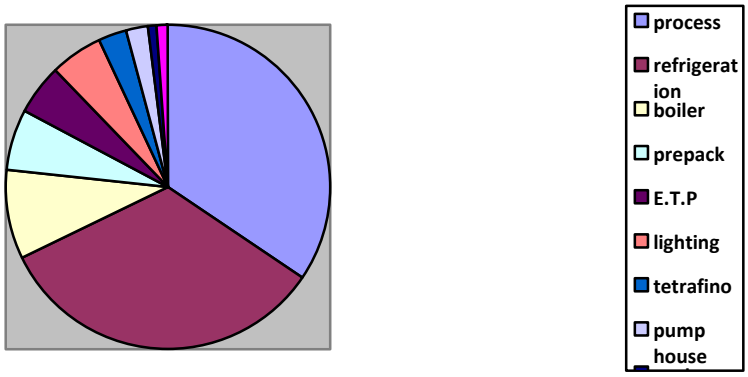

Fig4.-sectoral electrical consumption

Existing system Total power consumption Calculation

Total milk production per day = 240000litre
Total power consumption = 147319kw
Total power consumption per hour = 6138kw/hour
Total power consumption per liter = 1.62kw/liter
Electricity unit cost/tariff = Rs2.63
Milk Electricity cost per liter = Rs1.62*Rs2.63
= Rs 4.26/liter

Calculation of pasteurization process energy consumption

Total power consumption of pasteurization process per day = 50818kw
Total power consumption of pasteurization process per hour = 2117.4kw/hour
Electricity unit cost for pasteurization process = Rs0.2117*Rs2.63
= Rs0.556

Total milk production per hour = 10000litres

Research methodology

In this work we suggest methodology to improve efficiency of pasteurization process by reducing its wastage & discuss the different energy conservation techniques for milk dairy plant.

Different methods of energy conservation in milk dairy plan

By cogenration system

Dairy industry requires both electricity and process heat. There is a chance of co-generation. The co-generation system shows relative fuel saving and heat rate of co-generation is less than the heat rate of power plant. Hence cogeneration is seen to be feasible but it has following limitation: The Power generation is so small hence it is difficult to get the generator of such a small capacity. Even if we get the generator then scale of pay is very high hence it is not that affordable. The other methods are

- By economizer to heat feed water for boilers, so use waste heat
- By proper integration of chilling system to the main process by load balancing
- To use waste heat of air compression outlet to heat boiler inlet water
- By proper loading of electrical motors and lightening system
- By using variable frequency drives in air compressors
- By proper maintenance of equipments
- By using flat plate heat exchanger to preheat milk of chilling process raw milk

Out of all these methods the last method is more suitable due to less investment cost & in our case study it contributes maximum energy consumption that is 34.49 % of total energy consumption. We propose alternative designs for heating and cooling requirement during pasteurization process and then we compare the payback period & energy saving of the existing system.

Using a Plate Type Heat Exchanger

In this alternative it is suggested to utilize the energy wasted in the form of heat carried by the heated milk going into the chiller unit. The suggested alternative plans to use this heat and the same is used to preheat the milk coming from the supply and hence reduce the heating load required for the purpose of milk processing. This can be done by using a plate type heat exchanger The suggested alternative design to use this heat and the same is used to preheat the milk coming from the fresh supply and hence reduce the heating load required for the purpose of milk processing in chilling unit.

Proposed Alternative

In proposed alternative we suggest the improved design as shown in figure 4.This reduction in mechanical power input to chilling unit is because of the reduced cooling load and hence the decreased compressor power of the chilling unit because of the fact that in existing system we had to cool down the milk than 60℃ to 4℃ but now we have to cool it

from 30℃ - 40℃ (approx.) to 4℃, while the decrease in heat input required is because of the fact that the heating load is raising the temperature of milk from 40℃ - 50℃ (approx.) to 72℃ as compared to that in the existing system where we have to raise the temperature of milk from 4℃ to 72℃

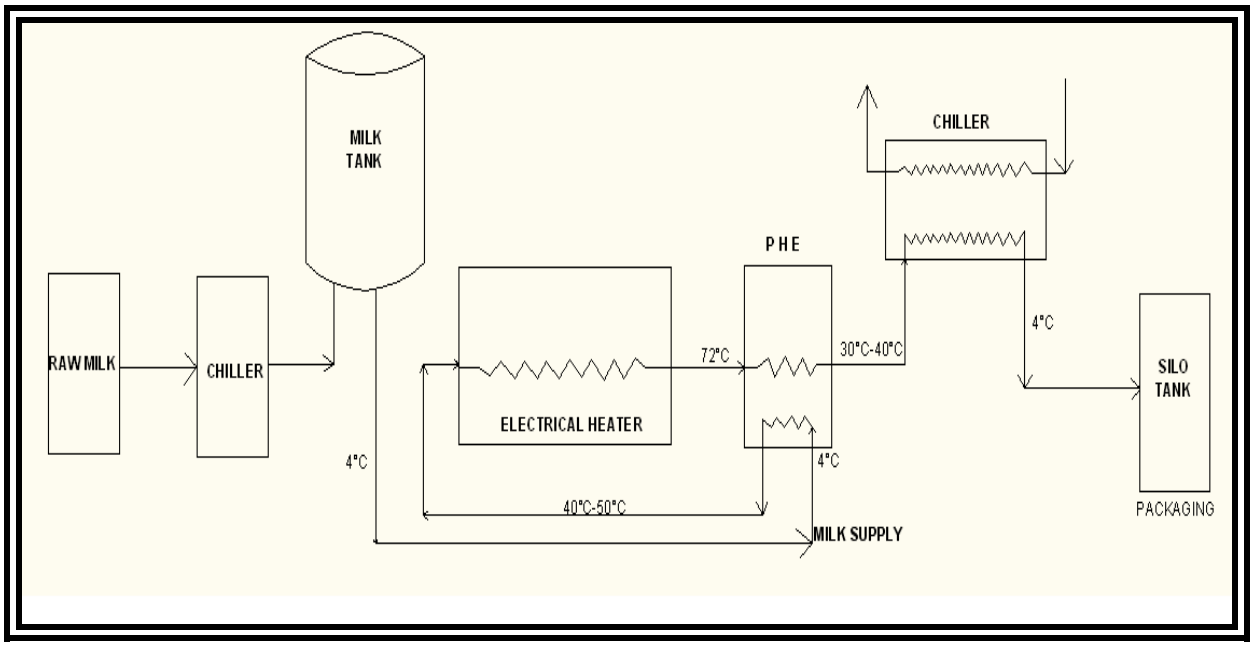

Fig.5. Proposed System's Layout

For the purpose of calculating energy needs, the effectiveness of this newly incorporated heat exchanger can be assumed to be 0.8 Using simple heat balance it has been found that electrical power now required (including electricity to run compressor for chilling unit) is as under-

Specific heat of milk	= 3.93kj/kg
Density of milk	= 1.03kg/liter
Energy saving for pasteurization process by heating raw milk	= 3.93*1.03*(72-28)
	= 178.10kj/liter
Assume effectiveness of heat exchanger	= 0.8
Therefore energy saving for pasteurization process	= (0.8*178.10*10000)/3600
	= 395.77Kw/Hr
Energy saving due to alternative system for 24 hours	= 9498.48 Kw
% energy saving	= (395.77/2117.4)*100
	= 18.69%
Per liter saving	= (0.556*18.69)/100
	= Rs 0.1 per liter
Per day saving	= 0.1*240000
	= Rs 24000 per day
saving Per month	= 24000*30
	= Rs 7, 20,000 per month

Criteria for investment analysis

For any capital investment in any industry the complete proposal is considered as a individual project, so before any change in the process the analysis of project appraisal is essential. The payback period method is the simplest method for investment analysis

Payback period

The payback period is the span of time within the investment made for the project will be recovered by the net returns of the project. For example in our project the total investment cost for the alternative system as proposed including the cost of plate type heat exchanger is Rs 1600000. The change over time period to shift into alternative system is around three days but if project is done parallel it require only one day to install the alternative system.

Calculation of payback period

Payback period for Rs 1600000 with monthly saving of Rs 720000=1600000/720000=2.2 month or maximum three month, so it is a feasible project

XI CONCLUSION

The energy audit is useful method and for any process industry like milk dairy plant by help of this technique the energy loss and wastages are easily identified and improved system or model can be developed. In this

alternative system to utilize the waste heat of pasteurization process we have proposed certain alternatives to reduce the milk processing energy cost. The results are represented by table-3 to compare the both existing system with alternative system.

Table 4- Comparison of existing system & improved system in pasteurization process

S.N.	System	Existing system load in kw	Improved system load in kw	% improvement
1	Pasteurization process load	50818	41319.52	18.69 %
2	Process Energy cost	Rs 0.556/liter	0.456/liter	18.69 %
3	Milk electricity total cost	Rs 4.26/liter	Rs 4.16/liter	2.3 %

The results also show that with improvements as suggested proposal in the dairy industries, considerable savings in energy expenditure can be obtained. The major reason why Indian dairy sector not catching up with the rest of the world is the fact that India being a developing country has all its potential resources scattered all over and we never figured out how to make the optimum use of these resources by bringing them under one roof. This is what is achieved from this paper i.e. implementing simple energy efficient, technologically feasible methods to reduce the milk processing energy cost to optimum. The suggested alternative method has very short payback period of 3 months only and the process energy audit indicates that loss of energy in milk dairy process are very high, so improvement chance are also high.

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