ENERGY CONSERVATION IN SUGAR INDUSTRY

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

ALTERNATE HYDRO ENERGY SYSTEMS

By

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CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in this dissertation, entitled " **ENERGY CONSERVATION IN SUGAR INDUSTRY**", in partial fulfillment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY** in **ALTERNATE HYDRO ENERGY SYSTEMS,** submitted in Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, is an authentic record of my own work carried out from July 2005 to June 2006 , Under the guidance and supervision of **Shri S.N.Singh,** Senior Scientific Officer, Alternate Hydro Energy Centre and **Dr. R.P.Saini,** Senior Scientific Officer, Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee.

I have not submitted the matter embodied in this dissertation for the award of any other degree or diploma.

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ABSTRACT

The gap between supply and demand of energy is continuously increasing despite of huge outlay for energy sector .In India, the rate of energy demand is increasing at a rate of 6.5% per annum. Future energy demand in India is substantial as the 120% increase in annual oil production at 50 million tons, almost 250% increase in annual coal production at 600 million tonnes and doubling of natural gas production at 100 million cubic meters per day for the year 2012. Thus, the energy security has key issue for our country. So to minimize the gap between supply and demand of energy, energy conservation may play leading role in Indian industries. Therefore, there is a good scope of energy conservation in various sectors like industries, agriculture, transport, and domestic. India is the largest consumer of sugar in the world and Indian sugar industry is the 2nd largest agro-industry located in the rural India. And there is a wide scope of energy conservation in sugar industry. The sugar industry has 25-30 % energy conservation potential.

Energy conservation (EC) in sugar industry is typically the results of process technology advancements and diligence in manufacturing operations and its intensity varies according to the chemical and mechanical process. However, so far there is no defined practice of energy conservation in sugar industry in India.

In the this Dissertation, the scope of energy conservation in various process in sugar industry such as; milling, juice clarification, juice concentration by evaporators, crystallization, electrical and mechanical drives, process vessel insulation, waste and renewable fuel use (Bagasse) and new process in mechanical, electrical and control technologies has been discussed. Under the present work, two section of Uttam Sugar Mills Ltd (USML), Libberheri, Haridwar (Uttaranchal) has been taken for energy audit, named as; mill house and boiler house. It was found that the net calorific value of bagasse has increased from 2650 to 4160 kcal / kg by reducing the moisture level from 50% to 30%. By energy auditing in these two sections, it was estimated that there is a potential of net energy saving of amount 2.70 x 10^{7} kWh per season (160 days).in the above stated section of USML. Based on the finding it is recommended that sustainable amount of energy could be saved in USML.

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INTRODUCTION AND LITERATURE REVIEW

1.1 GENERAL

Energy is vital for sustaining on earth. Energy was, is and will remain the basic foundation, which determines the stability of economic development of any nation. It is needed to increase quality of life. Supply of energy for both biotic and a-biotic life support system is only possible by exploiting natural resources. The energy problem is, thus synonymous to ecological and economical problems. The gap between supply and demand of energy is continuously increasing despite of huge outlay for energy sector since independence. The total installed generating capacity of electricity in India has increased from 14,709 MW in 1970-71 to 1, 12,684 MW in 2004[1]. Among installed capacity, at present the largest share (>60%) was because of thermal electricity. Annual coal production was 240 million tons and crude oil production was approximately 32 million tons. Annual production of natural gas, a very recent into the country's energy supply was approximately 29.7 billion cubic meters in 2002-03. Future energy demand in India is substantial as the 120% increase in annual oil production at 50 million tons, almost 250% increase in annual coal production at 600 million tones and doubling of natural gas production at 100 million cubic meters per day for the year 2012[2]. This extraordinary growth in demand will place great stress on the financial, managerial and physical resources of the country, creating capital and energy shortages as well as environmental problems.

In 2003-04, the sector wise consumption of electricity in India was having the order of 34% for industrial sector, 24% each for agricultural and domestic sectors and 18% for others [1].

World energy demand has been increasing exponentially. It has been estimated that the world population will reach 8 billion by 2020[2]. On other hand, the conventional energy resources are limited on the earth and also its use affects the environment. There is an urgent need to explore the wide use of alternative energy technologies. Accepting this challenge, engineers, scientists and energy economists are putting every effort to ensure that the energy needed will be provided distributed, used and conserved in a sustainable way. It is obvious that proper management of available natural resources and the energy technology is vital issue for satisfying the energy demand in a sustainable manner locally and globally. Table1.1and Table1.2 give the sector wise and fuel wise electricity scenario in India. Table1.3 gives the power situation in India.

Table 1.1: Sector wise electricity scenario [3]

Sl.No	Sector	MW	%age
1	State Sector	70,224	56.5
2	Central Sector	39,924	32.1
3	Private Sector	14,139	11.4
4	Total	1,24,287	

Table 1.2: Fuel wise electricity scenario [3]

Sl.No	Fuel	MW	%age
1	Total Thermal	82,410	66.4
2	Coal	68,519	55.1
3	Gas	12,690	10.2
4	Oil	1,201	1.0
5	Hydro	32,326	26.0
6	Nuclear	3,360	2.7
7	Renewable	6,191	4.9
8	Total	1,24,287	

Table1.3: Power situation in India [3]

Sl.No	Type	Demand	Supply	Surplus/ Deficit
1	Energy	575,384 MU	527,539 MU	-8.3 %
2	Peak Demand	92,968 MW	81,370 MW	-12.5 %

Since the post independence era the power sector in India has registered significant progress after the process of planned development of the economy began in 1950. Hydropower and coal based thermal power have been the main sources of generating electricity. Nuclear power development is at slower pace, which was introduced, in late sixties. The concept of operating power systems on a regional basis crossing the political boundaries of states was introduced in the early sixties. In spite of the overall development that has taken place, the power supply industry has been under constant pressure to bridge the gap between supply and demand. The per capita consumption of electrical power in India is around 408 units, which are very less than the average world per capita consumption and 32 times less than USA. The demand for power in the country has been growing at the rate of 8% per year. The present installed capacity in the country is around 1,24,287MW as on 3/04/2006 [3], 70% of which is supplied through fossil fuel (coal), about 25% through hydel where as the nuclear power contributes a little less than 5% of the total power. The nuclear energy share in the world is 16%. The demand for electrical energy in India is rapidly increasing due to industrial and population growth, outstripping the available generation.Fig.1.1 shows the sector wise power consumption in India [3].

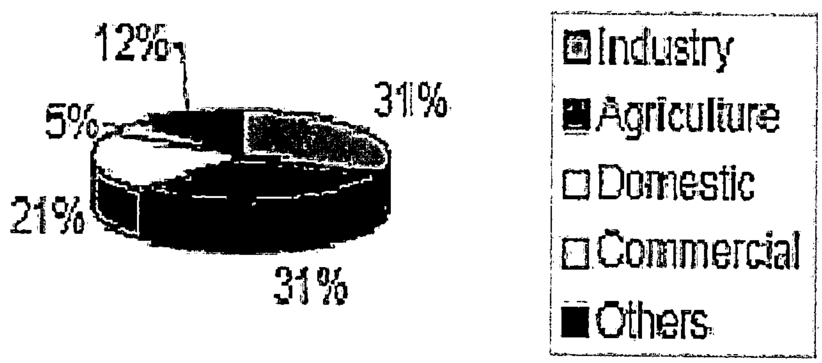


Fig.1.1: Sector wise power consumption in India [3]

Most of the above stated sector is utilizing now either inefficient technology in processes /machines or incurring wastage due to the poor maintenance and neglected attitude for shortage of energy for future. The intensity of energy use, defined, as the amount of energy consumed per unit product value added in many sectors of Indian industry is high. This signifies the today's need for energy conservation. Therefore, there is a good scope of energy conservation (EC) in various sectors like industries, agriculture, transport, and domestic and there is a wide scope of energy conservation in sugar industry also.

Sugar industry is the largest agro-based industry located in the rural India. About 45 million sugarcane farmers, their dependents and a large mass of agricultural labourer are involved in sugarcane cultivation, harvesting and ancillary activities, constituting 7.5% of the rural population. Besides, about 0.5 million skilled and semi-skilled workers, mostly from the rural areas are engaged in the sugar industry. The sugar industry in India has been a focal point for socio-economic development in the rural areas by mobilizing rural resources, generating employment & higher income, transport and communication facilities. Further, many sugar factories have established schools, colleges, medical centers and hospitals for the benefit of the rural population. Some of the sugar factories have also diversified into byproduct based industries and have invested and put up distilleries, organic chemical plants, paper and board factories and cogeneration plants. The industry generates its own replenishable biomass and uses it as fuel without depending on fossil fuel. The sugar industry's contribution to the Indian economy is, therefore, enormous.

There are 553 no. of installed sugar mills in the country with a production capacity of 180 lakh million tonnes of sugar. These mills are located in 18 states of the country. About 60% of these mills are in the cooperative sector, 35% in the private sector and rest in the public sector [4]. Table 1.4 gives the global sugar scenario.

Table 1.4: Global sugar scenario [4]

10 Largest Sugar Producers (Million ton, raw value)		
1.	India	20.2
2.	EU	17.9
3.	Brazil	16.5
4.	USA	8.1
5.	China	7.6
6.	Thailand	6.2
7.	Mexico	4.8
8.	Australia	4.4
9.	Cuba	4.1
10.	South Africa	2.7

1.2 TECHNOLOGY UPGRADATION IN SUGAR INDUSTRIES

Modernization and technology upgradation have to be seen as a continuous exercise for cost reduction and taking advantage of economies of scale. The future of sugar industry is also closely linked to this. All attempts to minimize costs have to be technology driven. The technology up gradation of the sugar industry is therefore every important to ensure its global competence and therefore has to be a continuous process. The key drivers in technology use are the following:

(i) Improvements in Capital Output Ratio
(ii) Improvements in Plant Efficiencies,
(iii) Energy Conservation
(iv) Optimizing cost of consumables
(v) Impact of sugar quality on price realization

Recently, there has been a rapid advance in the equipment, systems and process designs, which the industry should evaluate and adopt to be cost effective. These include the following:

(i) Low Pressure Extraction System
(ii) Use of Two-Roller Mill
(iii) Cane Separation System
(iv) Short Retention Clarifier
(v) Membranes for juice purification
(vi) Film Type Sulphur Burners
(vii) Continuous Pans
(viii) Advanced Condensing and Cooling System
(ix) High Gravity Centrifugals
(x) Equipment and Process automation etc.

It is noted that the collective use of some of the above technologies can optimize plant capacities, improve in plant efficiencies, and reduce the cost of consumables and manpower.

1.2.1 Energy Conservation

Consumption of energy is an important area of concern for all industries including sugar industry. The level of energy consumption has reduced considerably in the sugar industry in the past 50 years. The earlier sugar plants were all steam driven and required substantial quantities of extra fuel in the form of coal, wood and furnace oil for meeting the energy needs.

It is noted that now a large number of sugar plants in India are electrically driven, have optimized on process steam consumption and are therefore, self sufficient in fuel (bagasse), but with the rising price realization from sale of bagasse in the last few years, it has become necessary for the industry to save bagasse as possible to earn additional income. The present average levels of power and process steam consumptions in a modern plant are as 35 kW/Tonne cane and 480 Kg/Tonne cane respectively.

The targets of 27-28 kW/Tonne cane for power consumption and 400-420 Kg/Tonne cane for steam consumption for energy consumption can be achieved through use of modern technologies like use of falling and climbing film evaporators, Planetary Gear Boxes, Plant and Process automation, use of efficient motors and pumps and the various other technologies [4].

1.2.1.1 Energy conservation potential in Indian industries

Energy conservation potential in India is given in Table 1.5.

1.3 COGENERATION POTENTIAL IN INDIA

The sugar process is very energy-intensive, requiring inputs of both heat and power at many stages. This is why it is so well suited to the application of cogeneration. Table 1.6 shows that co-generation potential of various industries in India.

Table 1.5:Energy conservation potential in Indian industries [5]

Sl.No	Industry	Potential (%) conservation
1	Iron and Steel	8-10
2	Fertilizers & Pesticides	10-15
3	Textile	20-25
4	Cement	10-15
5	Chlor-alkali	10-15
6	Pulp and Paper	20-25
7	Aluminum	8-10
8	Ferrous Foundry	15-20
9	Petrochemical	10-15
10	Ceramics	15-20
11	Glass	15-20
12	Refineries	8-10
13	Ferro-alloys	8-10
14	**Sugar**	**25-30**

Table 1.6: Cogeneration potential in India [6]

Sl.No	Industry	Potential (MW)
1	Alumina	59
2	Caustic soda	394
3	Cement	78-100
4	Cotton textile	506
5	Iron & steel	362
6	Manmade fibres	144
7	Breweries	250-400
8	Coke oven batteries	200
9	Commercial sector	175-350
10	Dairies	70
11	Distilleries	2900
12	Fertilizer	850-1000
13	Petrochemical	250-500
14	Plywood manufacturing industry	50
15	Rice mills	1000
16	Solvent extraction	220-350
17	Sponge iron	225
18	Tyre plants	160-200
19	Paper & pulp	850
20	Refineries	232
21	**Sugar**	**5200**
22	Sulfuric acid	74-125
23	Total	**14628-15586**

1.4 LITERATURE REVIEW

Energy conservation is need of hour subject that has challenged power engineers for many years. Several researchers investigated the methodology of energy conservation in industry, which has been discussed under this part of the chapter.

M. Scott, et al [7] has investigated, the energy efficiency of an evaporation-crystallization plant in a sugar mill. A new design of transformer was developed to cope with the common situation prevailing in many process industries where there was both a need for different steam temperatures and access to waste vapors of various temperatures.

S.Kumar, et al [8] discussed the production processes, types of fuel used, energy use pattern and the overall specific thermal and electrical energy consumption in the desiccated coconut (DC) sector. An analysis of the energy use highlights the inefficient processes and the key energy loss areas. Options for energy conservation in the DC mills have been discussed, and carbon dioxide emissions from this sector and its mitigation potential were estimated.

Ratna Choudhury,et al [9] showed that the steel industry, by its very nature, is highly energy intensive with many heating and cooling,melting and solidification cycles. Typically, the specific energy consumption of Indian steel plants is quoted in the range of 35-50 GJ/tcs, compared to 17-25 GJ/tcs quoted for steel plants in advanced countries..

T. V. Ramachandra, et al [10] illustrated the industrial energy scene in Karnataka and found the possibilities of energy conservation. Analysis of the energy consumption data of Karnataka and India shows that the per capita consumption of energy is low (compared with 56 countries in the world), while for the industrial sector, energy per state domestic product (SDP comparable to GDP) is at least 10-20 times higher than that of industrialized countries. This implies inefficiency in energy utilisation.

C. Palanichamy, et al [11] highlighted the Energy Conservation (EC) potential availability and suggests some practicable environmental friendly EC policies suitable for the Indian context to achieve the estimated potential.

Ernst Worrell, et al [12] reported on an in-depth analysis of the US cement industry, identifying cost-effective energy efficiency measures and potentials. Between 1970 and 1997, primary physical energy intensity for cement production (SIC 324) dropped 30%, from 7.9 GJ/t to 5.6 GJ/t, while specific carbon dioxide emissions due to fuel consumption and clinker calcination dropped 17%, from 0.29 tC/tonne to 0.24 tC/tonne.

Mehmet Akbaba [13] discussed energy conservation by installing energy-efficient (EE) motors instead of standard efficiency motors. Therefore, the energy efficiencies of energy efficient motors are compared with those of standard efficiency motors ranging from 5 to 300 HP. To provide more clarification in this regard, full design details of 200 HP standard-efficiency and energy-efficient motors were compared. Pay back periods when replacing standard-efficiency motors with energy-efficient motors, with reference to Bahrain's market wise, discussed. Finally the energy-conservation capability of EE (Energy efficient) motors in the petrochemical industry was also discussed.

J W Fromme [14] studied the in-depth energy efficiency study of a recently privatized trailer plant in the Urals. In total, energy savings of 47% of current demand could be achieved.

G. Thomas Bellarmine, et al [15] showed that Electrical energy is the most important and critical of all resources for economic growth and human comforts, India continues to suffer from shortages of energy in spite of substantial investment in the power sector. Due to serious constraints on adequate availability of conventional energy sources in India, non-conventional energy sources must be developed to the fullest extent. Energy audits can bring down both demand and energy consumption in industry. By modifying the electricity tariff, the State Electricity Boards can become financially stable.

Wei-Jen Lee,et al [16] discussed energy management embodies engineering, design, applications, operation, and maintenance of electrical power systems to provide optimal use of the electrical energy. The key element of the energy management process is the identification and analysis of energy conservation opportunities. which discusses energy management and energy conservation for motors, systems, and electrical equipment.

David Yih-Liang Chan, et al [17] conducted a study on the current situation of energy conservation in high energy-consuming industries in Taiwan, including the iron and steel, chemical, cement, pulp and paper, textiles and electric/electrical industries have been presented. Since the energy consumption of the top 100 energy users (T100) comprised over 50% of total industry energy consumption, focusing energy consumption reduction efforts on T100 energy users could achieve significant results. Potential electricity savings of 1,022,656MWH, fuel oil savings of 174,643 kiloliters (KL), steam coal savings of 98,620 ton, and natural gas (NG) savings of 10,430 kilo cubic meters was identified. The total potential energy saving thus was 489,505KL of crude oil equivalent (KLOE), representing a reduction of 1,447,841 ton in the carbon dioxide emissions, equivalent to the annual carbon dioxide absorption capacity of a 39,131-ha plantation forest.

Jiankun He, et al [18] developed a quantitative algorithm for direct and indirect energy savings is developed based on the database analysis of China's energy consumption per GDP in the last two decades. The result showed that direct energy savings due to improved energy conversion and end-use utilization efficiencies only account for 26.5% of the total energy savings, and that indirect energy savings due to increased added value of products, product shifts, and structure shifts in industries account for 73.5% of the total energy savings.

M.G. Rasul , et al [19] carried out a simple model to assess the thermal performance of a cement industry with an integrated view to improve the productivity of the plant. The model was developed on the basis of mass, energy and energy balance and was applied to an existing Portland cement industry in Indonesia. This study showed that by replacing industrial diesel oil (IDO) with waste heat recovery from kiln and cooler exhaust for drying of raw meal and fuel, and preheating of combustion air, a cement industry in Indonesia can save about 1.264 · 105 US dollars per year.

Maranhao [20] suggested a method of bagasse drying in sugar mill, by this method, the 60% of the flue gases will pass through bagasse dryer and 40% will pass through air preheated and temperature of boiler can be raised up to 1230 °C and moisture content can be reduced up to 35 to38%. In this way, the calorific value of bagasse was improved significantly, and 12-15% bagasee could be saved.

Chiogiogi [21] found that for boiler of low capacity less than 20 tonnes/h, only economizer use is economical. A very large boiler for operating pressure 400 psi, a combination of air preheater and economizer is significant. The overall boiler efficiency will increase approximately 2.5% for every 37.7 °C decreased in stack temperature of 2% for every 37.7 °C increases in combustion temperature. According to the Hugot[22], a flue gases temperature reduces from 200 to 150C °C, than saving will be economically viable Hugot has also felt that equal technical economy, the heat surfaces of economizer and preheater or approximately equivalent, that of air heater being only 20-25% greater for then that for economizer. A drop of flue gases temperature of approximately 81.2°C, giving the saving of some 12% in fuel consumption. The thermal efficiency of boiler was 55% before economizer and it was increased up to 59% after economizer as per study conducted by Prof Patil [23] for sugar industry.

Keshava prakash[24] pointed out that there could be considerable savings in the use of electric power by installing variable speed motors to drive Toothed Pressure Feeders(TRPF), Rake Elevator, Centrifugal machines and ID / FD fans. The net power savings by using variable speed motors on the above equipment in sugar factory are expected to be as follows: -(i) 20 to 30% in TRPF Drive, (ii) 10 to 15% in Rake Elevator, (iii) 50% in Centrifugals and (iv) 30 to 40% in ID /FD Fans.

V.J.Bailliet [25] discussed the main advantage gained by drying bagasse as compared to an air-preheater is the substantial increase in burn-ability of bagasse, and hence, recommended its use in case of sugar factories using large quantity of extraneous fuels in addition to bagasse with high moisture content of above 52%.

Stafford [26], demonstrated that the fuel oil consumption in a wet bagasse fired boiler could be reduced by 80% by drying bagasse with flue gases.

Rajshree Sugars & Chemicals Limited [27] implemented the energy conservation schemes and a saving of Rs 34.97 lakhs has been achieved with an investment of Rs 38.16 lakhs .The power consumption of sugar per quintal has been reduced from 33.70 units to 32.01 units in 2002-03 and further to 31.91 units in 2003-04. Even when production was less by one lakh tons in 2003-04 in comparison with previous years of 2001-02 & 2002-03, they were able to achieve a lower specific power consumption of 31.91 units. This was possible only due to the implementation of the ENCON(name of EC project) projects in 2003-04. Also the specific thermal energy consumption was reduced from 402.43 Kcal/quintal to 385.78 Kcal/quintal in 2002-03 & 377.11 Kcal/quintal in 2003-04.These achievements were the result of the effective functioning of the Energy Cell.

ITC Saharanpur unit [28] implemented the energy conservation measures during the 2004-05 saving of energy 43440 Units / month and saving of Rs 2.38 lacs / month has been achieved.

Star Paper Mills Limited, Saharanpur [29] implemented the energy conservation measures and around 50 Ideas giving total energy savings of Rs. 279 lakhs /annum with an investment of Rs. 264 lakhs during 2001-02 and 2003-04.

1.5 OBJECTIVE OF DISSERTATION

Based on the literature survey, it was observed that research work has been done on energy conservation in various industries. Sugar industries have 25-30 % energy conservation potential. The main objective of the study is to identify the potential of energy wastage in the existing set up of the plant with view to eliminate or reduce these wastages by short-term measures and long-term measures to reduce the overall energy demand. Based on this study following objective made for this dissertation given as:

(i) To identifies a sugar mill for conducting study
(ii) To select the system / parameter
(iii) Collecting data
(iv) Analysis of data
(v) Conclusions and recommendation of measures for energy conservation in sugar mills.

ENERGY CONSERVATION METHODOLOGY

2.1 GENERAL

Energy is considered as important recourse for industry, transportation, and agriculture, commercial and domestic sectors of economy. Energy audit, energy conservation measures, waste recycling are essential functions of energy management. Energy management involves strategy, policy, organizational changes, energy audit, energy conservation measures, administrative action, training and awareness programs, association of working level personnel, evaluation of present energy consumption, implementing energy conservation measures (ECMS), monitoring of energy conservation efforts etc. Under this chapter a methodology for energy conservation is discussed.

2.2 ENERGY CONSERVATION

Energy conservation involves avoiding wastage of energy and adopting methods to save (conserve) energy without affecting productivity and comforts. Energy conservation does not imply avoiding essential use of energy for productivity and comforts. Waste is avoided. More energy efficient processes are adopted in place of less efficient. Energy conservation is achieved when growth of energy consumption is reduced, measured in physical terms. Energy conservation can, therefore, be the result of several processes or developments, such as productivity increase or technological progress.

2.3 ENERGY AUDIT

Energy audit is the key to the systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursuing comprehensive energy management programme. An energy audit is a preliminary activity towards instituting energy efficiency programs in an establishment. It consists of activities that seek to identify conservation opportunities preliminary to the development of an energy savings program

As per the energy conservation ACT, 2001, energy audit is defined as " the verification, monitoring and analysis of energy including submission of technical report containing recommendation for improving energy efficiency with cost benefit analysis and action plan to reduce energy consumption [31].

2.3.1 The Role of an Energy Audit

To institute the correct energy efficiency programs, one has to know first which areas in this establishment unnecessarily consume too much energy, e.g. which is the most cost-effective to improve. An energy audit identifies where energy is being consumed and assesses energy saving opportunities, so one gets to save money where it counts the most.

In the factory, doing an energy audit increases awareness of energy issues among plant personnel, making them more knowledgeable about proper practices that will make them more productive. An energy audit in effect gauges the energy efficiency of your plant against "best practices". When used as a "baseline" for tracking yearly progress against targets, an energy audit becomes the best first step towards saving money in the production plant.

In general, Energy audit is the translation of conservation ideas into realities, by lending technically feasibly solutions with economic and other organizational considerations within a specified time frame. The primary objective of energy audit is to determine ways to reduce energy consumption per unit of product or to lower operating costs. Energy audit provides a bench-mark for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

2.3.2 Type of Energy Audit

The term energy audit is commonly used to describe a broad spectrum of energy studies ranging from a quick walk-through of a facility to identify major problem areas to a comprehensive analysis of the implications of alternative energy efficiency measures sufficient to satisfy the financial criteria of sophisticated investors. The only way to insure that a proposed audit will meet the specific needs is to spell out those requirements in a detailed scope of work. Taking the time to prepare a formal solicitation will also assure the building owner of receiving competitive and comparable proposals.

The energy audits are classified into three categories as discussed below

(i) Simple walk-through energy audit

The Simple Walk-Through Energy audit alternatively called a Preliminary Audit audit, screening audit or walk-through audit, is the simplest and quickest type of audit. It involves minimal interviews with site operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and identify glaring areas of energy waste or inefficiency.

Typically, only major problem areas will be uncovered during this type of audit. Corrective measures are briefly described, and quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided. This level of detail, while not sufficient for reaching a final decision on implementing proposed measures, is adequate to prioritize energy efficiency projects and determine the need for a more detailed audit. Following observation are made during walk through energy audit:

(a) Various types of energy and material inputs and various types of energy outputs, such as; Inputs in the form of electricity, petrol, diesel, furnace oil, lubricating oil, chemical, metals, consumables (graphite electrodes, reagents etc.), coal/fire wood/other fuels and biomasses. Outputs: finished products, byproducts, waste, scrap, heating /air conditioning / ventilation, and lighting

(b) Spots for reducing influx, exflux in thermal systems. Heat flows from high temperature to low temperature. Thermal systems have tendency to loose energy continuously by inlet of cold media or out let of hot media.

(c) Opportunities for waste reduction and waste recycling. -Electricity: Power factor and its improvement, MVA-max demand and its reduction.

(d) Optimizing Operating Cycle to reduce energy consumption. - Substituting the prevailing energy form by more economical one *e.g.* heating by using renewable energy rather than costlier petrol or electricity use of diesel instead of petrol.

(ii) General audit (Intermediate)

The general audit alternatively called a mini-audit, site energy audit or complete site energy audit expands on the preliminary audit described above by collecting more detailed information about facility operation and performing a more detailed evaluation of energy conservation measures identified. Utility bills are collected for a 12 to 36 month period to allow the auditor to evaluate the facility's energy/demand rate structures, and energy usage profiles. Additional metering of specific energy-consuming systems is often performed to supplement utility data. In-depth interviews with facility operating personnel are conducted to provide a better understanding of major energy consuming systems as well as insight into variations in daily and annual energy consumption and demand.

This type of audit will be able to identify all energy conservation measures appropriate for the facility given its operating parameters. A detailed financial analysis is performed for each measure based on detailed implementation cost estimates; site-specific operating cost savings, and the customer's investment criteria. Sufficient detail is provided to justify project implementation.

(iii) Investment-grade audit (Comprehensive)

The investment-grader audit alternatively called a comprehensive audit, detailed audit, maxi audit, or technical analysis audit, expands on the general audit described above by providing a dynamic model of energy use characteristics of both the existing facility and all energy conservation measures identified. The building model is calibrated against actual utility data to provide a realistic baseline against which to compute operating savings for proposed measures. Extensive attention is given to understanding not only the operating characteristics of all energy consuming systems, but also situations that cause load profile variations on both an annual and daily basis. Existing utility data is supplemented with sub metering of major energy consuming systems and monitoring of system operating characteristic.

2.3.3 Procedures of energy auditing

The procedure is dictated by the size, complexity and recurring energy costs of the plant. Thorough comprehensive energy audit and high investments in energy conservation measures are justified for energy intensive processes/plants.

(a) Composition of comprehensive audit team

The team members are selected according to the size, complexity and technical requirements of the plant / process. The team members may generally include:

The energy consultant, civil manager, electrical o & m engineer, mechanical o& m engineer, representative of electricity supply company, oil and gas supply company, member of loss prevention board and a system analyst conversant with data base.

(b) Data for comprehensive audit

This is obtained before commencement of the Comprehensive Audit and includes:

(i) Energy Consumption data for the previous years

(ii) Total production of previous year

- Per unit energy cost of previous years (e.g. Rs./kg of steel)
- Tariff (Rate schedules) of Electricity, Petrol, Diesel, Fuel, Lub oil, Heat, Coal, Wood, Other fuels.
- Plant documentation, equipment documentation, energy efficiency curves.
- Operation schedules.
- Typical daily electrical load curves and peak kVA demand readings for

previous years.

(c) Site testing and measurement

The Testing and Measurement is the main activity in comprehensive energy audit investigation. The actual energy consumption and actual energy converted to work and energy wasted are calculated based on the measurements. Plant efficiency is calculated based on actual measurements.

(d) Report of energy audit

The Comprehensive Energy Audit Report is generally very extensive and covers

(i) Energy Conservation Opportunities (ECOs)

(ii) Energy Conservation Measures (ECMs)

(iii) Projected investments for ECMs.

(iv) Projected annual savings of ECMs and pay back period.

(iv) Feasibility studies for retrofitting / modification work.

The report should be helpful in taking decisions on execution of ECM projects.

2.4 NEW EC METHODS SUGGESTED BY SOME INDUSTRIES

Some industries adopting new ECM, which are discussed as follows:

2.4.1 Rajshree Sugars & Chemicals Limited (RSCL), Tamil Nadu[27]

RSCL is committed to energy conservation and has taken up energy conservation measures. They have made EC cell and EC cell has a 3-tier composition, namely.

(i) Apex team

The apex team consists of the chairperson, whole time director, director & chief operating officer and the chief financial officer. The apex team formulates the energy conservation policy, plans and targets. The quality policy itself has the specific power consumption target defined quantitatively. The energy manager compiles the energy data and presents it in the management review meetings held every 3 months. The performance of the energy conservation projects and the specific energy consumption data are reviewed. Resource requirement for and allotted in the management review meetings.

(ii) Core team

The core team consists of the unit head, head of the department (HOD) of engineering department, HOD of production department and the energy manager as its members. This team formulates the specific energy consumption targets for individual cost centres of the plant namely the mill house, boiler house, evaporation & clarification, boiling house & bagging house. The monthly data is compiled and is reviewed in the monthly review meetings

(iii) Working team

The working team consists of three groups namely Power, Steam & water. The employees and officers at the plant are the members of the teams. They carry out internal energy audit once in six months. They identify and propose the energy conservation projects. They also collect energy data with respect to each cost centres daily and compare it with the set targets. It promotes the 4 R (reduce, reuse, recover and recycle) strategy of reduce, reuse, recover and recycle wastes to conserve resources and reduce pollution by adopting sound energy saving and environmental protection measures. The hierarchy of EC Cell is given in Fig. 2.1.

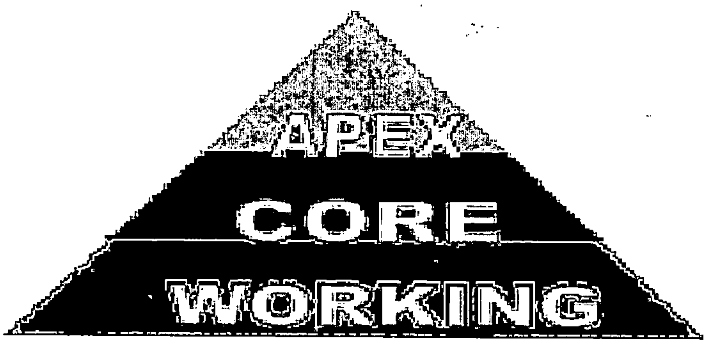


Fig. 2.1:The hierarchy of EC Cell

2.4.2 Indian Tobacco Company (ITC), Saharanpur [28]

ITC Saharanpur monitors committed to energy conservation through its commitment and actions. The unit is monitoring energy efficiency of supply and demand on daily basis. The unit has undergone periodic energy audits by competent organizations e.g. Siemens, TERI, Forbes Marshall, etc. Energy Conservation forms part of the unit's Environment, Health and Safety Management System. The Unit takes active participation in the divisional meet of ITC on energy every year to review the status of the projects and share the plans for the coming year. The senior management team chaired by the unit head reviews the performance on each of the performance indices in the area of energy conservation regularly. Variance on any index against the target is discussed in the daily review meetings.

Energy conservation projects and targets are part of yearly objectives for performance appraisal for engineers in the plant. Half yearly review is done by the superiors to ensure progress and mid term correction. Along with inputs from the expert team at the divisional head office, potential areas for conservation are studied and various solutions are explored towards achieving the potential savings.

ITC, Saharanpur has adopted the following strategies towards energy conservation:

(i) Strategy in the AIDA model (Awareness - Interest - Desire - Action)

ITC implemented AIDA model. By use of multiple channels & layers of communication leading to awareness, interest & desire. They have achieved following:

- Daily tracking of energy consumption per unit production (kWh/Mnc) with analysis at the morning meetings.
- One to one interaction amongst the members of energy team on fixed days every week in which the energy team members highlight the energy issues relevant to their respective areas.
- Special issue of the Unit's In-house magazine "Pukaar" (A Clarion Call) with energy conservation being the theme.
- Monthly meetings of energy team which is a cross functional group of managers and employees across departments, rank & hierarchy to discuss & resolve issues related to energy conservation.
- Energy suggestion scheme & felicitation of winners in public by the Unit head

- Devoting a cross functional team, as a fall out of the Kaizen initiative undertaken by the unit, to generate ideas related to energy conservation, evaluate, implement & share results with the Energy team
- Making energy a key index to measure the unit's performance and reviewing it every month at the branch performance Review chaired by the unit head.

(ii) Monitoring and reporting systems

They use multiple forums for effective review of energy consumption and sharing energy conservation projects.

(a) On daily base

Unit is reviewing performance every day morning, attended by top management, shop floor managers and key employees. Energy data is shared with team members in that meeting. Data on specific energy consumption for each department is monitored, recorded, compared against internal target and shared.

(b) On weekly base

One of the energy team members shares the performance on energy against the target as well as compares the same with last year performance for the corresponding period.

(c) On monthly base

Energy committee members are meeting on monthly basis to review the status. Energy consumption data, actions to be taken and energy conservation projects to be undertaken in the future are discussed. The senior management reviews the performance of the unit every month with managers from all functions being the reviewer.

(d) Daily reporting

Online energy monitoring captures data on different key areas of the factory and energy reports being generated every day.

2.4.3 Star Paper Mills Limited, Saharanpur [29]

Star Paper Mills Limited (SPML) is committed for the energy efficient usage of its assets. To achieve this, energy management has been integrated into the overall structure of the organization.

SPML has an "Energy Management Cell" which is responsible for the monitoring of energy consumption and also for implementation of "Energy Savings Ideas". In addition to this, Company gives strong emphasis on the involvement of all the persons down the line for productivity improvement.

General manager (Engg.) holds the additional responsibility as Head of the energy management cell who is assisted by "Certified Energy Manager" and other Process and Engineering Officers. Ideas are generated through Brain Storming and discussions. Ideas are evaluated and Cost-Benefit Analysis is being done and after approval of the management, implementation and monitoring is done. The flow chart of EC cell is given below in Fig. 2.2.

2.4.4 Thyssen Krupp Electrical Steel India Private Limited (TKES)[30]

TKES is committed to total energy management and prevention of energy wastage. Awareness & involvement of people at all levels has been a major plan for implementation of ENCON measures. TKES India believes not only in implementing latest Energy conservation techniques to achieve the target but also to sustain the same by providing adequate training and awareness on the project implemented. The ENCON activities are monitored by a well-structured setup called the ENCON Core Group. The cell continuously monitors the ENCON activities and reports the achievements to the top management on a periodic basis. As a continued effort towards achieving excellence in the field of energy conservation, an energy policy, has been formulated at TKES, which reflects the commitments of the top management towards conservation of energy, resources & environment. This commitment has enabled the company to reduce specific energy consumption on continual basis. The organizational structure of energy management cell shown in Fig.2.3.

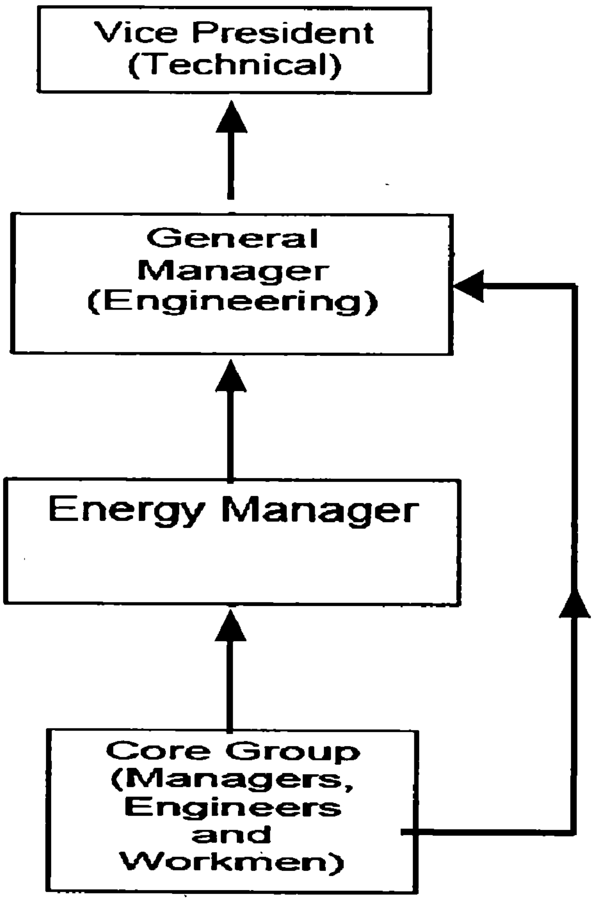


Fig. 2.2: Flow chart of EC cell [29]

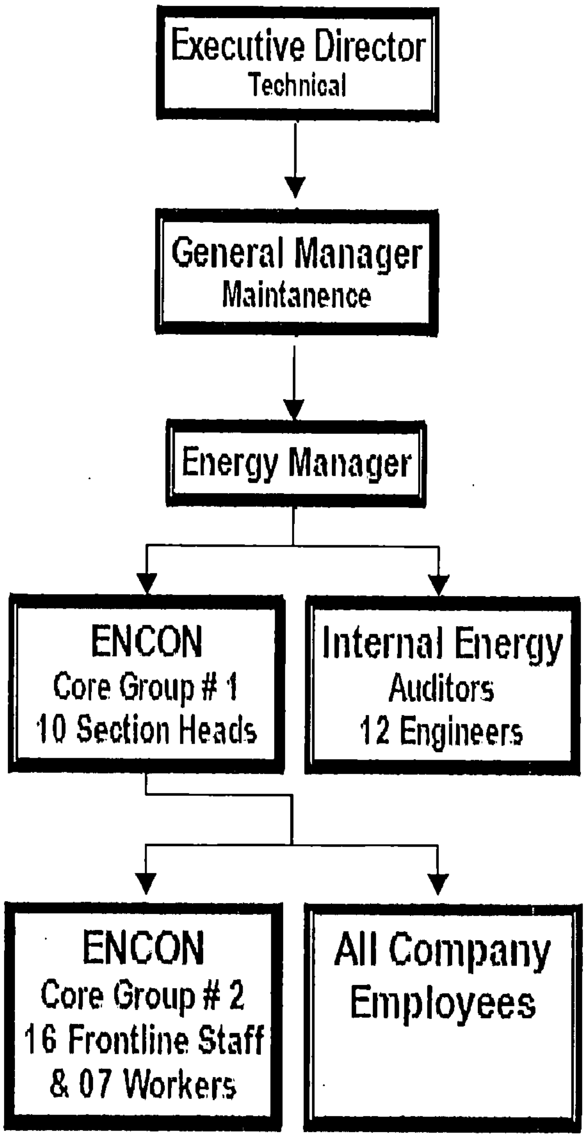


Fig. 2.3: Organizational structure of energy management cell [30]

2.5 ENERGY CONSERVATION BY USING DRYER [31]

Drying is perhaps the oldest, most common and most diverse of chemical engineering unit operations. Over four hundred types of dryers have been founded in the literature while over one hundred distinct types are commonly available. Energy consumption in drying ranges from a low value of under five percent for the chemical process industries to thirty five percent for the papermaking operations. Drying occurs by effecting vaporization of the liquid by supplying heat to the wet feedstock. Heat may be supplied by convection (direct dryers), by conduction (contact or indirect dryers), radiation or volumetrically by placing the wet material in a microwave or radio frequency electromagnetic field. Over 85 percent of industrial dryers are of the convective type with hot air or direct combustion gases as the drying medium. Over 99 percent of the applications involve removal of water. This is one of the most energy-intensive unit operations due to the high latent heat of vaporization and the inherent inefficiency of using hot air as the (most common) drying medium.

2.6 ENERGY CONSERVATION APPROACH IN INDUCTION MOTOR [32]

Electric motors are intrinsically very efficient. Their efficiencies vary from 85% to 95% for motors of sizes ranging from 10 HP to 500 HP. It is still possible to improve the efficiency of these motors by 1 to 4% by using more efficient motors. However, in the energy efficiency game, there are a number of other things also one should focus; more than just improving the efficiency of motors alone. The following Fig. 2.4 shows the break up of electricity use in motor driven systems in India.

In industry, most commonly used motors are 3 phase squirrel cage induction type. Use of Synchronous motors and DC motors for heavy duty and precision drives etc. are also common. With the introduction of variable frequency drives for speed and torque control, the 3-phase induction motors are finding increasingly acceptable for applications where DC drives were earlier used.

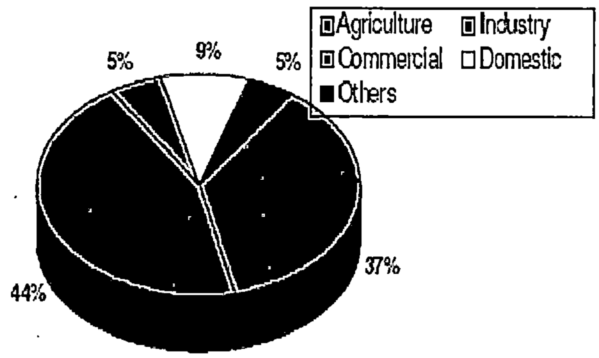


Fig. 2.4: Sector-wise break-up of electricity consumption in motor driven systems [33]

2.7 PROCESS DESCRIPTION OF SUGAR MILL

Sugar industry is the largest agro-based industry located in the rural India. About 45 million sugarcane farmers, their dependents and a large mass of agricultural labourer are involved in sugarcane cultivation, harvesting and ancillary activities, constituting 7.5% of the rural population. Besides, about 0.5 million skilled and semi-skilled workers, mostly from the rural areas are engaged in the sugar industry. Sugarcane is the main raw material for sugar industry and accounts for 70% of the cost of production of sugar. It is also the major source of income for millions of farmers.

There are 553 installed sugar mills in the country with a production capacity of 180 lakh MTs of sugar. These mills are located in 18 states of the country. About 60% of these mills are in the cooperative sector, 35% in the private sector and rest in the public sector. There are 10 sugar mills in Uttaranchal.

Sugar is a disaccharide extracted from sugarcane. The sugar manufacturing can be grouped in the following categories depending upon the nature and quality of the final product

(i) Gur and Sakkar manufacturing small units

(ii) Khandsari-manufacturing of unrefined low-grade sugar

(iii) Double carbonation/double sulphitation process

(iv) Double sulphitation process.

The Uttam Sugar Mill Limited with its installed capacity of 6250 TCD falls under the category of large scale.

2.8 STEPS INVOLVED FOR THE PRODUCTION OF SUGAR

2.8.1 Procurement of Sugar Cane

Depending upon the variety of the sugar cane, on maturity the sugar cane is harvested in the field where the roots and dry and green leaves are removed manually and the sugar cane is prepared for transportation to the factory. Depending on the location of the field the cane is transported to the factory by bullock carts, tractor trolleys and trucks.

2.8.2 Milling of Sugar Cane

The sugar cane is unloaded at the mill house by winch and grab on the cane carrier, which feeds the fibrizing system. Here the sugar cane is shredded into small pieces. The shredded sugar cane is then squeezed through a series of pressure milling rolls having grooved surface. Weak juice or water is added to last roller so that recovery of juice is of the order of 95-97%.

2.8.3 Juice Preparation Double Sulphitation Process

This is the latest process adopted for juice clarification. In this process, juice is heated to 70° C and is treated with lime and sulphur dioxide ($S0_2$). The juice is adjusted to neutral pH and passed to the heat exchanger to raise its temperature to the boiling point. It is then sent to clarifier where the juice is clarified and then sent to multiple effect evaporators. The sediment from the clarifier is sent to vacuum filters. The juice mud is taken out as solid waste and the extracted juice is mixed with raw juice.

2.8.4 Juice Concentration

The clarified juice is concentrated to about 65% solids from about 15% solids before entering the first multiple effect evaporator sending steam in the first evaporator Vapours from the first evaporation are fed to the second evaporator and so on spent steam from the first evaporator is returned to the boiler for reuse as feed water for steam generation. Spent steam from the second and third evaporator is used for process and vapours from last evaporator are condensed through condensers.

2.8.5 Syrup Processing and Crystallization

The concentrated juice or syrup from the evaporator is again bleached by passing sulphur dioxide through it and the pH of the syrup drops down to about 5.4. It is then sent to the vacuum pan where the thickened syrup is boiled for three to four times as per purity in order to extract the sucrose content. It is then sent to crystallizers to deposit any additional sucrose content on the crystals. Fine sugar is used as seed crystals.

2.8.6 Sugar Crystal Separation, Drying, Packing and Molasses Handling

The mixture of crystals and liquor, called massecuite, is sent to high-speed basket centrifuges. The liquor is reconcentrated and cooled successively to obtain more than one crops of crystals. The final mother liquor, called molasses, which is still very rich in sugar content, is sent to steel storage tanks. The molasses is sold to various distilleries and other users against permit issued by the excise department. The separated Crystals are to the hopper conveyors where hot and cold air is passed through the crystals. The appropriate size is dried and sent to elevators. The elevators feed the grading system bins. The fine crystals are reused for seeding. Finally the finished product is bagged and stored in the sugar is released for sale, through Government or private distribution systems against the release order.

2.8.7 Bagasse Utilization

The pulp expelled after extraction of juice is called bagasse. As it comes out of the mill house, it contains about 50% moisture. Number of drying processes have been tried in the industry but unfortunately none of these were found industrially viable. Therefore, the wet bagasse with 50% moisture is carried to boiler house by bagasse carrier. It is able to generate about 2 kg of steam per kg on wet basis. With efficient boilers coming in the market, the factories are able to save about 10-20% bagasse. The excess bagasse is carried to bagasse yard from where it is sold to paper mills and other users. During the general cleaning or shut down, bagasse return carrier brings the bagasse back to the boiler. A small fraction is sent to bailing plant where bagasse is compressed and tied by G. I. wire to form small bails. The bagasse can be stacked in the form of small bails. Manufacturing process of sugar mills shown in Fig.2.5.

MANUFACTURING PROCESS FLOW CHART

DEFECATION SECTION

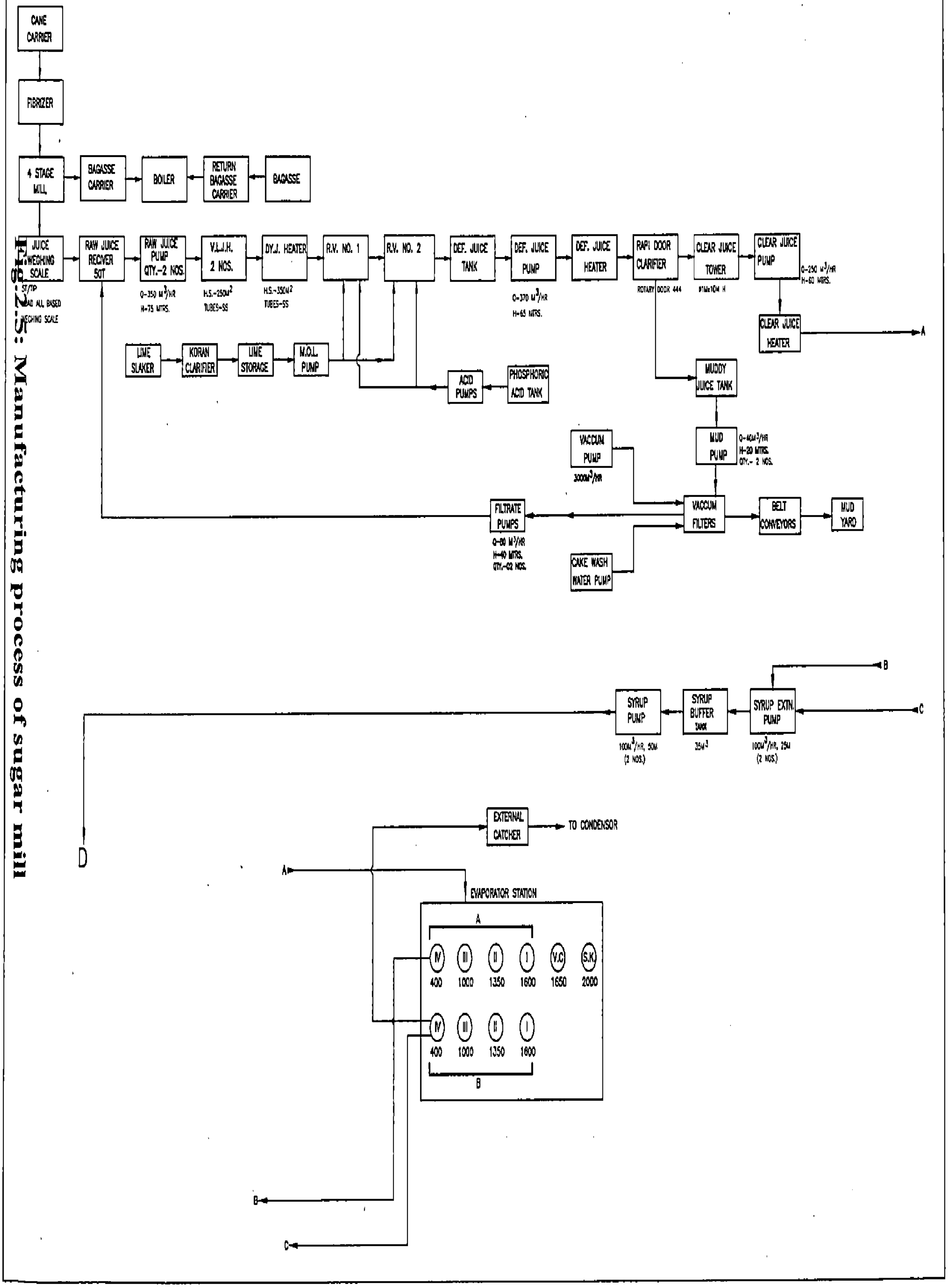
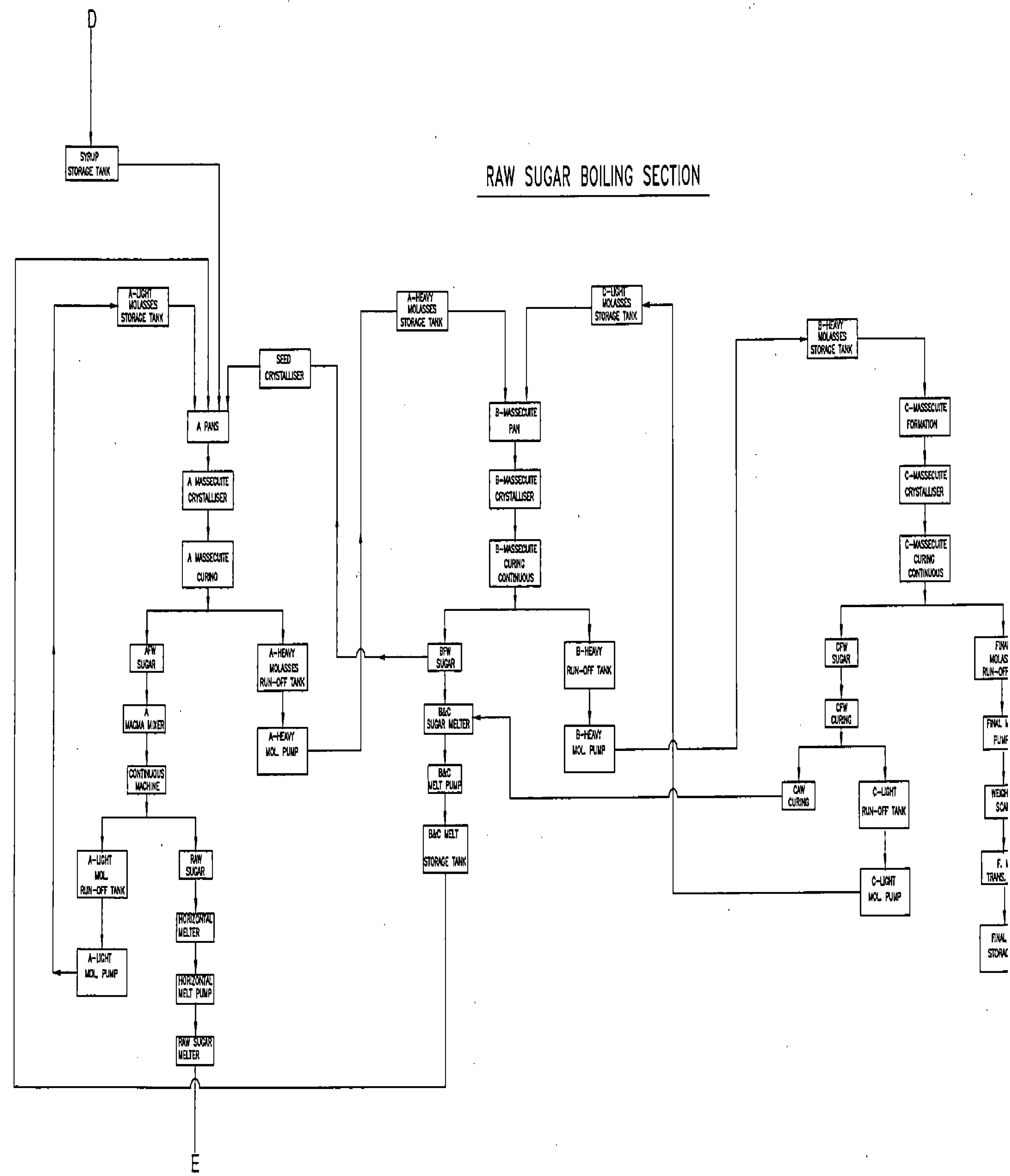
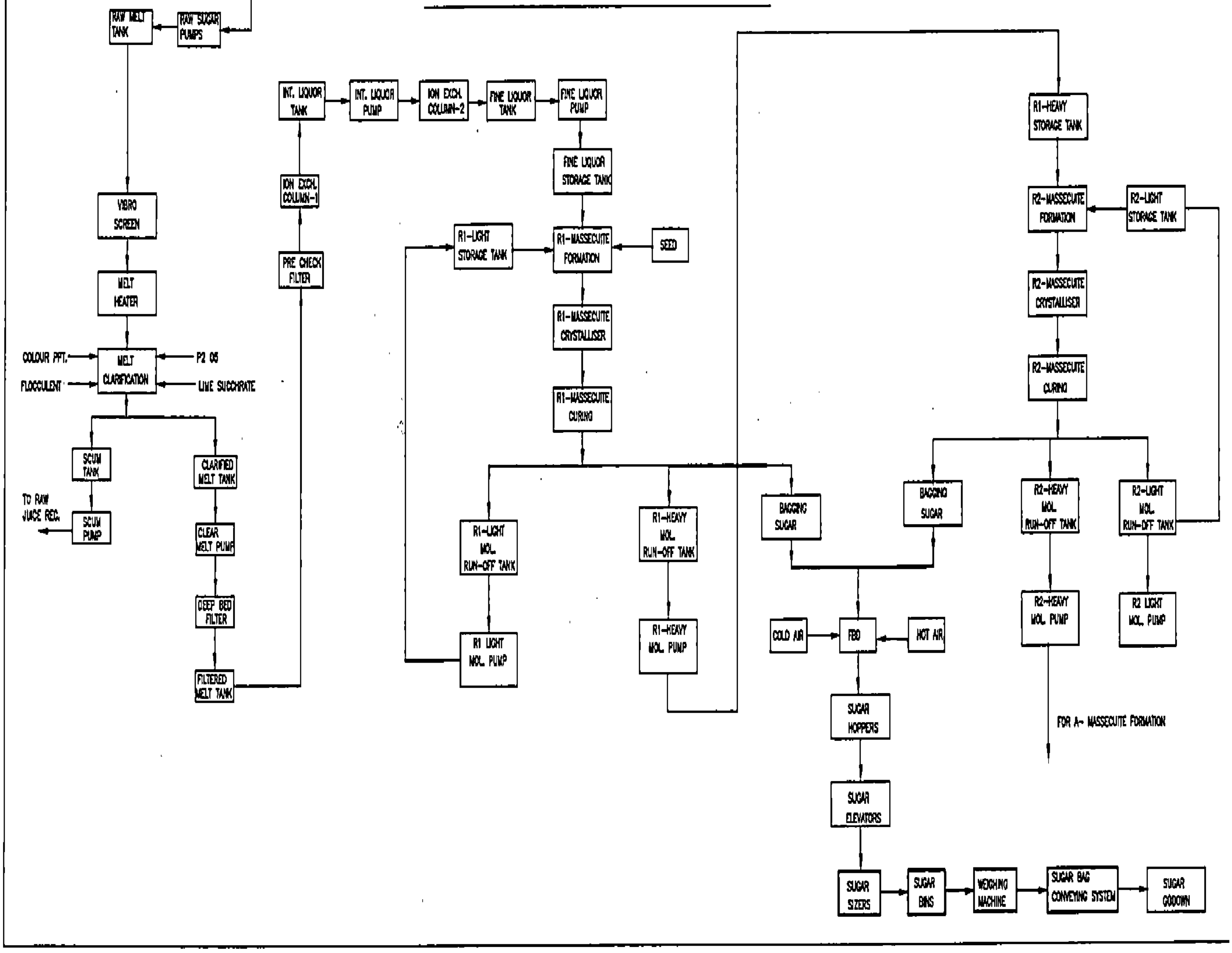


Fig.2.5: Manufacturing process of sugar mill


D
SYRUP STORAGE TANK
RAW SUGAR BOILING SECTION
A-LIGHT MOLASSES STORAGE TANK
SEED CRYSTALLISER
A PANS
A MASSECUITE CRYSTALLISER
A MASSECUITE CURING
AFW SUGAR
A-HEAVY MOLASSES RUN-OFF TANK
A MAGMA MIXER
A-HEAVY MOL. PUMP
CONTINUOUS MACHINE
A-LIGHT MOL. RUN-OFF TANK
RAW SUGAR
HORIZONTAL MELTER
A-LIGHT MOL. PUMP
HORIZONTAL MELT PUMP
RAW SUGAR MELTER
E
A-HEAVY MOLASSES STORAGE TANK
C-LIGHT MOLASSES STORAGE TANK
B-MASSECUITE PAN
B-MASSECUITE CRYSTALLISER
B-MASSECUITE CURING CONTINUOUS
BFW SUGAR
B-HEAVY RUN-OFF TANK
B&C SUGAR MELTER
B-HEAVY MOL. PUMP
B&C MELT PUMP
B&C MELT STORAGE TANK
B-HEAVY MOLASSES STORAGE TANK
C-MASSECUITE FORMATION
C-MASSECUITE CRYSTALLISER
C-MASSECUITE CURING CONTINUOUS
CFW SUGAR
CFW CURING
CAW CURING
C-LIGHT RUN-OFF TANK
C-LIGHT MOL. PUMP

REFINERY SECTION & BOILING SCHEME



ENERGY CONSERVATION IN SUGAR INDUSTRY

3.1 GENERAL

In the previous chapter, the various energy conservation measures and techniques have been discussed. In addition, a short discussion has been done related to the manufacturing process of sugar industry. Presently in India, more than 400 sugar industries are under operation. Sugar industry is one of the huge energy consuming sector. Most of the above industries are either utilizing conventional large power consuming devices or showing their neglect view towards energy conservation. Following conservations approaches in tandem with co- generation can save large potential about 5200 MWpower [6]. There are various sections / process in the sugar industry where maximum shear of energy are utilized. The processing of sugarcane into sugar involves a number of process steps. The cost of conversion from sugarcane to sugar is nearly 1/3rd of the total cost of manufacture of sugar. The major costs include manpower, energy and consumable costs. In addition, the sugar loss in processing and the maintenance of plant and equipment have a direct impact on the economics of sugar production. Necessary research is therefore required in all the above areas of process operation. Various sections where the scope of energy conservation in sugar industries is most are discussed in this chapter.

3.2 CANE PREPARATION

The first step is the cane preparation before milling cane to extract its juice content to the maximum extent. Cane preparation means, bursting or rupturing the hard rind portion of sugarcane or cutting it into small pieces, thereby exposing the juice cells for easy extraction of the juice contained in the cells. The advantages of good cane preparation and energy consumption reduce.

There are different types of cane preparatory device's in use at present. Using a set of knives, known, as cane leveller and cane cutter is an age-old practice in cane sugar factories all over the world. Even now, many factories are using 2 sets of knives, driven by either electric motor or steam turbine. Thus, consumption of electric power or steam at this station has to be reduced, as far as possible for achieving energy, conservation. From the year 1960 onwards, new types of cane preparatory devices like () Shredders, (ii) Fibrizers, (iii) Busters, (iv) Unigrators, (v) Mincers, and Many manufacturers in different countries developed disintegrators. All these devices have a rotor driven by a steam turbine or electric motor. On the rotor, there are many swing hammers, which rotate at 1000 to 1200 rpm in a casing having anvil plates with sharp corrugations. The hammer heads and anvil plates are made of special alloy steel to withstand the abrasion. The weight of each hammer head varies from 10 kgs to 25 kgs. Hence, enormous power is required to rotate them at a speed of 1000 to 1200 rpm with such heavy hammer heads, which may be 60 to 200 for different types of shredders / fibrizers.

3.3 JUICE EXTRACTION BY MILLING

After a good cane preparation, the next step is to extract the juice contained in the prepared cane by passing it through either a milling plant or a diffusion plant. Milling of sugar cane is a very complicated operation, as the milling plant consists of 4 to 7 sets of 3 roller mills driven by steam engines / steam turbines / D.C. or A.C. motors through sets of high speed and low speed gears, which also drive the intermediate carriers, underfeed rollers, pressure feeders etc. Of course, in the case of modern hydraulic drives, the complicated gears system is not necessary. Hence, the power consumption of a complete milling plant comprises of the power consumption of a number of components of the milling plant, power losses due to friction, power transmission efficiency etc. Hence, any effort to reduce power consumption in a milling plant is also complicated, as the total power consumption in a milling plant depends on many factors, some of which are as follows:

(i) Variety of sugarcane crushed
(ii) Fibre content of cane
(iii) Extent of cane preparation
(iv) Length of the milling tandem
(v) Size of the rollers and grooving pattern
(vi) Apex angle of mill and condition of the mills
(vii) Mill speed

(viii) Juice drainage and reabsorption of juice by bagasse
(ix) Total Hydraulic load on top rollers
(x) Pressure distribution on rollers and maximum pressure
(xi) Compression ratio on feed side and filling ratio on discharge side
(xii) Mill setting
(xiii) Trash plate setting
(xiv) Mill bearings
(xv) Mill lubrication efficiency
(xvi) Condition of intermediate carriers, pressure feeders etc.

Hugot [22] has pointed out that though determination of total power consumed by a milling tandem is rather complex, because of a number of factors entering into it, the power may be split up into the following 6 different principal parts:

(i) Power consumed by compression of bagasse
(ii) Power consumed in friction between the shafts and bearings of the rollers
(iii) Power consumed by friction between bagasse and trash plate
(iv) Power consumed by friction of scrappers and toe of the trash plate against the rollers, to which should be added the work of dislodging the bagasse at these points
(v) Power consumed in driving the intermediate carriers
(vi) Power absorbed in the gearing.

Furthermore, these components of power themselves depend on certain factors, which are rather difficult to measure or estimate, such as variety of cane, state of friction surfaces, quality and regularity of lubrication, adjustment of mill settings and of the trash plate etc. Owing to the impossibility of taking into account all these factors, Hugot is of the opinion, that there is no point in seeking great precision in the calculation of power for milling. Hence, the power requirement of milling tandems, as calculated by different milling experts like, Noel Deerr, Maxwell, Tromp, are quite different. However, the power requirement of Java mills, as given by Tromp more or less coincide with the figures given by other experts.

3.3.1 Scope of Energy Consumption Reduction in Milling

The main aim of milling is to extract as much sugar (juice) as possible from the prepared cane and leave lowest possible quantity of sugar in bagasse, which will be burnt as fuel in the boilers. As mentioned earlier, generally, in order to have a very good preparation of cane and high extraction, a large amount of energy (steam or electric power) has to be used. However, the aim of all sugar factories is to increase extraction efficiency with less or optimum quantity of energy.

The power requirement of mills can be brought down considerably by adopting good techniques:

(a) Pressure feeding devices

GRPF (Grove Tooth Roller Pressure Feeder), TRPF (Tooth Roller Pressure Feeder), are various types of pressure feeding devices. These units extract and drain the juice. The bagasse density increases due to compaction of bagasse. High density compacted bagasse with less moisture and having feeding force is the ideal condition of mill performance. The mill requires less hydraulic pressure as the thickness of the bagasse blanket gets reduced. With improved co-efficient of friction and high density bagasse, it is possible to run the mills at lower speed and at low mill work ratio to 1.5/1.6. All this will reduce the reabsorption and ultimately reduce the power requirement and improve extraction.

(b) Installation of perforated rollers

The juice in bagasse in the mill is under pressure. The juice will find its way with velocity through bagasse according to the permeability of the bagasse. The juice around the surface of the groove will find its least resistance path through the holes provided on it. There will be substantial juice drainage from bagasse in low pressure zone, which will increase the permeability of bagasse for further juice drainage in high pressure zone in the mill. Installing perforated rollers will have all process advantages, which are available in pressure feeding devices. Further, Lotus roller is having additional advantage of extracting air entrapped in bagasse.

Air under pressure gets dissolved in liquid and gets released with velocity and violently when pressure is removed. The air with high velocity carries the juice and fine bagasse particles ahead of the roller. This increases the volume of bagasse more than the ascribed volume. This is re-absorption in the mill.

(c) Roller grooving

The differential groove angles will have better juice drainage and will improve bagasse preparation. The angles - feed rollers - 30° / 35°, top roller - 55° and discharge roller - 50° are recommended. Higher pitch will be having more free flow area for juice. The pitches 65 m/m for 1st and 2nd, 50 m/m for 3rd and 4th mill and 40/45 m/m for 5th mill recommended for improved mill performance. Messchaert groove in each circumferential groove on all feed rollers are provided for additional free flow area. Better alternative is to have perforated roller on all feed rollers. This will avoid re-circulation of juice in the mill.

(d) Hydraulic load

The power consumption in the mill is directly proportional to the hydraulic load applied the efficient juice drainage in pressure feeders, lotus rollers, reduces the bagasse reaction. Subsequently, there will be reduction in applied hydraulic load. The hydraulic load applied is according to the square root of specific opening for given extraction. Efficient juice drainage through pressure feeders, a lotus roller reduces the bagasse blanket thickness. In the case of installation of pressure feeders, lotus roller, about 20 / 25% reduces the requirement of the hydraulic load from conventional one.

(e) Mill speed

Power consumption is directly proportional to rpm of roller. High-density bagasse lower moisture being received by mill will allow to run the mill at lower speed. The bagasse gets more retention time in mill for efficient juice drainage. The mill speed may be adopted in the range of 25 to 30 feet per minute (F. P.M.) (7.6 - 9.14 m/min.) according to the ability of the mill drive. Lower speed will improve coefficient of friction of bagasse with roller s for better feedability and reduce the re-absorption effecting reduction in power improvement in extraction. The other tangible advantage is it reduces the wear of the roller and oil consumption in the bearing.

(f) Mill openings

The power consumption is proportional to the square root of the specific opening approach to deciding the mill openings for the mill having provided with pressure. And or lotus roller will be different than that for the mill having conventional set up. The fibre index can be adopted safely 1.5 times higher than the figures used in the conventional setup for the effective use of pressure feeder and lotus roller. Further, the mill work is used safely as low as 1.5/1.6 for power efficiency and improvement in extraction. The tuning may be required in hydraulic load, mill speed and mill opening, according bagasse analysis of the mill.

(g) Re-absorption of juice

Re-absorption of juice in the mill is mainly responsible for increasing the power in and simultaneously affecting the mill extraction.
The following are the major reasons for increasing the re-absorption in the mill

(i) Poor cane preparation
(ii) Higher Speed iii) Higher hydraulic loads
(iv) Higher mill work ratio beyond *1.5/1.6*
(v) Inefficient Juice drainage through mill
(vi) Extrusion of bagasse: The extrusion of bagasse increases with increase in pressure and mill speed.

(h) Co-efficient of friction

The slip between the bagasse speed and roller speed increases with reduction in coefficient of friction of bagasse with roller surface. The following are the main reasons for reducing the coefficient of friction,

(i) Wet roller surface due to inadequate juice drainage.
(ii) Getting roller surface polished due to deficiency in the metallurgy of the shell material.
(iii) Excessive hot imbibition water.
(iv) Excessive peripheral speed. The coefficient decreases as per following equation.

$\mu = 0.43 - 0.002S$,

Where S = Roller surface speed in ft/min.

(v) Excessive hydraulic load.

The following precautionary measures are to be taken to improve the coefficient of friction.

(i) High density bagasse with low moisture is to be fed to mill by using positive pressure feeders.

(ii) Efficient juice drainage is to be provided by using pressure feeders and lotus rollers.

(iii) Improve the roller surfaces by hard facing. The operation should be maintained continuously throughout the season.

(iv) Positive displacement of bagasse by using Chevron grooves on the top and feed rollers. The Pineapple type pattern is preferred over conventional herring bone type, as it cuts the bagasse blanket at a time throughout the length of the roller.

(v) The lower roller speed will not only improve the coefficient of friction but also improve the mill extraction and reduce the power in the mill.

3.4 JUICE CLARIFICATION

In a sugar factory, the juice extracted from sugar cane is at a temperature of about 30°C (depending on ambient temperature and many other factors). This temperature has to be raised in stages upto almost boiling point, during the juice clarification process either by carbonation or sulphitation. Stage-wise heating means, heating with different vapours, the raw juice, treated juice and finally, clarified juice before it enters the evaporator for concentration. The quantity of juice to be heated is very large, almost equal to the hourly cane-crushing rate. To heat such a large quantity of juice from about 30°C to the boiling point, at atmospheric pressure, a very large source of heat energy is required. This is derived from the heat content of exhaust steam or low temperature vapours obtained from different bodies of the evaporator or even from continuous vacuum pans. The equipment normally used to heat the juice known as juice heaters, which are some-kinds of heat exchangers.

3.4.1 Use of Heat Exchanger (Juice Heater)

A heat exchanger is a device, which is used for transfer of internal thermal energy between two or more fluids, separated by a heat transfer surface. A heat exchanger consists of heat exchanging elements, such as a core or a matrix containing the heat transfer surface, and fluid distribution elements such as headers, manifold, tanks, inlet and outlet nozzles or pipes or seals. The heat transfer surface is the surface of the exchanger core, which is in direct contact with the fluids and through which heat is transferred by conduction.

There are a number of types of heat exchangers used for heating or cooling different types of fluids. But, the most relevant types used in the sugar factories and distilleries are (i) Shell and tube exchangers, (ii) Plate type exchangers and (iii) Spiral plate heat exchangers.

3.4.2 Best Heat Economy at the Juice Heaters

Taking vapours from various vessels of the multiple effect evaporators in turn and finally with exhaust steam generally does juice heating in sugar factories. By this arrangement, the vapours bled from different bodies of the evaporator, though they have a low temperature as compared to exhaust steam, are advantageously used to ensure energy conservation.

Efforts should made to make the best use of the heat content of each type of vapour by bleeding adequate quantity of vapour from each body without starving the next body of the evaporator for effecting proper concentration of the juice. Otherwise, the excessive heating surface, which will be necessary to obtain a hotter juice, would be out of proportion to the gain in temperature so obtained [35].

3.5 JUICE CONCENTRATION BY EVAPORATOR

The clarified juice is concentrated to about 65% solids from about 15% solids before entering the first multiple effect evaporator sending steam in the first evaporator Vapours from the first evaporation are fed to the second evaporator and so on spent steam from the first evaporator is returned to the boiler for reuse as feed water for steam generation. Spent steam from the second and third evaporator is used for process and vapours from last evaporator are condensed through condensers.

Energy experts in all the countries are of the opinion that in a sugar mill, so far as energy conservation is concerned, evaporator is the main equipment. Some experts have mentioned that in a sugar mill, boiler is meant for supplying steam at high pressure (live steam) to the prime movers like, steam engines/steam turbines driving the mills and power generator, whereas evaporator is meant for supplying steam at low pressure (exhaust steam) to the boiling house equipment like, juice heaters, different bodies of the evaporator, vacuum pans etc. This means, that in an energy efficient sugar mill, evaporator should work like a boiler of the boiling house, supplying the entire low pressure steam required for heating and concentration of the juice, till crystallisation in the vacuum pans.

3.5.1 Development of Evaporator

The need for evaporation of certain liquids to obtain dry solids had been felt thousands of years ago. Sometimes, solar evaporation was adopted by exposing the liquid to sunlight during the daytime. Even now, for producing natural salt from sea water, solar evaporation is adopted. Later on, heating the liquid in a pot by direct flame has been adopted. Even now, in many tropical countries, which grow sugarcane, cane juice is concentrated in open pans with direct, flame produced by burning bagasse or other fuels, for producing jaggery and khandsari sugar.

Multiple effect evaporators can be considered as one of the worlds greatest economic inventions and literally millions of tonnes of fuel are saved yearly through its adoption in the sugar and other industries.

3.6 CRYSTALLIZATION

The concentrated juice or syrup from the evaporator is again bleached by passing sulphur dioxide through it and the pH of the syrup drops down to about 5.4. It is then sent to the vacuum pan where the thickened syrup is boiled for three to four times as per purity in order to extract the sucrose content. It is then sent to crystallizers to deposit any additional sucrose content on the crystals. Fine sugar is used as seed crystals.

3.7 DRYING, PACKING AND MOLASSES HANDLING AND SUGAR CRYSTAL SEPRATION

The mixture of crystals and liquor, called massecuite, is sent to high-speed basket centrifuges. The liquor is reconcentrated and cooled successively to obtain more than one crops of crystals. The final mother liquor, called molasses, which is still very rich in sugar content, is sent to steel storage tanks. The molasses is sold to various distilleries and other users against permit issued by the excise department. The separated Crystals are to the hopper conveyors where hot and cold air is passed through the crystals. The appropriate size is dried and sent to elevators. The elevators feed the grading system bins. The fine crystals are reused for seeding. Finally the finished product is bagged and stored in the sugar is released for sale, through Government or private distribution systems against the release order.

3.7.1 Energy Conservation at Centrifugals

The separation of sugar crystals from the surrounding mother liquor is carried out in centrifugal machines. The centrifugal force created by rotating the centrifugal basket at high speed is responsible for separating the mother liquor, which gets out of the centrifugal basket through the perforations in the basket leaving the sugar crystals inside the basket.

There are two principal methods of electric drive for centrifugals, as follows:

(a) By 3-phase induction motor: this may have a wound rotor, but more often is of squirrel Cage type. The later type is distinguished by its simplicity and robustness.

(b) By direct-current motors supplied through thyristors from the A.C. network of the factory. This solution offers several advantages over induction motors, such as.

(i) Choice of speed of the centrifugal machine independent of the frequency of the A.C.supply.

(ii) Precise control of speed, hence of the drying time.

(iii) Specific power consumption of one-third to two-thirds of that of an induction motor:

(iv) Elimination of the peak current demands for each change of polarity of an induction motor.

(v) Less heating of the motor. The higher power consumption of the induction motor causes heating of the rotor before changing of polarity and braking. The efficiency of D.C. motor is much higher, leaving about one-third of the heat to be dissipated, thus rendering the motor much smaller.

(vi) Operation without sudden peak loads, due to elimination of the abrupt acceleration with an induction motor.

(vii) Flexibility of operation, due to control of the rates of acceleration and braking, thus permitting adoption of the centrifugalling to the quality of massecuite handled. This regulation is not possible with induction motors.

The efficiency of electric motors driving centrifugal machines is low, since they operate alternatively during acceleration and during running at speed, and there are no motors in existence, which give a good efficiency in conditions varying so greatly.

3.8 USE OF HEAT PUMPS FOR ENERGY CONSERVATION

Heat pump is a device, which extracts low-grade heat from suitable source (like condensate or even outside air) and upgrades this heat to a higher temperature using external higher-grade energy (like electric power). In fact, a heat pump acts exactly as a reverse of a refrigerator, in which heat is released from a cooling unit to the surrounding room. Thus, cold air outside the house can be regarded as the inside of a refrigerator and the heat pump acting between the outside and inside of a house can be used to warm the inside area. Heat pumps can also be used for cooling. Heat is then transferred in the opposite direction, from the application that is cooled, to surroundings at a higher temperature. Sometimes the excess heat from cooling is used to meet a simultaneous heat demand.

In many applications, however, industrial heat pumps operate with just one process. Heat rejected from a process is upgraded by the heat pump and is re-supplied to the process. Such industrial heat pumps provide an effective means of heat recovery and can achieve very good values of Primary Energy Ratio (COP) and Primary Energy Ratio (PER). However, the COP or PER of a one-process system should not be compared with that of a two-process system, since the operation of these energy systems is quite different. While COP and PER give a good indication of a heat pump's performance, a more thorough analysis of the energy system should be made in order to evaluate the true benefits of an industrial heat pump installation.

3.9 EFFICIENT UTILIZATION OF STEAM IN SUGAR MILLS

The usual practice in sugar mills is to generate steam at high pressure (varying from 30 to 65 kgs/cm^2 or even higher) for driving the prime movers like steam engines or steam turbines, in cane sugar mills to run the milling plant and power generator .The exhaust steam obtained at a low pressure varying from 1 to 2 kgs/cm^2 is known as process steam, as it is mostly used for heating, concentrating the beet or cane juice. Low pressure (exhaust) steam is used in the juice heaters for heating different types of juices (raw juice, treated juice, clear juice etc.), in evaporators for concentration of thin juice and in vacuum pans for further concentration of syrup to crystallize out the sugar. If the exhaust steam generated from the prime movers is more than the process steam required in juice heaters, evaporators, vacuum pans etc., then surplus exhaust steam has to be blown out to the atmosphere, which means, wasting valuable energy. On the other hand, if the exhaust steam generated from the prime movers is less than the process steam required in the above equipment, then a part of the expensive high pressure live steam has to be simply passed through a reducing valve to produce low pressure steam to supplement the exhaust steam generated by the prime movers. But, this practice of using a reducing valve, just to produce low pressure steam is not considered to be a wise practice nowadays, as during the reduction of high pressure to low pressure in a reducing valve, no useful work is done by the high pressure steam and its energy is simply wasted. On the other hand, if this high pressure steam is passed through a steam turbine, a dual purpose is achieved, as; (i) The steam turbine coupled to a power generator can produce electric power and (ii) the steam turbine delivers the required exhaust steam at suitable pressure to be used as process steam. In the process of reducing the steam pressure, electric power is generated and hence, this power is known as by-product power.

3.9.1 Steam Balance in Cane Sugar

Due to the reasons mentioned above, it is essential in every cane sugar factory, to establish a steam balance so that, the steam generated by burning fossil fuels or bagasse is sufficient to meet the steam requirement of the entire sugar factory. The live steam produced in a well balanced sugar factory should be equal to the process steam. For this, the equipment for steam generation, as well as steam consumption should be carefully designed.

The approximate break-up of the process steam requirement in the white sugar factories of India, after adopting energy conservation measures are as follows;

(i) Juice heaters	: 8.2% on cane
(ii) Evaporators	: 20.0 on cane
(iii)Vacuum Pans	:12.0% on cane:
(iv) Miscellaneous, (pan washing, centrifugals etc).	: 5.0% on cane

i.e. a total of 45% on cane crushed.

3.10 EFFICIENT GENERATION OF STEAM IN SUGAR MILLS

Boilers are meant for generating steam by evaporating water with the help of heat imparted by burning any type of fuel. Steam is used for heating and power generation in many industries. Process steam has many uses in the industry and is the largest consumer of industrial fuels and energy.

As far as steam for heating and process is concerned, there are just two fundamental things that govern every thing. These are follows as:

(i) The boiling point of water decreases with reduced pressure,

(ii) The Latent Heat (the "heating" heat) of steam increases with reduced pressure.

As far as steam for power is concerned, there are also two basic rules:

(i) Use highest practical initial pressure and temperature,

(ii) Use the lowest practical exhaust or back pressure.

As far as steam for any purpose is concerned, experience has shown the fundamental rules are still useful and guiding factors even in today's technology, while generating and using steam efficiently.

3.10.1 Improving Boiler Efficiency

Ways and means of improving boiler efficiency are almost common to all boilers, whether they are working in beet sugar or cane sugar industry. But, as beet sugar factories use fossil fuels like, fuel oil (bunker), natural gas, coal etc. as compared to cane sugar factories, which use bagasse as the main fuel, there are a few differences for achieving high boiler efficiencies, mainly due to type of fuel used.

The areas, which have the major potential for efficiency improvements, include the followings:

(a) Improving boiler operating cycles

The boiler fuel consumption can be reduced through improved load management. Boiler efficiency varies, depending on such factors as the age of the equipment, boiler design, fuels used, and firing rate. Effective load management, then, would demand the use of the optimum operating range for each boiler in the system, whenever practical and maintenance of this load to minimize efficiency losses during load variations.

Facilities with multiple boilers should be managed to achieve optimum system performance. One way to accomplish this is by loading the most efficient boilers to the desired operating level first, moving down to the least efficient boiler. Conversely, the least efficient boilers should be removed from service, first. It is advantageous to operate as close as possible to peak load for highest efficiencies, when there is a choice between partially loading several boilers or operating fewer boilers at high loads.

(b) Improving combustion

Another source of efficiency loss industrial boilers is caused by incomplete combustion, or more air being supplied than required for burning the fuel. Combustion efficiency can be improved and fuel can be saved, when steps are taken to ensure that only sufficient air needed for burning the fuel completely and safely are supplied to the combustion chamber.

(c) Controlling excess air

This excess air is required in all practical cases to ensure complete combustion. It to allow or normal variations in the precision of combustion controls and to ensure satisfactory stack conditions for some fuels. The optimum excess air level for the maximum boiler efficiency occurs, when the sum of the losses due to incomplete combustion and the losses due to heat in the flue gases are at a minimum. The optimum excess air level will vary with furnace design, type of burner, fuel, and process variables, and can be determined by conducting tests with different air-fuel ratios. A reduction in excess air is normally accompanied by flue gas temperature reduction. The actual temperature reduction is dependent on the initial stack gas temperature and on the excess air reduction. A reduction in excess air will have a greater effect, when the stack gas temperatures are high.

(d) Improving maintenance

In many cases, substantial improvements in boiler operating efficiency can be achieved without requiring the purchase of new equipment or retrofit devices. Through proper maintenance, efficiency losses can be minimized and can lead to the most efficient utilization of existing steam generating equipment. Proper maintenance can also have an important bearing on plant reliability, load carrying ability, and safety.

Efficiency degradations can be traced directly to problems with mechanical linkages controlling fuel and air flows, to malfunctioning or poorly calibrated combustion analyzers, to inoperable or maladjusted dampers or boiler instrumentation, to the degree of boiler tube cleanliness, to boiler loss during blow downs, and to other such factors.

A boiler tuneup is a very cost effective means of achieving efficient operation, saving fuel, and reducing operating cost. Adjustment and maintenance of fuel burning equipment and combustion controls permit operation with the lowest practical excess air, and reduces stack losses. These tuneups can be accomplished through plant personnel, engineering consulting firms, boiler manufacturers, and service organizations.

(e) Wall and soot blowers

Wall and soot blowers should be employed to remove carbon and slag deposits on heat transfer surfaces in boilers. Wall blowers remove slag deposits from the furnace walls of coal fired units, while soot blowers remove fly ash and soot deposits from the boiler tubes. However, boiler manufacturers claim that proper soot blowing can increase unit efficiency by up to 1%.

(f) Thermal insulation

Heat lost from the boiler jacket through its insulation is generally termed "radiation loss". The quantity of heat lost in this manner is fairly constant, even at different boiler firing rates; thus, it is an increasingly higher percentage of the total heat loss at the lower firing rates. This loss may be unavoidable to some extent, but deteriorated insulation and deteriorated furnace wall refractory will increase the loss at all loads.

Properly applied insulation can result in large savings in energy losses, depending on the type, thickness, and condition of the existing insulation.

(g) Waste heat recovery

The greatest potential for improving the boiler efficiency is the installation of waste heat recovery equipment to minimize loss of heat through stack gases and losses through blowdown water and expelled condensates. Majority of industrial boilers have very large stack gas losses, because they operate with high excess air levels and at high stack gas temperatures. The boiler furnaces are operated with high excess air levels to ensure complete combustion of the fuel and safe operation. But, this results in the unnecessary heating of tonnes of air, which is let out into the atmosphere through the chimney. Waste heat energy losses in stack gases consist of the flue gas heat loss and the moisture loss due to latent and sensible heat in water vapour contained in stack gases.Stack gas waste heat recovery can be achieved through the use of (i) Economiser, (ii) AirPreheater and (iii) Bagasse drier.

(h) Waste heat recovery from boiler blow down

Blowdown is a procedure, which removes boiler water with high impurity concentration that can affect steam quality and result in tube scale deposits. The amount of water discarded is dependent on boiler and make up water quality and can be as much as 5-10% of the total boiler steam flow. This waste water loss can occur from excessive drum water blowdown beyond what is required to maintain satisfactory dissolved solids concentration. This represents not only lost energy but also a waste of water and of the chemicals used in its treatment. The increasing cost of energy makes the recovery of these losses more economical.

3.10.2 Improving Efficiency of Bagasse Fired Boilers

The cane sugar factories use bagasse as the main fuel. The cane sugar factories use mill-wet bagasse (bagasse as it comes out of the mills or diffusion plants with moisture) as fuel. in general, the average composition of mill wet bagasse is as follows:

(a) Moisture	:	50.0%
(b) Fibre pith	:	47.0%
(c) Sugar	:	2.5%
(d) Minerals	:	0.5%

In the above analysis, fibre means, the water insoluble portion of bagasse and consists of different types of cellulose, pentosans, lignin etc.

(a) Calorific value of bagasse

The peculiarity of mill wet bagasse, when used as fuel, as compared to other fuels like coal, fuel oil, natural gas etc is its high moisture content, to the extent of 45 to 55%. Due to the high moisture content of bagasse, its calorific value is low.

All the constituents of mill wet bagasse with the exception of moisture are combustible. Hence, mill wet bagasse is conveyed directly from the milling plant in a sugar factory to the boiler on a bagasse conveyor and fed into the boiler furnaces for burning it and raising steam in the boilers. But, the presence of water in bagasse reduces its fuel value, as a part of the heat value of bagasse is used for the evaporation of the moisture content of bagasse, before bagasse can catch fire. Thus, heat is wasted.

The calorific value of wet bagasse, which is the actual fuel in the sugar factories and also dry bagasse, as follows[35]:

(a) Gross calorific value of wet bagasse of with 50% moisture :4075 Kcal/ kg

(b) Net calorific value of wet bagasse of with 50% moisture :3220 Kcal/ kg

(c) Gross calorific value of dry bagasse :4600 Kcal/kg

(d) Net calorific value of dry bagasse :4250 Kcal/kg.

The lower calorific value of bagasse depends on the sugar (Pol)% bagasse and moisture content of wet bagasse. Usually, in the sugar factories, the pol% bagasse varies from 1.0 to 4.0 and moisture percentage bagasse varies from 48.0 to 52.0%.

(b) Calorific value of substitute fuel

The Gross Calorific Value (GCV) (higher heating value) of various fuels is given in Table 3.1.

Table 3.1: Gross calorific value (GCV) (higher heating value) of various fuels [37]

Sl.No	Type of Fuel	Gross Calorific Value in Kcal / kg
1.	Coal	6665
2.	Oil (bunker C)	9997
3.	Natural gas	9380
4.	Hardwood bark	4830
5.	Softwood bark	5025
6.	Bagasse (Bone dry)	4555
7.	Cereal straw (Bone dry	4555

(c) Present use of bagasse, as fuel

All the constituents of mill wet bagasse with the exception of water are combustibles with fairly high calorific value. the calorific value of each of these constituents of bagasse as given in Table 3.2.

Table 3.2: Calorific value of each of bagasse constituents 35]

Sl.No	Constituents	Calorific Value in Kcal/kg
1.	Fibre	4,600
2.	Sugar	4,000
3.	Impurities	4,100
4.	Water	0

3.11 METHODS OF REDUCING MOISTURE CONTENT OF BAGASSE

The moisture content of bagasse can be reduced by adopting the following methods:

(a) Mechanical methods

There are following mechanical methods such as:

(i) Adoption of low mill roller speeds

The need to reduce moisture content of bagasse in order to increase its calorific value, pointed out that the most energy efficient method of reducing the moisture content of bagasse is to do it mechanically in a press or a mill, but there is a practical lower limit. It is very well known in the sugar industry that by running the milling plant at low speed (of 30 feet peripheral speed of the rollers per minute), it is possible to obtain bagasse with low moisture content.

(ii) Use of two roller pressure feeders and pressure chutes

In the recent years, many sugar mills in different countries have installed 2 roller pressure feeders or underfeed rollers along with the conventional 3 roller mills, in order to ensure positive feed of prepared cane or intermediate bagasse to the 3 roller mills. This arrangement has resulted in reducing the moisture content of bagasse to some extent, as reported by many mill engineers. This arrangement along with installation of pressure chutes of different types has also resulted, in the reduction of bagasse moisture to some extent.

(iii) Use of lotus rolls

When sugarcane is at its peak recovery period, the juice content of cane is very high. Similarly, when high imbibition % cane is adopted with a view to extract more sugar from cane, the juice flooding takes place on the mill rollers, particularly at the maximum compression zone. Due to this phenomenon of flooding of juice, a part of the juice extracted is again reabsorbed by the bagasse, which is spongy in nature. This results in lower mill extraction. In order to arrest this, different types of grooving on the roller surface have been adopted to drain out the. Extracted juice quickly without getting it reabsorbed.

(iv) Use of high hydraulic pressure on top rollers

High hydraulic pressure is exerted on all the top rollers in a milling tandem, in order to squeeze out as much juice as possible, which means, extracting maximum quantity of sugar contained in the juice. If such hydraulic pressure is exerted on the last mill in the milling tandem, residual sugar, as well as moisture contained in final bagasse are extracted, which leads to reduction of moisture content of bagasse going to the boilers, as fuel. Hence, some sugar mills make it a point to exert very high pressure on the top roller of last mill in a milling tandem in order to obtain bagasse with low moisture, to have high calorific value.

(b) Thermal methods

There are following chemical methods such as:

(i) Use of hot imbibition water

In the recent years, the use of hot condensate at a temperature of 75°C to 85°C, as imbibition water has become a common practice, as it has many advantages, the main. advantage being extraction of more sugar. Incidentally, by the use of hot imbibition water, the temperature of bagasse is raised and by the exposure of this hot bagasse to the ambient air, a part of the moisture contained in bagasse is evaporated, leading to reduction in moisture content of bagasse.

(ii) Installation of improved bagasse return carrier

Usually, bagasse is conveyed from the mill house to the boilers by means of a long bagasse carrier and fed into the boiler furnaces through rotary feeders. During this long passage, a part of the moisture content of bagasse is evaporated by exposure to the ambient air. In all sugar mills, where there is surplus bagasse, the bagasse carrier is designed in such a way as to carry the excess bagasse to the open area outside the sugar mill building and the bagasse is brought back by the same carrier to feed to the boilers. This is known as Bagasse Return Carrier. By this, every particle of wet bagasse is exposed to the ambient air, as well as, sunlight.

(iii) Installation of bagasse dryers

From the early 1970s, particularly after the global energy crisis in 1973, a number of reports on the industrial application of and experiences with bagasse dryers appeared.

In the drying of bagasse utilizing flue gases for energy conservation, the amount of flue gas available is such t at complete drying cannot be effected, nor is it desirable. The normal reduction in an operating system would be from 50% w.b. to 35/40% w.b._From the results obtained and the qualitative mechanism proposed, 'the bulk of the moisture_removed will be surface moisture with control being strongly external. Drying times would only be of the order of a minute or two even for, the larger particles, and of the order of seconds for smaller particles. This explains the potential for the use of pneumatic driers more particularly for sugar factories where the extent of preparation prior to milling is high i.e. utilization of shredders.

Thus, in the past, a number of research workers designed and worked with different types of bagasse dryers on commercial scale in the sugar mills of different countries. Lot of published literature on this subject is available, as mentioned above and much more, to guide any sugar mill or research organisation to develop a suitable dryer. There are various type of dryer used in industries, which are follows:

3.11.1 Type of Dryer [33]

There are following type of dryer below as:

(i) Rotary Dryers
(ii) Pneumatic/Flash Dryer
(iii) Spray Dryers
(iv) Fluidized Bed Dryers
(v) Hot Air Dryer- Stenter
(vi) Contact Drying- Steam Cylinders/Cans
(vii) Infra red drying
(viii) Radio frequency drying

(i) Rotary dryers

All rotary dryers have the feed materials passing through a rotating cylinder termed a drum. It is a cylindrical shell usually constructed from steel plates, slightly inclined, typically 0.3-5 m in diameter, 5-90 m in length and rotating at 1-5 rpm. It is operated in some cases with a negative internal pressure (vacuum) to prevent dust escape. Solids introduced at the upper end move towards the lower or discharge end. Depending on the arrangement for the contact between the drying gas and the solids, a dryer may be classified as direct or indirect, con-current or counter-current. The drum is mounted to large steel rings, termed riding rings, or tires that are supported on fixed trunnion roller assemblies. The rotation is achieved by either a direct drive or chain drive, which require a girth gear or sprocket gear, respectively, on the drum. As the dryer rotates, solids are picked up by the flights, lifted for a certain distance around the drum and showered through the air in a cascading curtain. Most of the drying occurs at this time, as the solids are in close contact with the gas. Flight action is also partly responsible for the transport of solids through the drum. Which is shown in Fig. 3.1.

(ii) **Pneumatic/Flash Dryer**

The pneumatic or 'flash' dryer is used with products that dry rapidly owing to the easy removal of free moisture or where any required diffusion to the surface occurs readily. Drying takes place in a matter of seconds. Wet material is mixed with a stream of heated air (or other gas), which conveys it through a drying duct where high heat and mass transfer rates rapidly dry the product. Applications include the drying of filter cakes, crystals, granules, pastes, sludges and slurries; in fact almost any material where a powdered product is required. Salient features are as follows.

(a) Particulate matter can be dispersed, entrained and pneumatically conveyed in air. If this air is hot, material is dried.

(b) Pre-forming or mixing with dried material may be needed feed the moist material

(c) The dried product is separated in a cyclone. This is followed by separation in further cyclones, fabric sleeve filters or wet scrubbers.

(d) This is suitable for rapidly drying heat sensitive materials. Sticky, greasy material or that which may cause attrition (dust generation) is not suitable. Which is shown in Fig.3.2.

(iii) **Spray dryers**

Spray drying has been one of the most energy-consuming drying processes, yet it remains one that is essential to the production of dairy and food product powders. Basically, spray drying is accomplished by atomizing feed liquid into a drying chamber, where the small droplets are subjected to a stream of hot air and converted to powder particles. As the powder is discharged from the drying chamber, it is passed through a powder/air separator and collected for packaging. Most spray dryers are equipped for primary powder collection at efficiency of about 99.5%, and most can be supplied with secondary collection equipment if necessary. Which is shown in Fig.3.3.Salient features of Spray dryers are as follows.

(a) Solutions, suspensions, slurries and pastes, which can be pumped, can be dried on spray dryers. The advantage of spray dryer is rapid and non-contact drying.

(b) Much higher initial temperature of drying medium can be used. High evaporation rates and thermal efficiencies are achieved.

(c) It can be quickly started and shut down.

(d) It is capable of handling volatile or inflammable solvents in a closed cycle.

(iv) Fluidized bed dryers

Fluid bed dryers are found throughout all industries, from heavy mining through food, fine chemicals and pharmaceuticals. They provide an effective method of drying relatively free flowing particles with a reasonably narrow particle size distribution. In general, fluid bed dryers operate on a through-the-bed flow pattern with the gas passing through the product perpendicular to the direction of travel. The dry product is discharged from the same section. Which is shown in Fig 3.4. It has certain steps, which are follows;

(a) With a certain velocity of gas at the base of a bed of particles, the bed expands and particles move within the bed.

(b) High rate of heat transfer is achieved with almost instant evaporation.

(c) Batch/continuous flow of materials is possible.

The hot gas stream is introduced at the base of the bed through a dispersion. distribution plate.

3.12 EFFICIENT UTILIZATION OF ELECTRIC POWER IN SUGAR MILLS

Electrical power is mainly used in sugar factories for driving the various electric motors. Following are the main processes where these motors are used; (i) Cane unloading equipments, (ii) Milling plants and diffusion plants, (iii) Different pumps for juice, water, syrup, massecuites, molasses etc, (iv) Injection and spray water pumps,(v) Crystallisers, (vi) I.D and F.D fans of the boilers and (vi) Conveyors, blowers, cleaning equipment, workshop machinery etc.

About 90% of the total electric power consumption in sugar industry is for these drives and the balance 10% is used for lighting, air condition of the office rooms. And by proper selection of the electric motors and their operation, improved power factor and improving lighting practices, there is a possibility of the electric power consumption by 20 to 50%. There are different type of motor used in sugar industry like synchronous motor and asynchronous motors. Most of the industrial motors are rated in the 50 to 70% efficiency range. The following parameter of induction motor below discussed;

3.12.1 Fundamentals of Induction Motor [33]

Induction motor has following main characteristics as;

(i) Speed
(ii) Torque
(iii) Power

(i) Speed

Synchronous Speed of an ac induction motor depends on the frequency of the supply voltage and the number of poles for which the motor is wound. The term poles refers to the total number of magnetic north and south poles produced by the stator winding when supplied with polyphase current. The higher the input frequency, the faster the motor runs. The more poles a motor has, the slower it runs at a given input frequency.

Slip represents the inability of the rotor to fully keep up with the moving AC voltage waves generated on the stator. Slip of an induction motor defined as:

$$S = Ns - N / Ns$$

Where,

S = slip
Ns = synchronous speed, N = Actual speed.

Full-load slip varies from less than one percent (in high-HP motors) to more than five percent (in fractional-HP motors).

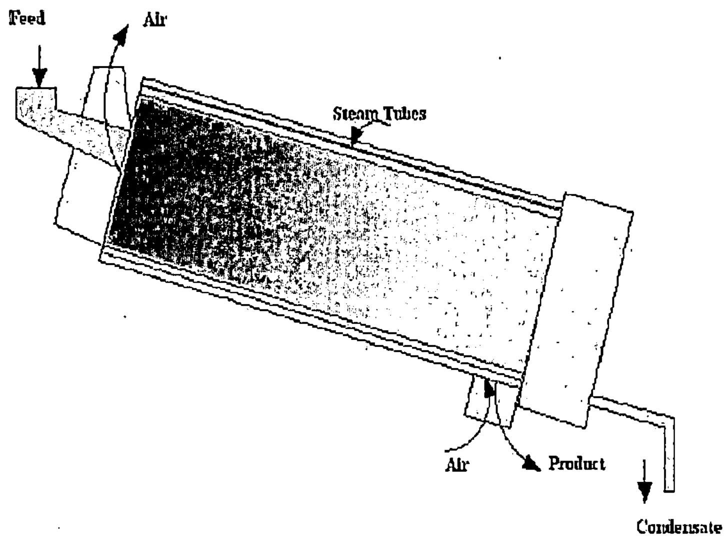


Fig. 3.1: Indirect rotary dryer

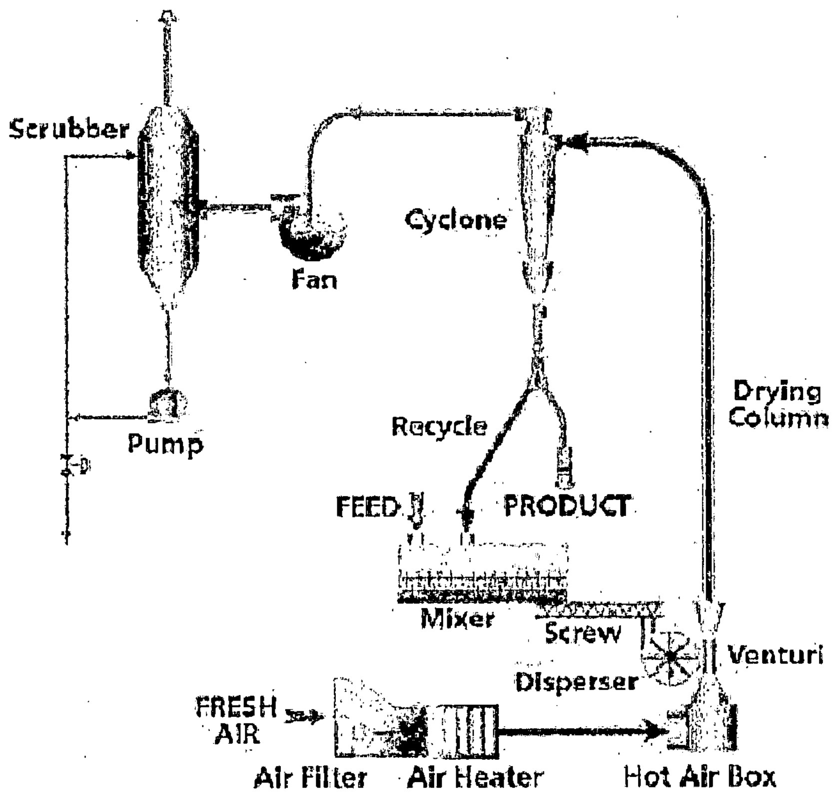


Fig. 3.2: Pneumatic/Flash Dryer

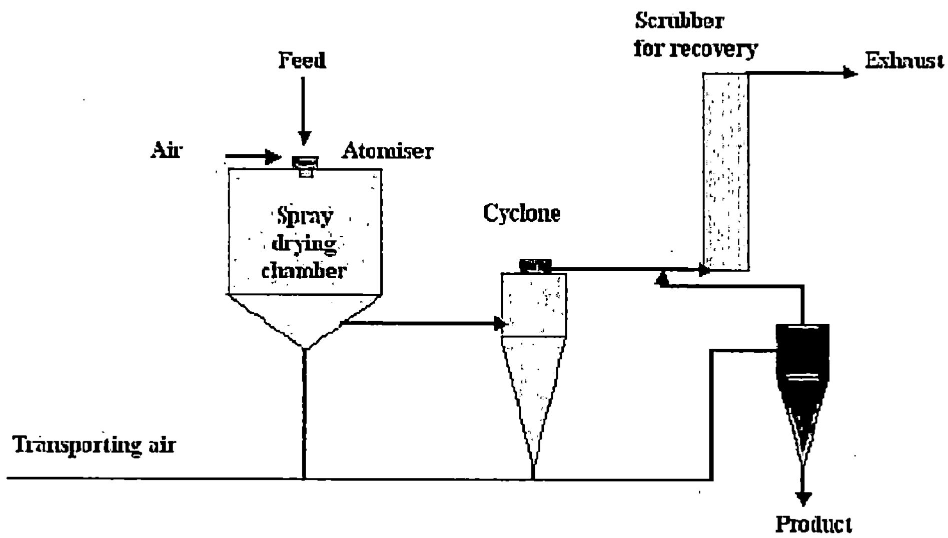


Fig. 3.3: Spray dryer

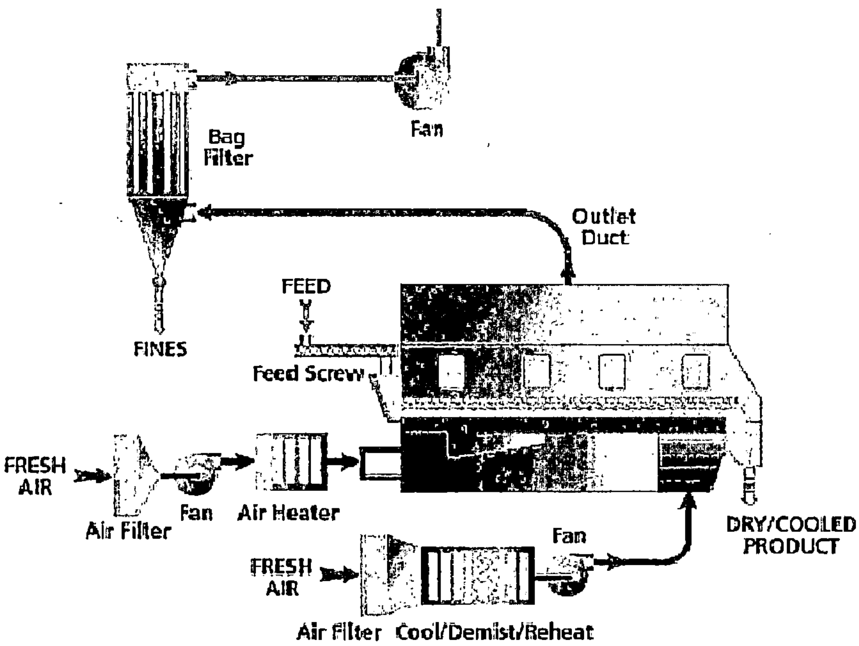


Fig. 3.4: Fluidized bed dryer

(ii) Torque

Torque is the turning effort. For example, suppose a grinding wheel with a crank arm one meter long takes a force of one Newton to turn the wheel at steady rate. The torque required is one-meter times one Newton or one Newton-meter. If the crank is turned twice as fast, the torque remains the same. Regardless of how fast the crank is turned, the torque is unchanged as long as the crank is turned at a steady speed.However, there are loads in which the torque changes directly with speed (Agitators of viscous fluids) and torque changes with square of speed (Centrifugal pumps, fans).

(iii) Power

Power or shaft power takes into account how fast the crank is turned. Turning the crank more rapidly takes more horsepower than turning the crank slowly. It is the rate of doing work. The nameplate power rating of a motor is generally the rated output power.

3.12.2 Type of Load Considerations

The driven equipment characteristics decide how much shaft power the motor has to deliver at the operating point. Examples of the common types of loads are given below along with the expected variation in torque and power with speed. Understanding this behaviour is important while selecting motors and more so when selecting variable speed drives. There are following parameter below as;

(i) Constant torque

Constant torque most frequently encountered type of load (essentially friction loads), where the torque required by the load is constant throughout the speed range. The constant torque characteristic is needed to overcome friction. Friction loads require the same amount of torque at low speeds as at high speeds. For example, a 10-ton load on a conveyor requires about the same torque whether the conveyor speed is 5 or 50 feet per minute. The horsepower requirement, however, increases with speed. Common applications include general machinery, hoists, conveyors, printing presses, etc.

(ii) Constant power

In this group, the load decreases with increasing speed. Common applications are processes that are changing diameters such as lathes, winders, unwinders,and metal-cutting tools operating over wide speed ranges. With an initial large diameter work piece, maximum torque and slow speeds are required. As the work piece diameter decreases, torque decreases, but speed increases to provide constant surface speed.

(iii) Variable Torque

These loads increase with speed and are usually associated with centrifugal fan and pump loads, where, in theory, the horsepower requirement varies as the cube of the speed change. When driving positive-displacement pumps, some mixers, and some types of extruders, in theory, the horsepower requirement varies as the square of the speed change. These applications usually have the greatest opportunities for energy savings as well as improved control.

(iv) Shock Loads

These loads may range from a small fraction of rated load to several hundred percent for a small fraction of the time. Examples include crushers, separators, grinders, and, perhaps, conveyors, winches, and cranes. Under these conditions, the drive has two fundamental tasks: to move the load and to protect the prime mover and driven equipment. For example, the electric motor as a prime mover can experience bearing damage from shock loads.

3.12.3 Power Factor

Power factor is not a measure of efficiency. It is a ratio of Real Power, in total kilowatts, to total Apparent Power, in kilovolt amps. If a load draws Reactive Power, the power factor is said to be "lagging." Most electric motors have a lagging power factor. The operation of electrical systems with low power factor results in reducing the overall power carrying capacity of the power supply system. As an incentive for customers to operate at high power factors, utilities levy power factor penalties to customers whose overall power factor falls below certain levels. An understanding of the difference between the three aspects of power, kilowatts, kilovoltamps, and kilovolt-amps reactive, is essential to an understanding of power factor. Useful mechanical work derives from "real power," the energy consumed by the load. Real power is expressed in kilowatts. Fig.3.5 gives the vector diagram showing all three types of power for lagging p.f. load.

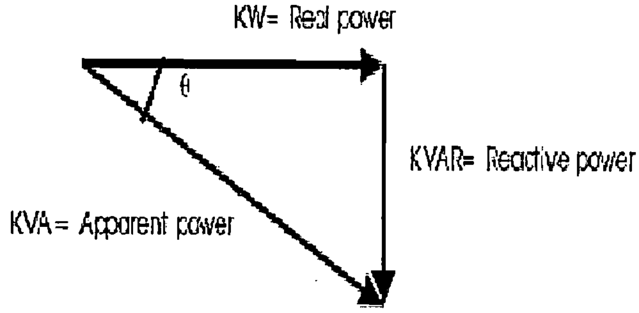


Fig. 3.5: Vector diagram

A motor is an inductive load. The current drawn by the motor lag behind the voltage applied. In this situation, the motor draws the reactive power. Reactive power does not provide useful mechanical work. However, most AC motors do require reactive power for developing magnetic fields. Reactive power is expressed as Kilovolt-amps Reactive, or kVAR. The vector sum of Real Power and Reactive Power is Apparent Power, expressed as kilovolt-amps or kVA. Apparent Power is calculated by multiplying voltage times amperage. A motor operating at a given load and supply voltage, draws active and reactive power. If the motor is connected to the grid, without any capacitors, the entire active and reactive power is drawn from the grid. A capacitor is a device which draws a leading current, and is ready t o discharge current when motor need it. If capacitor is connected at the motor, the reactive power drawn by the motor from the grid will be less or almost nil in case of unity power factor correction.

It is not necessarily to have higher power factor for a high efficiency motor. It is often difficult to get a good a motor design by concentrating on high power factor. The motor designer has to consider a number of parameters such as temperature rise, torque characteristics and efficiency, as well as power factor, and he can't optimize them all. It's costly to try to design both high power factor and high efficiency into a motor, and some of the design changes that improve power factor, such as a reduced air gap, actually have the opposite effect on efficiency.

3.12.4 Efficiency

Motor efficiency is a measure of the effectiveness with which a motor converts electrical energy to mechanical energy output to drive a load. It is defined as a ratio of motor power output to source power input. The difference between the power input and power output comprises electrical and mechanical losses. Higher horsepower ratings generally correspond to higher efficiency ratings. Small fractional horsepower motors tend to have low operating efficiency, while large integral horsepower motors are generally very efficient. At a particular operating voltage and shaft load, the motor efficiency is fixed by design; it cannot be changed externally, while power factor can be corrected externally.

The following may be found of induction motor

(i) The motor efficiency remains almost constant up to 40% load, below which the efficiency drops significantly and becomes zero at 0% load.

(ii) For a particular operating voltage and shaft load, the motor efficiency is determined by design, it cannot be changed externally.

(iii) The power factor reduces with load. At no load the p.f. is in the range of 0.05 to 0.2 depending on size of the motors.

(iv) Note that at 50% load, the efficiency has dropped by 3%, where as the power factor has dropped from 0.84 to 0.7 for the same load change.

(v) At no load, the power consumption is only about 1 to 5% ; just sufficient to supply the iron, friction and windage losses.

(vi) The no load current is however, of the order of 30 to 50% of the full load current. This magnetising current is required because of air gap in the motor.

3.12.5 Motor Loading

Use of a portable power analyser (also known as load analyser, clamp on power meter etc.) is required to establish the power consumption of any equipment. Measurement of voltage, cur rent and guessing the power factor of motor to calculate power consumption, can lead to large errors. This can, in turn, lead to wrong Estimation of energy saving as well. Estimation of shaft loading on the motor is very important while assessing motor performance. However, there is no direct measurement of shaft power possible under typical site conditions. Ratio of the measured current with the rated full load current on the motor in percentage terms gives the % current loading. Many times, this ratio is mistakenly used as % loading (read 'shaft loading') on the motor. This can be inaccurate if the current drawn is much less than full load current. This is because the current a no load (i.e. zero shaft load) can be about 25% to 40% of the full load current of the motor. To estimate % shaft loading from % current loading, figure 2.6 can be used. Note that this figure is indicative only and it represents a large number of motors in different ratings combined together.

3.12.6 Use of Electronic Soft Starters

An induction motor draws current from the supply in order to magnetize the core. At rated load, full magnetizing flux is needed for the machine to operate satisfactorily. At part loads however, full flux is not required but is still maintained if the terminal voltage is held at the nominal level. Therefore, for a motor operating at light load, the losses associated with maintaining full flux will be a significant proportion of the motor demand, hence the motor runs with a lower efficiency. Soft starters are essentially stator voltage controllers, suitable for the following applications having:

- restriction on starting current
- Frequent starts and stops
- Undesirable jerky starting due to step change in voltage
- Problem of sudden deceleration when supply is switched off.

This reduction in voltage causes the motor's magnetizing current to reduce, with a corresponding improvement in power factor. And the actual energy consumed is indeed reduced for an extremely lightly loaded motor.

3.12.7 Application of High Efficiency Motors

The following steps are taken to improve motor efficiency and reduce losses. It must be emphasized that normal motors have reasonably good efficiencies.

(i) Core losses are reduced by using low loss steel (cold rolled), lower density (larger core area) and thinner steel stampings. The material is more expensive.

(ii) Friction and windage losses are reduced by better fan design, improved bearings and improved aerodynamic design of rotor and airflow. In high efficiency motors, losses are low and hence cooling requirements are also lower.

(iii) Stator copper losses are reduced by increasing the copper cross-section of winding wires; hence resistance and I^2R losses reduce, the weight of copper increases.

(iv) Rotor copper losses are reduced by increasing the section of rotor bars and end rings, again more material is used.

(v) Stray losses are reduced due to increase in air gap, better electromagnetic design of slots and windings. It is clear that high efficiency motors use more and better material and hence are more expensive. It should be understood that high efficiency motors have better performance even at partial loads.

- **Efficiency Standards**

Values of motor efficiency as given in IEEMA Standard 19-2000 is summarized below in Table 2.1There are two efficiency categories of efficiency viz. Eff1 & Eff2. To get good high efficiency motors, users are advised to specify efficiencies of new motors as per IEEMA standards. Always mention efficiency values and do not just mention 'high efficiency motor'.

In general the following rules will apply:

(i) For purchase of motor for a new application, the pay back period on the differential price is likely to be up to 1 year, depending on the rating, running hours and the tariff.

(ii) For replacing an existing running motor, the pay back period is likely to be about 1-2 years, after considering some salvage value for the existing motor.

(iii) For replacing a burnout motor, which otherwise would have been rewound the pay back period is likely to be about 1.0 to 1.5 years. Table 3.3 gives values of performance characteristic of 4-pole energy efficient induction motors (IEEMA – 19 – 2000).

Table 3.3:Values of performance characteristic of 4 pole energy efficient induction motors (IEEMA – 19 – 2000)[33]

Sl.No	Rating output (kW)	Frame size	Full load speed in rpm	Full load current in Amp	Efficiency (equal & above)	
					Eff.2	Eff.1
1	0.37	71	1330	1.4	66	73
2	0.75	80	1360	2.2	73	82.5
3	1.5	90L	1380	3.8	78.5	85
4	3.7	112M	1410	8.1	84	88.3
5	5.5	132S	1420	11.4	85.7	89.2
6	7.5	132M	1430	15.4	87	90.1
7	11.0	160M	1440	22	88.4	91
8	18.5	180M	1440	36	90	93.2
9	30.0	200L	1450	56	91.4	93.2
10	45.0	225M	1460	84	92.5	93.9
11	75.0	280S	1470	134	93.6	94.7
12	90.0	280M	1470	164	93.9	95
13	110.0	315S	1480	204	94.4	95.2
14	125.0	315M	1480	234	94.7	95,5
15	132.0	315M	1480	247	94.7	95.5
16	160.0	315L	1480	288.0	95	95.8

ENERGY CONSERVATION —A CASE STUDY AT UTTAM SUGAR MILLS LTD

4.1 GENERAL

In the previous chapters of the report, the scope of energy conservation in industries has been discussed in details. Chapter 3, devoted to discuss the details of all the processes in sugar industry. Various aspects for energy conservation in sugar industries been discussed in details. In order to carry out the energy conservation in sugar industry "Uttam Sugar Mills Ltd" has been considered under the present study. Two main processes i.e milling and boiler have been audited in order to discuss the energy conservation. Under this chapter details about the location, capacity and process have been presented. A detailed survey in order to collect the data regarding processes. Various equipment and their specifications, form of energy consumed has been conducted.

This chapter is devoted to present the information discussed above. Energy audit for two main section i.e. mill house and boiler house has been presented. The scope of the energy conservation in the two sections has been discussed as a case study.

4.2 UTTAM SUGAR MILL LTD (USML) AT A GLANCE

Uttam Sugar Mills Ltd (USML) is the flagship of the Uttam Group of companies. USML unit is located at Libberheri on Delhi-Haridwar high way, in Haridwar district of Uttaranchal. It is 45 km away from Haridwar. The geographical location of USML is given the Fig.4.1. USML has capacity 6250 TCD (Tonne cane per day) with an average recovery of 10 %. USML produces refined sugar. It is setup in year of 2001.USML was selected for this study for energy conservation considering the following reasons as:

(i) Easy approach

(ii) No co-generation existence

(iii) Significant energy saving potential

The factory was visited during the study for collection of different technical details of different section of USML. During the visit instruments for speed, tempreture, dimension, potential and current measurement were taken to the factory for measurement of the parameters to verify the different parameters, which have been provided by manufacturer for optimum efficiency run during the installation. Some technical details have been noted down, that where these already mentions on nameplate of machines. The data colleted during the visit site of USML are given in Appendix-I.

4.2.1 Visit at USML

In the planning phase USML was decided as study industry for the purpose of estimation of energy conservation potential. The site was visited for many days for collection of different technical details of different section of USML. The site was visited on 2-02-2006 first time. During the first visit, the meeting was held with the general manager of USML to discuses the purpose of visit. The General manager was kindly agreed to provide all necessary support during the collection of data He also deputed the concern technical staff for this work. On same day, the preliminary visit of USML was made. From second day onward, the critical examination of certain equipment running at USML was done. During the observation, the technical details for particular machine / equipment was collected either from name plate or data available in the drawing section of department. With of help of this technical details, it was tried to verifies the matching between currently existing parameter measured by equipment i.e thermometer, tong tester, measuring scale, millimeter etc and parameter given on the name plate of the particular machine. For carring out above stated work, the Site visit was made from Feb 06 to April 06.

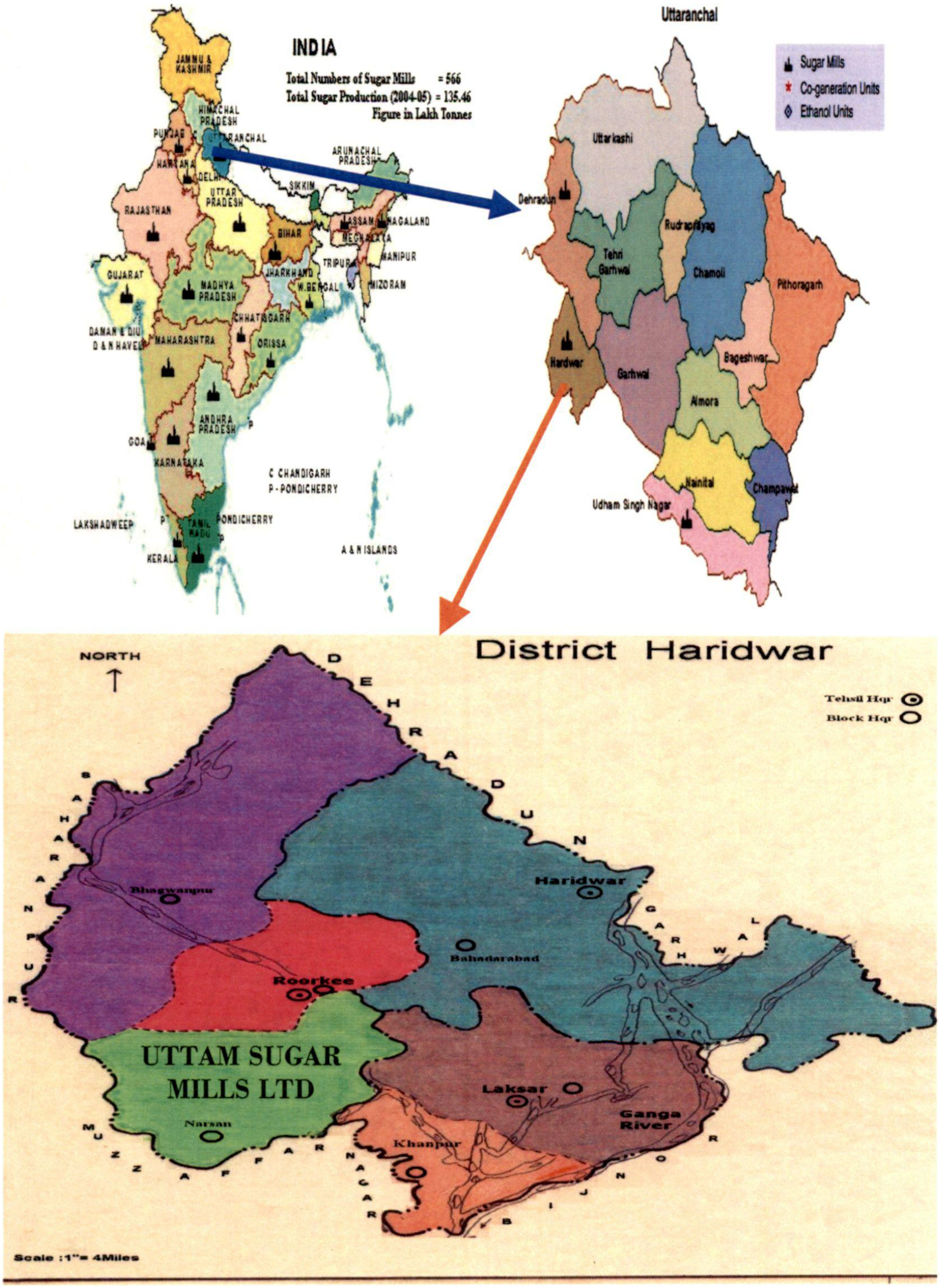


Fig. 4.1: Geographical location of USML

4.3 MODE OF THERMAL ENERGY GENERATION IN USML

Thermal energy generated in form of steam by boiler at USML.

4.3.1 Boiler

There are three boiler of same capacity for steam generation at USML. The typical specification of boiler is given in Table 4.1. Bagasse was main fuel used for firing for boiler in uttam sugar mill, which has composition as; (i) Sugar % is1.89, (ii) Moisture is 50.8% and (iv) fiber is 46.17%. All three boiler has the pressure of 45 kg/cm^2. And superheated steam by superheater after that the steam distributed for various section / process according the requirement of pressure and quantity of individual process. Pressure of steam for turbine's required was 45kg/cm2. Pressure of steam for juice heater, evaporator, clarifier, crystallization, lime station, centrifugal machines, pan station, refinery section, fibrizer and other process's requirement was at reduced pressure about 7 kg/cm^2 .The steam of reduced pressure was available by reducing the pressure reducing system (PRDS) and exhaust of turbine. The steam flow through various section of the mill is given in Fig.4.2.

4.3.1.1 Furnace

Spreader stoker furnace for burning bagasse with 50% moisture has been provided .Its dimensions was 4.398 m of width, 4.50 m of depth and 15.20 m of height. Furnace is designed to given maximum continuous rating with bagasse firing only when chamber has being cleaned.

4.3.1.2 Chimney

There were two reinforced cement concrete of 3 m diameter at top and 3.9 m bottom with a height of 56 m.

4.3.1.3 Induced Draught Fan

One I.D fan designed for 180000 m^3/ h capacity. It coupled with a 350 HP rating A.C motor.

4.3.1.4 Forced Draught Fan

A 100 HP rating A.C motor-coupled FD fan has been provided. The ID and FD Fan are interlocked so that FD fan can run only when ID fan was running.

Table 4.1: Specification of boiler in USML

Sl.No	Name of item	Quantity
1	MCR rating	45 TPH
2	Outlet steam pressure	45 kg/cm^2
3	Outlet steam pressure Temperature	440 ^{0}C
4	Feed water Temperature	105 ^{0}C
5	Flue gases Temperature	380 ^{0}C
6	Super heater Temperature	430 ^{0}C
7	Feed water inlet to economizer Temperature	105 ^{0}C
8	Flue gas outlet from the chimney Temperature	85 ^{0}C
9	Flue gas outlet from air preheater Temperature	170 ^{0}C
10	Flue gas outlet from economizer Temperature	250 ^{0}C
11	Feed water flow	130 ton /hr
12	Fuel	Bagasse with 50% moisture

4.4 THERMAL ENERGY CONSUMPTION

The total steam generation by boiler is 125 tonnes / h or 3000 tonnes / day. Steam consumption in steam turbine was about 60 tonnes/ h or 1400 tonnes / day. Steam consumption in process was about 65 tonnes / h or 1600 tonnes / day. Steam consumption in various sections is given in Table 4.2.

Table 4.2: Steam consumption in various equipment

Sl.No	Equipment	Steam consumption in Tonnes/h
1	Steam Turbine – Alternator (3NOS)	60
2	Juice Heater	14
3	Evaporator	9
4	Clarifier	7
5	Lime Station	7
6	Centrifugal machine	5
7	Pan Station	5
8	Refinery	10
9	Other System	8

4.5 ELECTRICAL ENERGY

4.5.1 Electrical Energy Generation

Electrical energy required for sugar mill is generated through the three turbo alternator of specification during is given in the Table 4.3, 4.4 and 4.5. All the turbo alternator were suitable for parallel operation with proper governing and all the turbo alternator were fully equipped with necessary protection devices and different fault annunciation given as:

(i) Over speed trip with audio visual alarm

(ii) Low oil pressure trip with audio visual alarm

(iii) Manual trip knob on turbine High back pressure trip will audio visual alarm

There are following electrical control panels for turbo generator sets

(i) Desk control panel for turbine having temperature and pressure gauge for steam and oil.

(ii) Battery panel with automatic battery charger.

(iii) AVR panel, one standby AVR through the manual change over switch. AVR panel having the over voltage relay for over voltage protection also having control facility on the panel with necessary metering arrangement.

(iv) Excitation panel having auto-cut off facility in case of turbine/alternator trips. It also has necessary metering for voltage, current with auto/manual change over switchs.

(iii) Alternator breaker panel with 6000 Amp capacity of air circuit breaker" having shunt trip coil for auto tripping. The breaker is interlocked with auxiliary power supply breaker. This panel have following protection device.

- (i) Instantaneous earth fault relay
- (ii) Inverse type phase earth fault relay
- (iii) Over current relay
- (iv) Instantaneous over voltage relay
- (v) Under voltage relays
- (vi) Reverse power relays

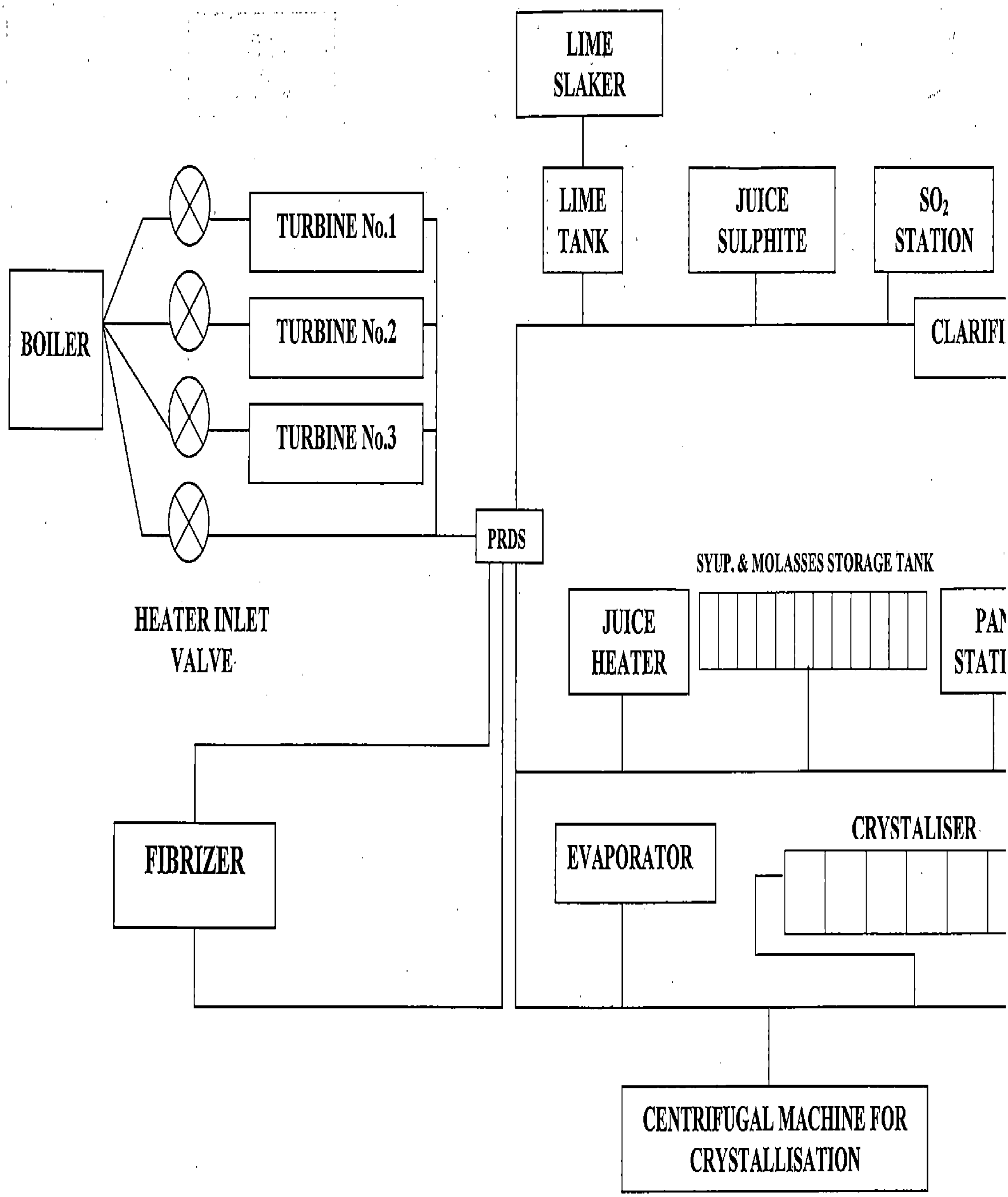


Fig. 4.2: Steam flow through various sections of the sugar mills

4.5.1.1 Metering on alternator panel

Alternator Breaker panel have an Ammeter in each phase ammeter, volt meter with selector switch, 3 phase power factor meter, KWh meter. Audio-Visual Annunciation of D.C. failure trip restricted 'earth fault trip, over current trip, over voltage trip, under voltage trip, turbine high speed trip, turbine shut down, turbine governor oil pressure trip, lubricating oil pressure trip, high winding temperature trip, axial movement trip, high back pressure trip.

4.5.1.2 Main power supply panel

It is designed for ambient temperature of 45°C and the maximum- operating ambient temperature of 85°C. Panel is interlocked in such a way that it is not possible to open the panel without closing the breaker. The earth bus bar is located at the bottom and is continuous through out the length of the panel. Cable termination is provided through cable gland. Each panel individual air circuit breaker for outgoing feeder, for motor control centres for cane preparation mill drive, motor for boiler and centrifugals pump, each panel has individual switch fuse unit for feeders for auxiliary panel and electric oil pump for turbo generator set. This panel has one bus section, coupler consisting of 1000 A air circuit breaker, which is connected in such a way that important electrical load can be switched over from turbo generator set to power supply from diesel generator set.

All the circuit breakers are interlocked with the alternator breaker panel in such a way that only one source of power supply is to fed to the bus bar at a one time. Neutral isolating switch is also provided on the panel.

4.5.1.3 Electrical distribution system

Different electrical distribution panel in power house such as:
Auxiliary power supply panel, main and sub-lighting distribution panel boards, motor control panel, all electric motor starters and switches for all lighting and control panel electric earth earthing system are connected with alternator through circuit breaker. There is separate distribution panel for lighting of factory building, cooling tower and cane yard.

Table 4.3: Rating of turbine

Sl.No	Name of the item	Values
1	Type	HES-14
2	Plant progressive No	BM/4605/B
3	Max output	3000 kW
4	Max Inlet pressure	45 kg / cm^2
5	Max inlet temperature	450 ^{0}C
6	Max Exhaust pressure	1.8 kg / cm^2
7	Over speed	11300 rpm
8	Gear type	GN-95
9	KW	3000
10	Ratio	10250 / 1500
11	Lub.oil quantity	150 lpm
12	Pressure	1.8 kg/cm^2 (Min)

Table 4.4 Rating of alternator

Sl.No	Name of item	Values
1	No. of the alternator	3
2	KVA	3750
3	KW	3000
4	RPM	1500
5	Stator Voltage	420 Volt
6	Stator current	5155 Amp
7	P.F	0.8 Lag
8	Insulation class	F
9	Connection	Y
10	Ambient temperature	50 ^{0}C
11	Inlet temperature	50 ^{0}C
12	Excitation voltage	95 Volt
13	Excitation current	385 Amp
14	Frequency	50 Hz
15	Make	BHEL

Table 4.5 Rating of exciter (brush less)

Sl.No	Name of item	Values
1	KW	45.9
2	Excitation current	4
3	Exciter voltage	132 Volt
4	Connection	Y
5	RPM	1500
6	Frequency	50 Hz

The installed electrical power capacity of power plant was 9 MW. The rated electrical load of whole sugar mills was 8700 kW. And running load was 7600 kW. Total electrical power generated at 0.83 p.f was about 7900 kW. So remaining power was about 1 MW.

Electrical power is mainly used in sugar factories for driving the various electric motors. Following are the main processes where these motors are used;
(i) Cane unloading equipments, (ii) Milling plants and diffusion plants, (iii) Different pumps for juice, water, syrup, massecuites, molasses etc, (iv) Injection and spray water pumps, (v) Crystallisers, (vi) I.D and F.D fans of the boilers and (vi) Conveyors, blowers, cleaning equipment, workshop machinery etc.

About 90% of the total electric power consumption in sugar industry was for these drives and the balance 10% is used for lighting, air condition of the office rooms.

The electrical power consumption in various houses of USML is given in Table 4.6. In the study found that electrical load of Mill house is largest, which was about 2919 kW. And second largest was 61932 kW of boiling house. Electrical load pattern of USML shown in Fig. 4.3. So energy conservation study has been carried out for mill house and boiler house. Table 4.7 gives various kW rating of 3-phase induction motor used as drive the system of the boiler and boiling house. The kW rating varies from 0.75 to 110 kW of house. List of the total electrical motor used in the plant are enclosed in Appendix-2.

4.5.1.4 Power and control cable

All power and lighting cable are PVC insulated armoured and are for use at 1100 volts. All the control cable are of copper conductor with minimum cross-section area for core is 2.5 mm^2 for aluminum conductor and 1.5 mm^2 for copper conductor. All the lighting cable are 3-core. The cables from main distribution panel to auxiliary panel are 3-core. AII power cables are 3 core. All the power cable on the ground are laid in the trench, on the racks, and have suitable spaced and are clamped to the racks.

All cable termination are made by cremping type cable lugs. Cable and gland provided at panels, starters, motor, push switch.

Table 4.6: Electrical load in various houses of USML

Sl.No	Name of House	Electrical loads in kW
1	Cane House	475.
2	Mill House	2919
3	Boiler	1357
4	Boiling House	1932
5	Refinery	697.5
6	Cooling tower	1097
7	Godown & 1Kg Packing	153
8	Workshop	14.15
9	Colony and Street light	52.8

Table 4.7: Various kW rating of 3-phase induction motor of the boiler and boiling house

Sl.No	Type of Motor	KW	Quantity
1	Three phase Induction Motor	110	5
2	Three phase Induction Motor	90	3
3	Three phase Induction Motor	30	6
4	Three phase Induction Motor	75	5
5	Three phase Induction Motor	45	6
6	Three phase Induction Motor	15	13
7	Three phase Induction Motor	3.7	8
8	Three phase Induction Motor	260	1
9	Three phase Induction Motor	6.3	2
10	Three phase Induction Motor	200	1
11	Three phase Induction Motor	18.5	5
12	Three phase Induction Motor	0.75	1
13	Three phase Induction Motor	2.25	1
14	Three phase Induction Motor	0.74	1
15	Three phase Induction Motor	11.2	1
16	Three phase Induction Motor	11	14
17	Three phase Induction Motor	5.5	7
18	Three phase Induction Motor	4	1
19	Three phase Induction Motor	22	6
20	Three phase Induction Motor	37	1
21	Three phase Induction Motor	33	1
22	Three phase Induction Motor	220	1
23	Three phase Induction Motor	7	1
24	Three phase Induction Motor	14.8	1

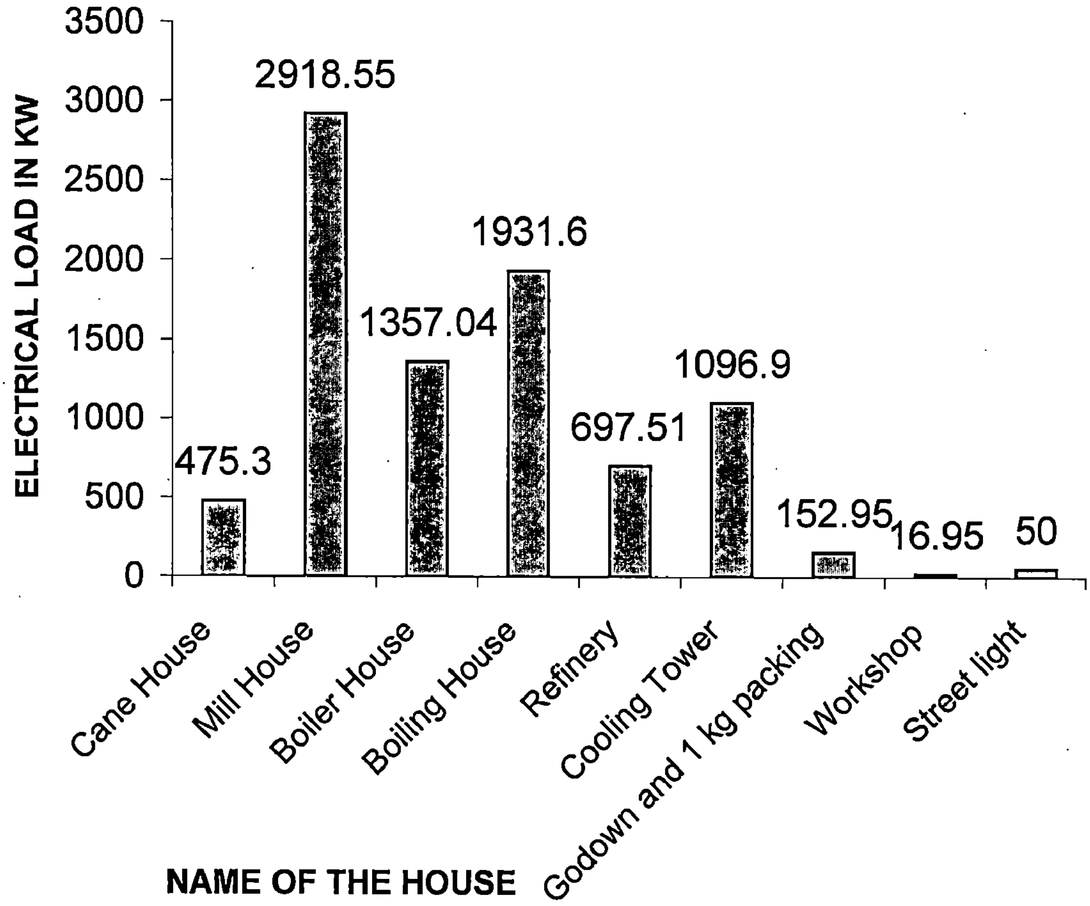


Fig. 4.3:Electrical load pattern in USML

4.6 ENERGY AUDIT IN MILL HOUSE

After a good cane preparation, the next step is to extract the juice contained in the prepared cane by passing it through either a milling plant. Milling of sugar cane is a very complicated operation, as the milling plant consists of 6 roller mills driven by D.C. motors through sets of high speed and low speed gears, which also drive the intermediate carriers, underfeed rollers, pressure feeders etc. Hence, the power consumption of a complete milling plant comprises of the power consumption of a number of components of the milling plant, power losses due to friction, power transmission efficiency etc. and they used variable frequency drive (VFD) and milling plant was fully automization with help of PLC controlled. Hence, any effort to reduce power consumption in a milling plant is also complicated. Power consumption was very high in milling of D.C motor; those have rating of 1000 HP and 750 HP. Table 4.8 gives rating of 3-phase induction and D.C motor. The picture of mill house shown in Fig.4.4., PRDS shown in Fig.4.5 and coupling between D.C motor and low speed conversion gear shown in Fig.4.6.

4.6.1 Fault Observed

During the energy conservation study, the following fault observed in Mill house. Which are responsible for energy losses given as:

(i) There was a lot of sparking in the carbon brush of D.C motor shown in Fig.4.7

(ii) Surface temperature of motor was higher than recommended and measured as 60 ^{0}C.

(iii) Gear temperature was 70 ^{0} C. It was high than references temperature (60 ^{0}C).

(iv) Lubricating of mill's gear was not proper.

(v) Unscreened juice did not operate with optimum efficiency.

(vi) Bagasse had 50% moisture.

After extraction of juice of cane is called bagasse. This bagasse has moisture 50 % with lower caloric value. There is a chance to dry the bagasse to increase the calorific value. By drying there is a chance to save the fuel or energy.

Table 4.8: Rating of electric motor in mill house

Sl.No	Type of Motor	KW	Quantity
1	Three phase Induction Motor	22	2
2	Three phase Induction Motor	90	2
3	Three phase Induction Motor	37	3
4	Three phase Induction Motor	18.5	1
5	Three phase Induction Motor	30	1
6	Three phase Induction Motor	11	1
7	Three phase Induction Motor	14.8	1
8	Three phase Induction Motor	45	1
9	Three phase Induction Motor	5.5	1
10	Three phase Induction Motor	0.75	1
11	Three phase Induction Motor	11.2	1
12	Three phase Induction Motor	9.3	1
13	D.C Motor	750	1
14	D.C Motor	562.5	3

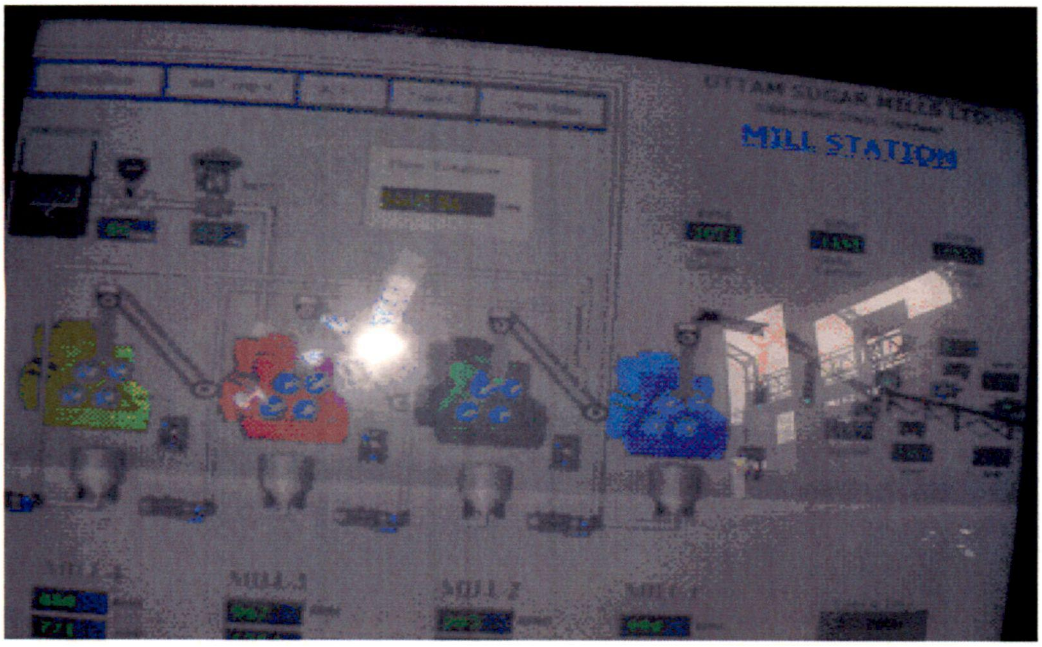


Fig .4.4:The picture of mill house

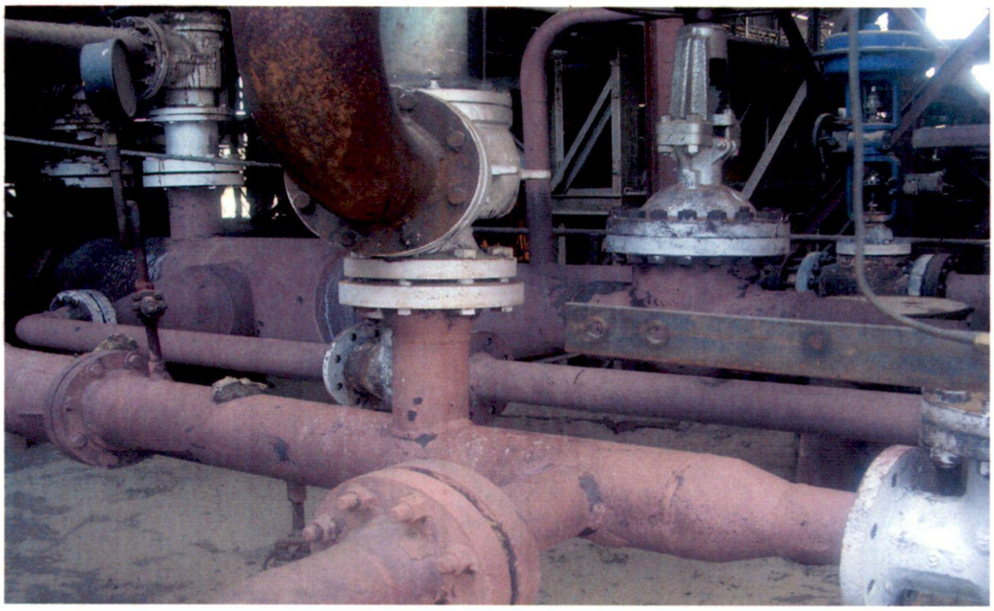


Fig.4.5: Uninsulated pressure reducing system (PRDS)

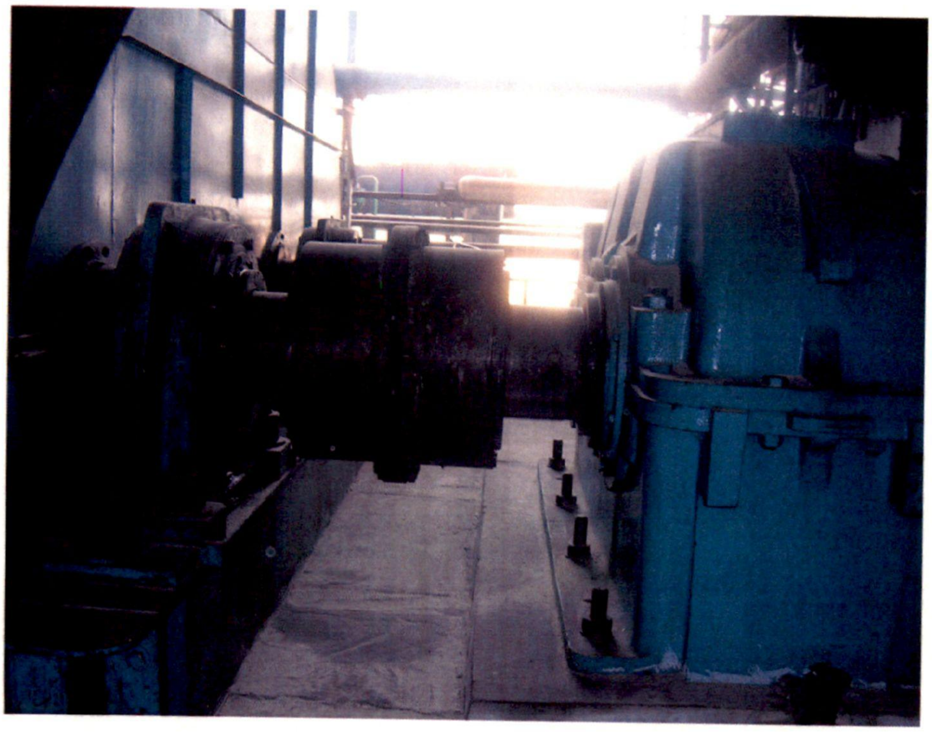


Fig.4.6: Coupling between D.C motor and gear

Fig.4.7: Sparking in the carbon brush of D.C motor

4.6.2 Calculation of Calorific Value of Bagasse

The sample of bagasse was brought to laboratory for its measurement of calorific value and moisture level. Initially the moisture level of bagasse was calculated by taking the difference in the weight of sample after its heating at 105 ^{0} C for one hour and before heating. The level of moisture was observed, as it was about 50 %. It was then dryed for moisture level up to 30%. In the similar fashion the calorific value of the bagasse at 30 % moisture level was calculated by constant volume bomb calorimeter.

The high calorific value (HCV) of bagasse was measured by constant volume bomb calorimeter, which is shown in Fig.4.8. The oxygen pressure in side bomb was maintained as 25 kg/cm^2. A known amount of sample is burnt in a sealed chamber (i.e. bomb). The air is replaced by pure oxygen. The sample is ignited electrically. As the sample burns, heat is produced. The rise in temperature is determined. Since, barring loss of heat, the amount of heat produced by burning the sample must be equal to the amount of heat absorbed by the calorimeter assembly, a knowledge of the water equivalent of the calorimeter assembly, and of rise in temperature enables one to calculate the heat of combustion of the sample. If

W = water equivalent of the calorimeter assembly in calories per degree centigrade

T = rise in temperature in degree centigrade

H = heat of combustion of materials in calories per grams

Then WT = HM

While closing the bomb, one should always make sure the head gasket or sealing ring is in a good condition and it should not disturb the sample. The sample size was kept less than 1 gm. After completing all initial arrangement, stirrer was started and initial reading of temperature was taken for five minutes. When the fluctuation in the temperature between prior and just after was about 0.001 ^{0}C per reading, then, this temperature was noted as initial temperature. After this, the circuit for fuse wire was closed and combustion was taken placed inside bomb. The temperature was started rising and it was noted at an interval of half minute till it becomes constant and fluctuation matches with 0.001 ^{0} C per reading. At last, the stabilized temperature was noted. The formula used for HCV is given as:

HCV	= W x T / M (kcal/kg)
W	= 2298 calorie / ^{0} C
T	= ^{0} C (temp. rise)
M	= weight of sample (g)

Lower Calorific Value (LCV)

LCV (Kcal / kg)	= HCV- (mass of steam × 2442.3) / 4.20
Mass of steam	= 9 × (wt% of hydrogen in sample)

The experiment was repeated for two times and the sample calculation for HCV and LCV are given as:

First set of reading:

Weight of bagasse sample (g)	= 0.43
Initial temperature (^{0} C)	= 23.87
Final temperature (^{0} C)	= 24.42
Temperature rise (0 C)	= 24.43 - 23.87 = 0.56
So, HCV (Kcal/kg)	= W x T / M
	= 2298 x 0.56 / 0.43 = 2992.74

Since the hydrogen percentage by weight in bagasse is about 6.5 % from table

LCV (Kcal / kg) = HCV (Kcal / kg) – (mass of steam x 2442.3) / 4.20

= 2992.74 - (9 x 0.065 x 2442.3) / 4.20 = 2652.64

So on the basis of above calculation, the higher calorific value and lower calorific value were found as 2992.74 Kcal / Kg and 2652.64 Kcal / Kg respectively.

On the basis of above calculation, the net calorific value of bagasse (50% w/w moisture level) was found about 2650 Kcal / kg. But after drying it up to30 % moisture level .the net calorific value was observered as about 4160 Kcal / kg. So the significant gain of about 50 % in calorific value was found. Thus the net calorific value of bagasse will result the saving of bagasse, which could be support, the running of power plant for more number of days. The calorific value of bagasse at different moisture level shown in Fig.4.9.

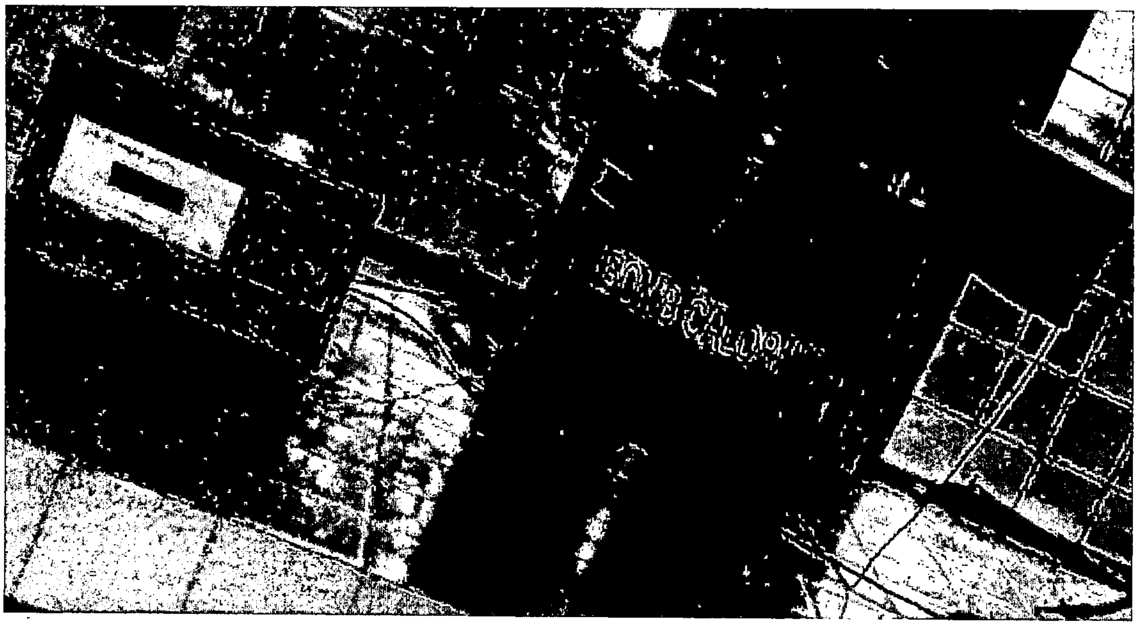


Fig.4.8: Bomb calorimeter

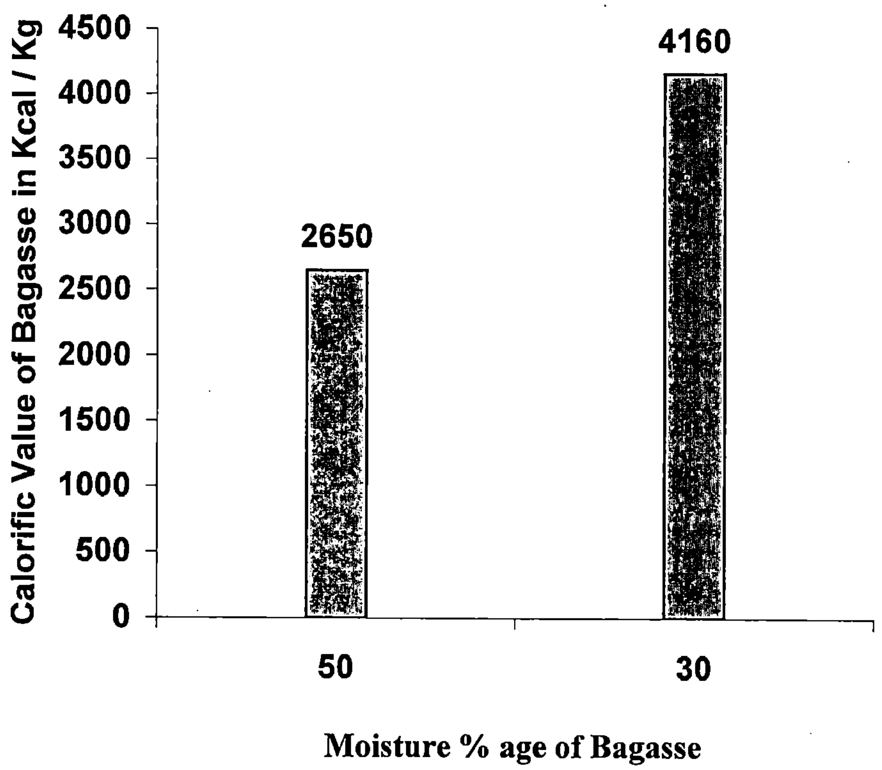


Fig. 4.9: The calorific value of bagasse at different moisture level

4.6.3 Fuel Saving by Drying

The bagasse required for firing the boiler to produced the steam for running their power plant and other uses is about 2,40,000 tonnes per season (about 160 number of days) at moisture level of 50%. If the above bagasse is dryed up to moisture level of 30%, then its calorific value increases about 40%. This increase of calorific value will result in the same proportion of fuel saving i.e. about 72,000 tonnes. As per factory data, the bagasse required per day for firing the boiler is about 1500 tonnes. So the saved bagasse due to high calorific value could run the power plant for 48 days more in comparison to in previous number of running day.

4.6.4 Extra Unit Generation by Moisture Reduction in Bagasse

As per factory data, the steam required for per unit generation of electricity is about 8.5 kg [38]. The bagasse required for per kg generation of steam is about 0.35 kg. Thus extra quantity of steam produced corresponding to saved bagasse of amount 72,000 tonnes is about 205712 tonnes. Thus the extra amount of electricity could be generated about 2,42,01360 units. The money earned by selling it to nearby grid may be about Rs 6.65 crores at rate of Rs 2.75 per unit. Table 4.10 gives the fuel and energy saving per year (160 days). For obtaining above stated energy saving there is required one Bagasse dryer known as Fluid bed steam dryer. Which has the total cost including installation about Rs 4.25 cores [39]. So total expenditure would be paid for first year given in Table 4.9.

Table 4.9: Net expenditure paid in first year (in Rupees)

Sl.No	Items	Rs in crores
1	Cost of dryer	4.25
2	Installment / year (1 /5 of cost)	0.85
3	Interest return @12 %	0.51
4	Repair &maintenance cost @ 6%	0.255
5	Depreciation cost @ 5%	0.212
	Total cost	**1.83**

So in first year Rs 18.3 crores would be paid.

Net saving in Rupees = 4.5 – 1.83 = Rs 2.42 crores.

Table 4.10: Fuel and energy saving per year (160 days)

Sl.No	% Age Moisture in Bagasse	Steam consumption / day in tonne	Consumption of Bagasse / day in tonne	Bagasse saving per day in tonne	Energy saving per day in KWh	Saving in Rupees@ of Rs 2.75 /day	Savin Rupe /year day)
1	50	2750	1500				
2	30	2750	1050	450	1,51,260.5	41.15 lakhs	6.56 c

4.6.5 Energy Saving Potential of Pump of Mill House

There are various pumps in mill house of USML and technical details of these pump are given below in Table 4.10.List of Mill house details is given in Appendix-I.

4.6.5.1 Procedure of calculating efficiency of pump

(i) Calculation of standard efficiency

Data has been collected from site, those are given Table 4.11. At this stage head (H), discharge (Q) and speed (n) are known to us. To know the standard efficiency of pump from Stepanoff 's efficiency curve, which is given in Fig.4.10 the knowledge of specific speed of pump is required. So the sample calculation of specific speed for pump is given as:

$N = n\,Q^{½} / H^{¾}$

Where, n = speed of pump in rpm

Q = discharge in m^3/s

H = head in meter

N = Specific speed

Q = 0.096 m^3/s, H = 12 meter and n = 980 rpm.

$N = 980 \times (.096)^{1/2} / (12)^{3/4} = 47.$

So the specific speed was found as 47. Now from the efficiency curve, the standard efficiency of pump corresponding to specific speed 47 and discharge 0.096-m3/ s is about 80-83 %.

Table 4.11: Technical details of mill house pump

Sl.No	Pump	Capacity m^3/s	Head meter	Power HP	RPM
1	Unscreened Juice Mill 2 , A	0.096	12	50	980
2	Unscreened Juice Mill 2, B	0.096	12	50	980
3	Unscreened Juice Mill 3 A	0.033	12	15	980
4	Unscreened Juice Mill 3 B	0.022	12	15	980
5	Unscreened Juice Mill 4 A	0.022	12	15	980
6	Unscreened Juice Mill 4 B	0.033	12	15	980
7	Raw Juice 1	0.064	12	60	1450
8	Raw Juice 2	0.064	40	60	1450
9	Raw Juice	0.014	40	20	1440

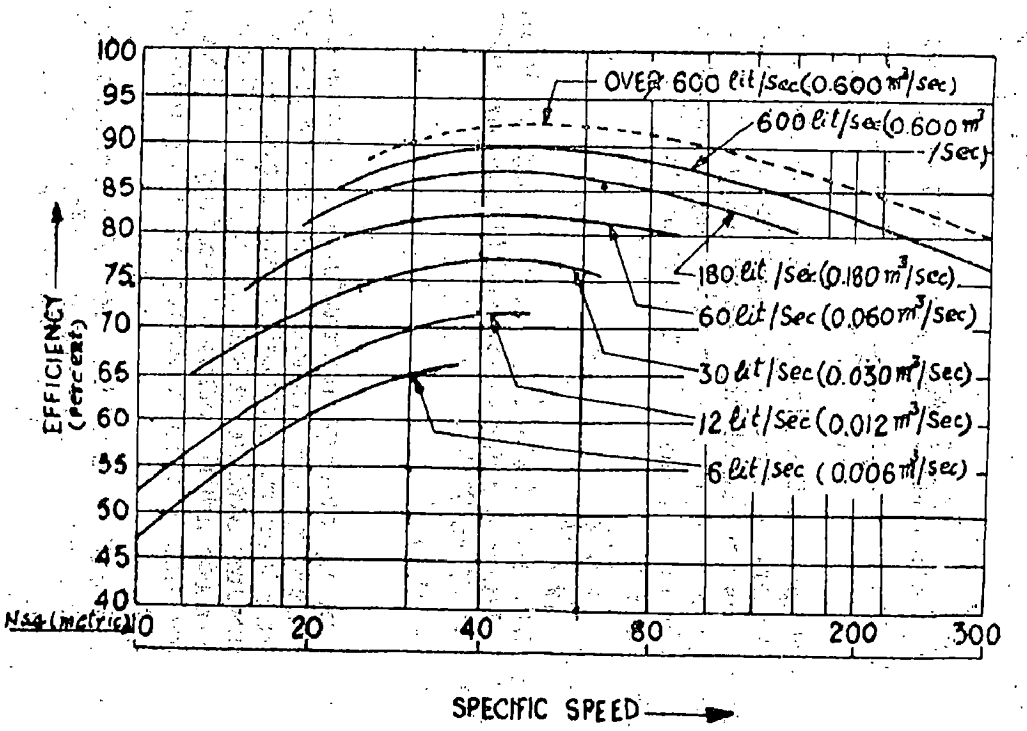


Fig. 4.10: Stepanoff 's efficiency curve [40]

Now system comprises of pump and induction motor so the system efficiency will be multiplication of motor efficiency and pump efficiency. The standard motor taken as 90 % considering full load and other factor. So the system efficiency (pump and motor both) is about 72%.

(ii) Calculation of actual efficiency

The sample calculation of actual efficiency of system is given as;

Efficiency = output power / Input power

Output power (kW) = 9.8 x Q x H x Density

Q = 0.096 m^3/ s and H = 12 meter and Density = 1140 kg/ m^3

Output power = (9.8 x 0.096 x 12) x 1000 x 1.14 / 746 = 17.25 HP

Input power = 50 HP

Efficiency (%) = (17.25 / 50) x 100 = 34.5%.

So above calculation of efficiency show that the system is running at lower efficiency. Table 4.12 gives the efficiency comparison and energy saving of system (Pump & Motor).

Table 4.12: Efficiency comparison and energy saving of System (Pump & Motor)

Sl.No	Pump	Standard system Efficiency (pump &motor) in%age	Actual system efficiency (pump &motor) in %age	Energy saving in Units (KWh)
1	Unscreened Juice Mill (2A)	72	34.5	16328
2	Unscreened Juice Mill (2B)	72	34.5	16328
3	Unscreened Juice Mill (3A)	67	39.6	12031
4	Unscreened Juice Mill (3B)	58.5	26.2	13750
5	Unscreened Juice Mill (4A)	58.5	26.2	13750
6	Unscreened Juice Mill (4B)	67	39.6	12031
7	Raw Juice	67	19.4	82501
8	Raw Juice	67	63.8	6875
9	Raw Juice	67	42.2	14323

From the above table, its seems that if all the pump and motor systems are run at near by the standard efficiency then, significant amount of about 1,77,920 units per season (160 days) could be saved. The efficiency comparision chart shown in Fig.4.11

The total expenditure of pump system for improvement of efficiency =Rs 15000 /pump

No. of pump = 9,

Net expenditure in Rupees= 15000 x 9 = 90000

Energy saving per season = 177920 units

Energy could be selling at the rate of Rs2.75.

Saving in Rupees = 4,89,271

Net saving in Rupees = 4,89,271 – 90000 = 399271.

In above calculation show it would be resulted in financial gain of about Rs 4 lakhs.

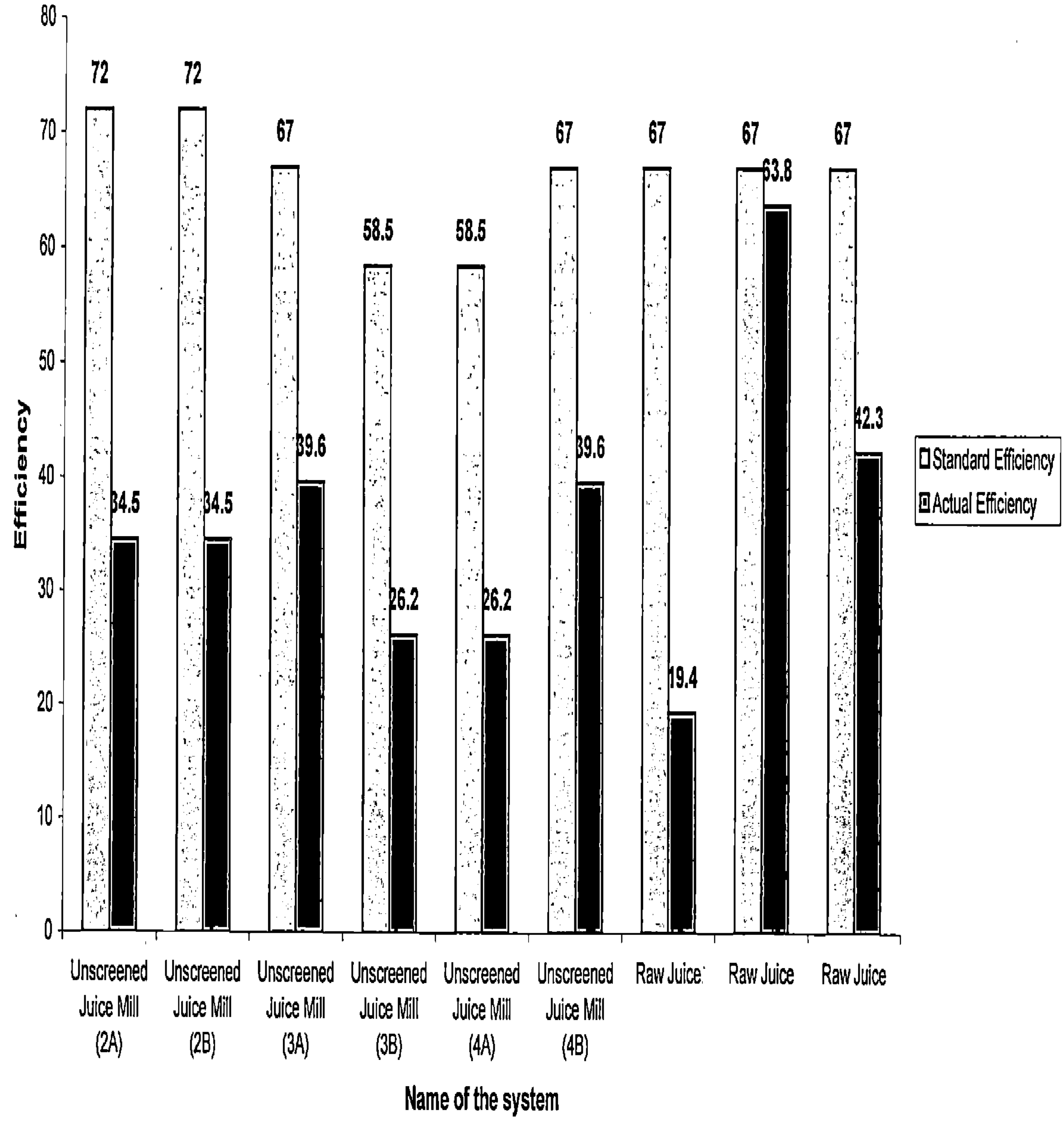


Fig. 4.11: Efficiency comparision of the system (pump & motor)

4.7 ENERGY AUDIT IN BOILER HOUSE

4.7.1 Fault Observed

The steam sent through the M.S. pipe to various section of sugar mill. There are so many chances of heat by mostly convection and radiation, when the steam pipe and flanges are unlagged of the insulation.

There were following faults found during the study as:

(i) 25 steam pipe flanges were unlagged (without insulation)

(ii) There was steam leakage at many places of steam pipe

(iii) Over heating of gears

After identified the unlagged steam pipe flanges, the temperature and dimensions of unlagged steam pipe flanges measured by thermameter (0-1200 °C) and scale respectively. And the heat loss due unlagged of the insulation of the flanges calculated and also found the energy saving potential in steam pipe flange providing the insulation.

4.7.2 Energy Saving Potential of Steam Pipe Flange

The amount of heat loss due to radiation at 1000 °C will be 46 times more than radiation at 100°C. Thus to reduce this heat loss, suitable type of insulating materials and its optimum thickness should be used. The most common lagging materials are asbestos 85% Magnesium, Glass wool, Mineral wool. From the energy conservation study point of view, the diameter and the thickness of stream pipe flange was measured as 0.36 m and 0.07 m respectively. The surface area of steam pipe flange was calculated as about 0.1896 m^2. The surface temperature (T_s) of unlagged flange was measured as151°C.the atmospheric temperature (T_a) was taken as 30 °C .The picture of unlagged flange located in the route of steam flow has been shown in Fig.4.12 ,4.13 and 4.14. The sample calculation for heat loss through unlagged flange is given in Table 4.13.

Table 4.13: Energy saving calculations of steam pipe flange

Sl.No	Items	Values
1	Surface Heat Transfer Coefficient of Hot Surface, h=(0.32+. 005(Ts-Ta)) x 10 in W/m^2 K, Ts = 424 K& Ta= 303 K.	9.25
2	Surface Heat Transfer Coefficient of Hot Surface After Insulation h'==(0.32+. 005(Ts-Ta)) x 10 in W/m^2 K	4.7
3	Total Losses From Unlagged Surface of Flange, Q=h x A x (Ts-Ta) in Watt	**212.28**
4	Total Losses From Insulated Surface of Flange, Q'= h' x (Ts-Ta) in Watt	54.54
5	Power Saved By Providing Insulation, P= Q-Q' in Watt	**157.60**
6	Annual Working Hours (n)	3840
7	Energy Saving After Providing Insulation, E=P x n in KWh /Year	605
8	No. of Flange (N)	25
9	Net Energy Saving E_t in KWh / Year	**15129**
10	Potential of Bagasse Saving in Kg /Flange	**300.11**
11	Total Potential of Bagasse Tonne /Year	**7.51**
12	Total Potential of Steam in Tonne/ Year	**15.76**

(i) Total investment for insulation

Thickness of insulation =. 06 m

Area of steam pipe flange after providing insulation= .3872 m^2

Volume of steam pipe flange = .3672 x .06 =. 02323 m^3

Density of glass wool = 64 kg /m^3 [41]

Required glass wool in kg = .02323 x 64 =1.49

Rate of glass wool per kg =500

Expenditure in Rupees =1.49 x 500 =743.36 per flange.

Rate of energy / unit is Rs 2.75.

Saving in Rupees per season = 605 x 2.75 = 1663.75

Net saving in Rupees = 1663.75 – 743.36 =920.39 / flange / season.

No. of flange = 25

Net saving in Rupees = 920.39 x 25 = 23009.75 / season.

From the above calculation, it was found that a single no. of unlagged flange could be lost energy equivalent to about 605 units /season. So for 25 no. of flanges it would be about 15,130 units / season. And money could be earned Rs 40,000 per season by selling the electricity to the nearby grid. Soothe net saving would be about Rs 23,000 per season.

Fig. 4.12: Unlagged steam pipe flange

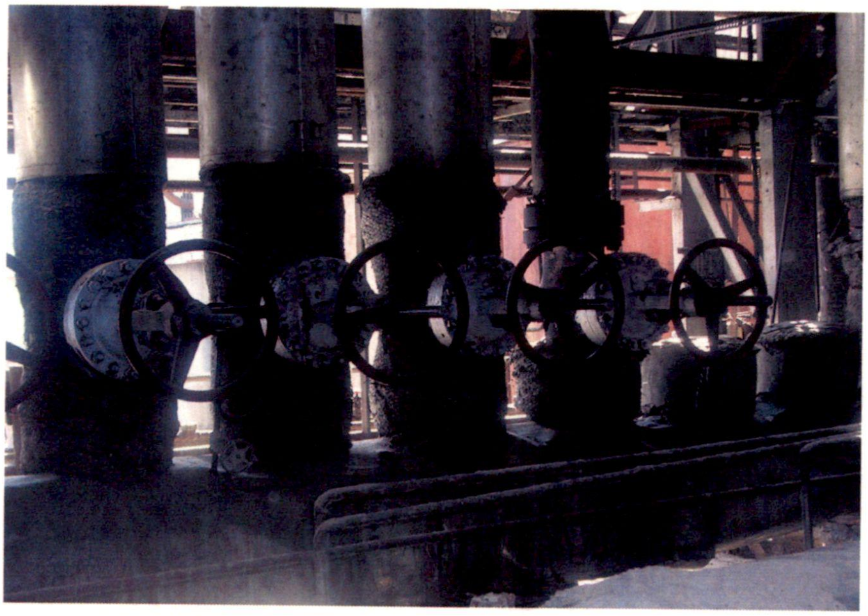


Fig. 4.13: Unlagged steam pipe flanges of header

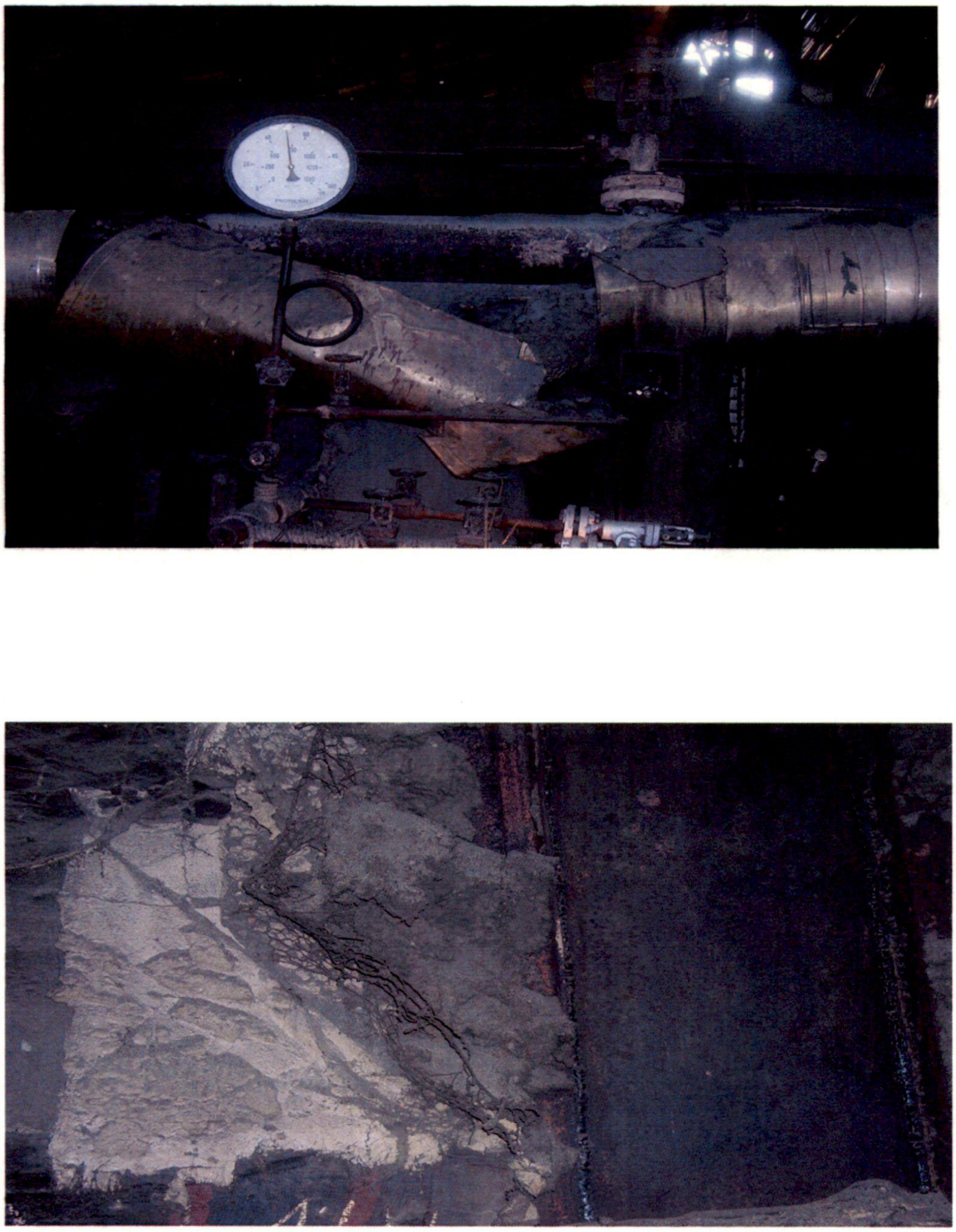


Fig. 4.14: Unlagged steam pipe

4.8 ELECTRICAL ENERGY SAVING POTENTIAL DUE TO IMPROVEMENT IN POWER FACTOR

The existing power factor could be improved by equipping the capacitor bank at generator and the technical details required for calculation of required kVAR of capacitor is given as:

Turbo generator set specification = 3750 kVA (3.NOS)

Total installed power = 3 x 3750 x .8 = 9000 kW

Generated electrical power = 9600 kVA at p.f 0.83

Generated electrical power = 7968 kW

Capacitor 510 kVAR are using for improving the power factor and it was found 0.83.Now to improve the power factor at level of 0.90.the sample of calculation of required kVAR is given as:

kVAR = kW[tanΦ1 - tanΦ2]

Cos Φ1 = 0.83, Φ1 = 33.90

Cos Φ2 =0.90, Φ2 = 25.84

kVAR = 7968[0.67-0.48]=1479.8

Generated electrical power at 0.90 = 9600 x 0.90 = 8640 kW

Generated extra electrical energy at 0.90 p.f per season (160 days)

= (8640-7968) x 160 x 24 = 2580480 units

If rate of one unit approximate is Rs 2.75 / unit.

Total saving in Rupees in one season = Rs 7096320 =70 lacs.

The investment for capacitor bank Rs1200 per kVAR[42].

So total investment in Rupees = 1200 x 1480 = 177600

Net saving in Rupees in one season =7096320 –177600 = 53.2 lakhs

On the basis of above calculation, it seems that if p.f is improved from 0.83 to 0.90 by adding addition capacitor bank of about 1480 kVAR, may be resulted in the direct saving of about 25 lakh units and in other wards saving of about of Rs. 50 lakh.

4.9 NET SAVING

After the energy conservation study carried out of above stated houses, net saving in Rupees follows as:

(i) Mill house

Energy saved in mill house per season (160 days) = 2,42,01,360 +1,77,920 = 2.43 x 10^7 units

(a) Saving using bagasse dryer in Rupees = 2,42,25,000/season
(b) Saving in system (pump & motor) in Rupees =4,00000 /season
(c) Net saving in mill house in Rupees =2,42,25,000 + 400000 = Rs2.46 crores

(ii) Boiler house

(a) Energy saved in steam pipe flanges per season =15,130 units

(b) Saving in steam pipe flange due to providing insulation in Rupees = 23,000 / season

(iii) Power house

(a) Energy saved due p.f improvement per season = 25,80,480 units

Saving due to power factor improvement in Rupees = 50 lakhs /season

(i) Net energy saving in all houses per season = 2,43,79,277 + 15130 + 2580480
= 2.70×10^{7} kWh.

(v) Total saving from all the houses in rupee per season = saving of mill house + saving of boiler house + saving of power house.

= 2,46,25000 +23000 +5000000 = Rs 2.52 crores / season (160 days).

So above calculation shows that, the power could be sell at rate of Rs 2.75 per unit to the near by grid. So net the revenue of Rs 2. 50 crores could be earned. By doing all stated energy conservation practices. Energy saving per season (160 days) of the stated house of USML is summarized in the Table 4.14.

Table 4.14: Energy saving per season (160 days) of USML

Sl.No	Energy saving in Mill house in kWh		Energy saving in Boiler house in kWh	Energy saving due to P.F improvement kWh	Total energy saving per season (160 days) in units (kWh)
	Pump	Bagasse drying	By insulation		
1.	1,77,920	2.42×10^{7}	15,130	25,80,480	**2.70×10^{7}**

CONCLUSIONS

5.1 CONCLUSIONS

As discussed in previous chapter that there is a lot of scope of energy conservation in sugar industry in India. Uttam Sugar Mills Ltd (USML) in Haridwar district of Uttaranchal has been selected to carry out energy conservation and the study carried out presented under this work of dissertation. Following conclusions are drawn from the study:

(i) Various processes involve in production of sugar of the sugar mill were studied by visiting the mill. It has been found that there is lot of scope of energy saving mainly in two processes i.e. (a) Mill house and (b) Boiler house.

(ii) The selected process i.e. (a) Mill house and (b) Boiler house were critical examined and data were collected. The main data collected were (a) Rating of electrical motor (b) Rating of the pump (c) Temperature of gear of mill house (d) Temperature of unlagged and lagged surface of the steam pipe flange (e) Boilers rating (f) Steam consumption and fuel consumption per day (g) power generation (h) Existing Power factor (i) kVAR rating of power house and individual motor KVAR rating and (j) Sample of bagasse having of 50 % moisture.

(iii) In order to estimate the fuel saving in boiler by increasing the calorific value of bagasse from 2650 Kcal / kg to 4160 Kcal / kg by drying process. It has been estimated the energy can be saved of about 2.42×10^{7} kWh and net saving in term of money may be of Rs 2.42 crores per season (160 days).

(iv) In the process of milling the energy audit in pumping was carried out, the energy saving could be about 1,77,920 kWh per season (160 days). As most of pumps being operated of under efficiency because of poor maintenance.

(v) In the boiler section, the energy can be saved 15,130 kWh by providing proper insulation of stream pipe flange. Which may result in net saving of Rupees 23000 per season (160 days).

(vi) Energy could be saved 2,58,0480 kWh and net saving in term of money is 50 lakhs per season (160 days).

In summary, it is concluded that in this main two processes of Uttam Sugar Mill Ltd i.e. (i) Milling and (ii) Boiler house, a total energy of about 2.70×10^{7} kWh per season (160 days)could be saved.

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Appendix-I

Detial of Electrical load of Cane House

Sl.No	Type of Motor	Location	Power (KW)	Rated Current(A)	Rated Voltage (V)	RPM	Ambient Temp (oc)	Frame No.	Effiency	Make
1	Three phase Ind Motor with slip ring	Choper	300	585	415	590	50	Rw136	92.5	Alstom
2	Three phase Ind Motor with slip ring	Crane,1,2,3,4 (4x4)	16	11	415	900	45	1LT3133-6	95.5	BBL
3	Three phase Ind Motor with slip ring	Pump(Hyduralic)	11	21	415	1445	45	160 M	88.5	Siemens
4	Three phase Ind Motor	Presure Pump (2x30)	60	63.5	415	1465	45	200 L	92	BBL
5	Three phase Ind Motor	Water Pump	18.5	33.2	415	1460	45		91.2	BBL
6	Three phase Ind Motor	Water Pump	9.3	17.1	415	1450	50		92	BBL
7	Three phase Ind Motor	Water Pump	5.5	11.2	415	1440	45		91	ABB
8	Three phase Ind Motor	Chain of Choper	55	96	415	1475	45	250M	93.5	Siemens
		Total	**475.3**	838						
	Detials of Elecrical loads of Mill House									
1	Three phase Ind Motor	Blower for D.C Motor (4x5.5)	22	11.2	415	1445	45		86	ABB
2	Three phase Ind Motor	Screen Juice Pump	90	156	415	1480	45	280 M	94.2	Siemens
3	Three phase Sqrrel Ind Motor	Screen Juice Pump	90	158	415	1475	45		93.2	ABB
4	Three phase Sqrrel Ind Motor	Screen Juice Pump	37	68	415	985	45		93.2	ABB
5	Three phase Sqrrel Ind Motor	Unscreen Juice pump for Mill-2	18.5	34	415	975	45		91	BBL
6	Three phase Sqrrel Ind Motor	Unscreen Juice pump for Mill-3,4 (2x15)	30	29	415	960	45		91	ABB
7	Three phase Ind Motor	Bagasse Belt drive for Mill-4	11	21	415	1460	45	160-M	88.5	Siemens
8	Three phase Ind Motor	H.G.Box for Mill-1,2,3,4 (4x3.7)	14.8	7.5	415	1430	45	PM 112M	s	Kilosker
9	Three phase Ind Motor	Main Fans for Elavator	45	75	415	1475	45	225 M	82.7	
10	Three phase Ind Motor	Eqarlizer	5.5	11.2	415	1475	45		86	Siemens
11	Three phase Ind Motor	Rear Eqarlizer	22	39.5	415	1460	45		88	BBL
12	Three phase Ind Motor	Oil lubricator for Mill-1	0.75	1.7	415	1410	55	N 080	77	BBL
13	Three phase Ind Motor	Rake Elevator	37	65	415	1475	45	225 S	92.5	Siemens
14	Three phase Ind Motor	Oil lubricator for Mill-2,3,4(3x.37)	11.2	1.2	415	1425	40	B 56	77	Crompton
15	Three phase Ind Motor	Fibrizer oil pump	9.3	19	415	1450	45		91	ABB
16	Three phase Ind Motor	Mill Elevator	37	65	415	1475	45	25 S	92.5	Siemens
17										
18	D.C Shunt Motor-1			Armature Curr	rmature Volta	ield Vota	Field Current		RPM	
19	D.C Shunt Motor-2	Mill No-1	750	1721	460	340	10.8	ILW 400L	1100	
20	D.C Shunt Motor-3	Mill No-2	562.5	1291	460	340	10.8	ILW 400L	1100	
21	D.C Shunt Motor-4	Mill No-3	562.5	1291	460	340	10.8	ILW 400L	1100	
22	D.C Shunt Motor-5	Mill No-4	562.5	1291	460	340	9.9	ILW 400S	1100	
		Total	**2918.55**							

	Detials of Elecrical loads of Boiler									
1	Three phase Ind Motor	F.D fan for Bioler-3	110	191	415	988	45		94.5	BBL
2	Three phase Ind Motor	S.A fans for Boiler-3	90	149	415	1480	45	280 M	91.5	
3	Three phase Ind Motor	P.S fans for Boiler-3	30	51	415	2940	45		91.5	ABB
4	Three phase Ind Motor	F.D fan for Bioler-2	75	123	415	1480	45		94	Siemens
5	Three phase Ind Motor	S.A fans for Boiler-2	75	123	415	1480	45		94	Siemens
6	Three phase Ind Motor	S.A fans for Boiler-2	45	75	415	2955	45		93.5	ABB
7	Three phase Ind Motor	F.D fan for Bioler-1	75	135	415	1475	45		94	ABB
8	Three phase Ind Motor	S.A fans for Boiler-1	75	135	415	1475	45		94	ABB
9	Three phase Ind Motor	S.A (II) fans for Boiler-1	45	75	415	2970	45		93.6	BBL
10	Three phase Ind Motor	P.S fans for Boiler-1	15	29	415	960	45	D160 L	91	ABB
11	Three phase Ind Motor	Slarry Pump	15	29	415	1460	45	D160 L	93.5	Alstom
12	Three phase Ind Motor	Fair pump for Boiler	3.7	7.5	415	1430	45	112 M	98.5	Hindustan
13	Three phase Ind Motor	I.D Fan	260	475	415	743	45	335 KSE	94	Alstom
14	Three phase Ind Motor	Dyno drive motor	6.3	10.3	415	1440	50		89	Siemens
15	Three phase Ind Motor	Feed Water Pump-5	200	324	415	2980	45	315 L	95.5	Siemens
16	Three phase Ind Motor	Feed Water Pump-2,3	30	52	415	2940	45		94	ABB
17	Three phase Ind Motor	Feed Water Pump-1	90	144	415	2965	45		94	ABB
18	Three phase Ind Motor	Trbsecer pump	18.5	33	415	2910	45		88.5	Siemens
19	Three phase Ind Motor	Trcer oil pump	3.7	7.6	415	1425	45		93.5	ABB
20	Three phase Ind Motor	Chemical Doozzing panel board	0.75	1.76	415	1405	45		88.5	BBL
21	Three phase Ind Motor	Chemical Doozzing pump-2,3,4(3x.75)	2.25	1.76	415	1390	50		88.5	BBL
22	Three phase Ind Motor	Chemical Doozzing pump-5,6(2x.37)	0.74	1.2	415	1440	50		88.5	PBL
23	Three phase Ind Motor	Bagasse Feed Pump in Furnace-3	3.7	7.5	415	1430	50		84	PBL
24	Three phase Ind Motor	Bagasse Feed Pump in Furnace-2,1(3x3.7	11.2	7.5	415	1430	50		84	BBL
25	Three phase Ind Motor	Bagasse Feed Pump For RBC	3.7	6.5	415	1475	45		92.5	Siemens
26	Three phase Ind Motor	Belt No.2 for bagasse	11		415	1450	45	PM 160 M	94.5	Kirloskar
27	Three phase Ind Motor	Belt No.3,4 for bagasse	11	20.5	415	1450	45	PM 160 M	94.5	Kirloskar
28	Three phase Ind Motor	Belt No.1 for bagasse	5.5	10.4	415	1445	45		94.5	BBL
29	Three phase Ind Motor	Crane for bagasse	30	63.2	415	1465	45	200 L	91	BBL
30	Three phase Ind Motor	Crane for bagasse	4	11	415	900	45	ILT 3133-6	82	BBL
31	Three phase Ind Motor	Elevator	11	20.4	415	1445	45	Pm60 M	94.5	BBL
		Totals	**1357.04**							

	Detials of Elecrical loads of Boiling House									
1	Three phase Ind Motor	Raw Juice Pump	110	191	415	1455	45		90	ABB
2	Three phase Ind Motor	Semiconditional Condenencing	18.5	33.2	415	1440	45		90	Siemens
3	Three phase Ind Motor	Juice transfer Pump	45	75	415	2855	45	HX225MB2	80	ABB
4	Three phase Ind Motor	Clear Juice Pump	75	135	415	1475	45	IX280SMA	94	ABB
5	Three phase Ind Motor	Water Imbibation Pump	45	78	415	1475	45	225 M	91	Siemens
6	Three phase Ind Motor	Filter Juice Pump	22	37.5	415	2830	45		90	Siemens
7	Three phase Ind Motor	Cake Wash hot water pump	5.5	10.4	415	1445	45			
8	Three phase Ind Motor	Muth circulation juice pump	7.5	14.5	415	1440	45	132 M	87	Alastom
9	Three phase Ind Motor	Lime pump	7.5	14.5	415	1440	45	133 M	87	Alastom
10	Three phase Ind Motor	Vacuum pump	110	185	415	1485	50		95.2	ABB
11	Three phase Ind Motor	Lined juice pump	110	185	415	1485	50		95.2	ABB
12	Three phase Ind Motor	Syrup pump	37	65	415	1475	45			
13	Three phase Ind Motor	Heater condenser pump(3x11)	33	21	415	1475	45			
14	Three phase Ind Motor	vapour self condenser pump	18.5	33.2	415	1450	45			
15	Three phase Ind Motor	Juice transfer Pump	22	37.5	415	1475	45		94	ABB
16	Three phase Ind Motor	Cold water circulation pump	15	29.5	415	1455	45	887633		ABB
17	Three phase Ind Motor	Molasses pump CL	11	21	415	1445	45		91	
18	Three phase Ind Motor	Magama pump-CF	15	29.5	415	1445	45		91	
19	Three phase Ind Motor	Hot water pump	7.5	14.5	415	1440	45			
20	Three phase Ind Motor	Magama pump for CA	15	29.5	415	1445	45		91	ABB
21	Three phase Ind Motor	Magam pump mixer under CF	7.5	14.5	415	1440	45	Pm13211	84	Kirlosker
22	Three phase Ind Motor	Hot water circulation pump for ver.carys	15	29.5	415	1445	45	160 M	91	
23	Three phase Ind Motor	Final molasses pump	7.5	14.5	415	1440	45		84	Kirlosker
24	Three phase Ind Motor	Magama pump for B	15	29.5	415	1445	45	D 160L	91	
25	Three phase Ind Motor	Molasses pump BH	11	21	415	1445	45	160 M	87	
26	Three phase Ind Motor	Cold water circulation pump (B.Cry)	15	29.5	415	1445	45	160 M	91	
27	Three phase Ind Motor	Pug Mill-B	22	21	415	1445	45	160 M	87	Siemens
28	Three phase Ind Motor	Hot water for auto	5.5	10.4	415	1445	45	132M	87	
29	Three phase Ind Motor	Magam mixer under B M/c	5.5	10.4	415	1445	45	132M	91	
30	Three phase Ind Motor	B.Massecute liquidation pump	15	29.5	415	1445	45	160 M	91	
31	Three phase Ind Motor	Pan condensate pump No.1,2	11	21	415	1445	45	160 M	91	
32	Three phase Ind Motor	Pan condensate pump No.3	45	75	415	2955	45		94	
33	Three phase Ind Motor	Cooling water pump for final molasses	5.5	10.4	415	1440	45	132 M	87	
34	Three phase Ind Motor	C-1 molasses pump	5.5	10.4	415	1440	45	132 M	87	
35	Three phase Ind Motor	Horizantal meter	15	29.5	415	1455	45	160 M	94	ABB
36	Three phase Ind Motor	Magama pump	30	52	415	1440	45			

37	Three phase Ind Motor	Cetrifugal M/C AFW	55	96	415	1475	45	250 M	93	BBL
38	Three phase Ind Motor	Melting Pump	15	28	415	1445	45	160 L	83	
39	Three phase Ind Motor	Magam pump	30	52	415	2940	45		94	
40	Three phase Ind Motor	Cont.C/F M/CAFW	90	149	415	1480	45	280 M	91.5	
41	Three phase Ind Motor	AFW raw magama mixter(5x7.5)	37.5	14.5	415	1440	45	Pm13211	88	
42	Three phase Ind Motor	Melting Pump	15	28	415	1445	45	160 L	83	
43	Three phase Ind Motor	AAW UC-1100(2x55)	110	96	415	1475	45			
44	Three phase Ind Motor	Magama pump	22	37.5	415	2930	45			
45	Three phase Ind Motor	Magama pump new	22	37.5	415	2930	45			
46	Three phase Ind Motor	Melter	11	21	415	1445	45	160 L	89	
47	Three phase Ind Motor	Pug Mill-B,C(4x7.5)	30	14.5	415	1440	45	Pm13211	88	BBL
48	Three phase Ind Motor	C/F M/C Koni(4x55)	220	96	415	1475	45	250 M	93	BBL
49	Three phase Ind Motor	Pug mill-	11	21	415	1475	45	160M	95.5	Siemens
50	Three phase Ind Motor	Pug mill-c	11	21	415	1445	45	PM160 M	88	
51	Three phase Ind Motor	Crystlizer(2x11)	22	21	415	1445	45			BBL
52	Three phase Ind Motor	Crystlizer, Compressor	18.5	35	415	1460	45		90.5	ABB
53	Three phase Ind Motor	Crystlizer	18.5	35	415	1460	45		90.5	ABB
54	Three phase Ind Motor	Molasses condensor(2x3.5)	7	6.5	415	1455	45		85	
55	Three phase Ind Motor	Vcc crystlizer at pan station	7.5	14.84	415	1440	45		85	
56	Three phase Ind Motor	Water pump	11	21	415	1445	45	160 L	89	Siemens
57	Three phase Ind Motor	Quard condensor pump-B(3x15)	45	29.5	415	1445	45	161 L		ABB
58	Three phase Ind Motor	Quard condensor pump-A	11	21	415	1445	45		88	ABB
59	Three phase Ind Motor	Quard condensor pump- 4th A	6.3	12	415	1450	45			ABB
60	Three phase Ind Motor	Quard condensor pump-B	11	21	415	1445	45		88	ABB
61	Three phase Ind Motor	Syrup pump,B-A(2x22)	44	37.5	415	2930	45			
62	Three phase Ind Motor	Lime pump	2.2	5.1	415	1440	45			PBL
63	Three phase Ind Motor	Vapour filter pump,5,2(2x5.5)	11	10.4	415	1445	45			Siemens
64	Three phase Ind Motor	Vacuum Filter pump Drive	3.7	11	415	1445	45			Siemens
65	Three phase Ind Motor	MWD Drive	3.7	11	415	1445	45			Siemens
66	Three phase Ind Motor	Lime mixer pump(2x7.50)	15	14.5	415	1440	45	131 M	87	
67	Three phase Ind Motor	Prelimer stirrer drive	5.5	10.4	415	1440	45	131M	87	
68	Three phase Ind Motor	Drive for molasses storage stirrer	7.5	14.5	415	1440	45	132M	87	
69	Three phase Ind Motor	Lime slaxer drive	7.5	14.5	415	1440	45	PM112M		
70	Three phase Ind Motor	Lime classifier drive	3.7	11.5	415	1445	45	PM112M		
71	Three phase Ind Motor	Elevator drive for lime classifier	3.7	11.5	415	1445	45	PM112M		
72	Three phase Ind Motor	Heater washing(4x3.7)	14.8	11.5	415	1445	45	PM112M		
73	Three phase Ind Motor	Lime mixer tank(2x5.5)	11	10.4	415	1445	45			
		Total	1931.6							