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μ *bfUnjk xka/kh*

ßEducation is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances.Þ

μ *Indira Gandhi*

Indira Gandhi
National Open University
School of Engineering and Technology

OEY-003
ENERGY MANAGEMENT : AUDIT AND CONSERVATION

Block

3

ENERGY CONSERVATION MEASURES-I

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ENERGY CONSERVATION MEASURES

The adequate and right kind of energy is necessary for the sustainable development of human society. Today, we need energy for various activities like cooking, lighting, heating, air-conditioning, transport, agriculture and industrial applications. Most of the energy for these applications is derived from burning of fossil fuels (coal, oil and natural gas).The excessive use of these finite sources is posing a serious challenge to human society. On one hand, their use is deteriorating the environment and on the other hand their stock is fast depleting. The only option left to human society is to adopt the policy of interaction of 3E's (Energy, Economy and Environment). In its simplest form, it refers to adopting the policy of Energy Conservation and Energy Substitution. Energy conservation means to use energy efficiently and hence cutting out waste to zero level. Energy substitution means to make use of renewable energy so that dependence on fossil fuels is reduced. In this course, you will learn about various energy audit techniques, energy conservation measures.

When you look around at all the machines that are running, the lights, fans, cars, etc., you simply cannot imagine life without all these. But can you imagine the amount of energy that is being used to run all this? Fortunately, people all over the world are becoming aware of the problem of consuming too much energy and are making a conscious effort to conserve it and thereby put less pressure on the earth. By conserving energy we also lower the amount of pollutants we release into the air and thereby help to keep the air clean.

The interaction between the natural resources and the population has to be maintained at a balance in order to ensure the continuity of the human race. Energy is essential to life and its conservation has become an absolute necessity.

India's overall consumption of energy is very low, but compared to its gross domestic production its relative consumption is very high. The cost of commercial energy is also high compared to that in most other countries. The industrial sector consumes about 50% of the total commercial energy produced. There is a growing need to bring about improvement in the efficiency of energy use in the industrial sector.

Concerns over the negative environmental impacts of inefficient uses of energy are growing, both globally and regionally. Such concerns require greater national efforts and greater international cooperation to promote energy efficiency and energy conservation. Local air pollution, emissions of greenhouse gases, and acidification of soil and water can all be reduced if energy and resource conservation concepts are more widely applied. More efficient energy use can increase productivity and economic competitiveness as well as lower greenhouse gas emissions per unit of output.

Energy conservation has been recognized as a national priority for a very long time, but concrete steps have not been taken seriously. The growth and demand for energy is increasing at a very fast rate, specially in the industrial sector, transport sector and the house hold sector, thereby putting a great deal of pressure on the available resources. The need of the hour has now become energy conservation. Conservation and efficient use of energy in industry has for a long time been a priority of the Government of India. People on their part should become aware of the seriousness and do their best to conserve and preserve this energy.

The concern for energy conservation and the insight into various energy related processes gained over the years has led to development of variety of energy conservation measures. Some of them are :

- Housekeeping measures to use the available sources in an optimum way,
- New energy efficient systems for improving efficiency of energy supply and consumption, and
- Renewable energy systems to promote energy substitution for energy conservation.

There are several reasons to conserve energy. Using less conventional fuels like oil, gas and electricity, we will save not only money but also pollution associated with extracting fossil fuels and using fossil fuels. Reducing greenhouse gases will reverse global warming. The conservation of energy is a movement in which each one of us can contribute.

In this unit, we will discuss various short term energy conservation measures. Usually, short term energy conservation are good house keeping measures which requires no expenditure or minimum expenditure but lead to huge savings.

UNIT 1 ENERGY AUDIT AND CONSERVATION IN STEEL COMPANY

Structure

1.1 INTRODUCTION

So far you have learnt about energy audit, instruments of energy audit, development of energy balance and identification of energy conservation measures. You have also learnt about how to carry out energy audit of your home. Findings from the energy audit of a few industries have also been discussed. In this Unit we shall discuss the energy audit and the conservation measures in a steel manufacturing company.

You have learnt that energy audit quantifies energy used for various discrete functions and identifies areas of energy wastage. The main object is to find specific consumptions, i.e. energy consumed per unit production, to identify the areas of energy wastage and to suggest some energy conservation measures.

You are perhaps aware that there is a huge gap between demand and supply of commercial energy. Bridging this gap requires increasing energy production, for which enormous investments are needed. This problem can be overcome to a large extent by judicious use of energy, i.e. making use of energy efficiently. This can only happen if one has proper energy audit of a given energy consuming unit.

The company under consideration produced steel by using mild steel scrap. The preliminary energy audit of the company was done to identity the energy conservation opportunities. The following data were recorded during the energy audit.

1. The company was using mainly two fuels (coal and electricity). The percentage distribution of coal and electricity in total energy consumption was as below :

   Coal consumption : 90.44%

   Electricity consumption : 9.56%

2. Specific energy consumption (energy consumption per unit production) = 8.192×10^5 KCal/Tonne.
3. Average maximum demand : 264 KVA.
4. Most of the motors were running in under-loaded condition.
5. About 42.5% of heat supplied was lost through M. S. block covers.

The following recommendations were made.

1. Use of energy efficient lamps
   A. Replacing 100 W bulbs by FL tubes (with electronic ballast).
   B. Replacing conventional ballast by electronic ballast.
2. Use of alumina bricks instead of M.S block covers for reducing heat losses significantly, i.e. about 4% from existing 42.5%.

You will learn various steps in arriving at the above recommendations.

Objectives

After studying this Unit, you will be able to understand the following:

- Energy audit of a steel company,
- Developing energy balance in such a company, and
- Identifying energy conservation measures in such a company.

1.2 PROCESS

Steel is produced in the form of round bars by using scrap which is obtained from various industries. Firstly scrap (which is generally in the form of round or rectangular bar is cut into pieces having length 1 to 2 feet. This cutting of scrap is done on shearing machines. This scrap is kept on pusher which feeds the scrap into the furnace where it is heated up to a temperature of about 1400ºC. After this, these red hot bars are passed to hot drawing machines where the length of the red hot bar is increased and its diameter is reduced as per the requirements.

In hot drawing machine (run by 250 HP motor) bars are passed between two rollers and in this way an increase in length and reduction in diameter takes place. Now these bars are passed through twisting machines where twisting of bars takes place and the final product (round bars) is prepared. The complete process flowchart is given in the Figure 1.1.

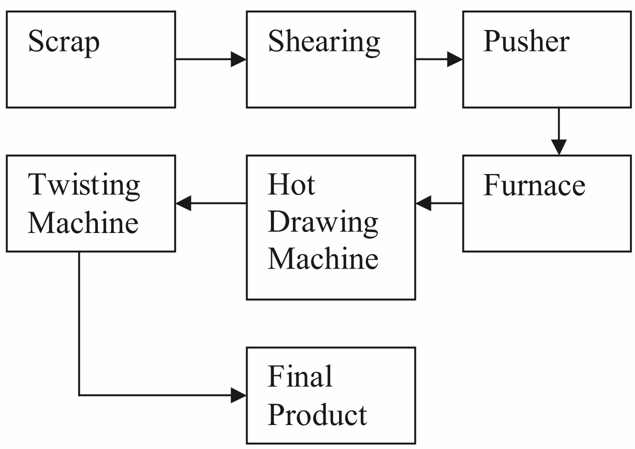

Figure 1.1 : Process Flow Chart

1.3 ENERGY CONSUMPTION

All the energy needs of the plant are met by coal and electricity. Monthly variation of electricity consumption, maximum demand and power factor are shown in Table 1.1.

Table 1.1 : Monthly Electricity Consumption, Maximum Demand, Power Factor and Bill Amount

Month	Electricity Consumed (KWh)	Maximum Demand (KVA)	Power Factor	Cost of Electricity (Rs.)
May	34020	247	0.94	68245
June	35970	261	0.93	71888
July	37830	249	0.94	76761
August	31080	276	0.97	62401
September	34482	266	0.92	69231
October	33780	261	0.91	72486
November	35482	273	0.92	71183
December	28229	298	0.90	70278
January	44280	255	0.94	96106
February	40740	258	0.94	89552
March	29220	268	0.91	65339
April	38070	255	0.95	84455

The contract demand for electricity is 308 KVA. The annual electricity consumption during the audit period was 423183 KWh. The actual maximum demand varies between 247 KVA to 298 KVA.

The coal consumption, electricity consumption and specific energy consumption are shown in Table 1.2. The calorific value of the coal is 5800 KCal/Kg. The percentage of coal and electricity in the total energy consumption is shown in Figure 1.2.

Table 1.2 : Coal Consumption, Electricity Consumption and Specific Energy Consumption

Month	Coal Cons.	Equivalent Coal Cons.	Electricity Cons.	Equivalent Electricity Cons.	Production	Specific Energy Cons.
	(Kg.)	(KCal) × 10^8	(KWh)	(KCal) × 10^6	(Tonnes)	KCal/Tonnes × 10^5
May	74430	4.32	34020	29.26	593.723	7.769
June	75160	4.36	35970	30.93	540719	8.635
July	64875	3.76	37830	32.53	556.436	7.345
Aug	63760	3.70	31080	26.76	607.238	6.542
Sept	60120	3.49	34482	26.65	462.465	8.192
Oct	35830	2.08	33780	29.05	259.637	9.151
Nov	37510	2.18	35482	30.51	275.808	9.028
Dec	28920	1.68	28229	24.28	204.221	9.416
Jan	55310	3.21	44280	38.08	456.353	7.871
Feb	38110	2.21	40740	35.04	262.827	9.743
March	27488	1.59	29220	25.13	182.313	10.114
April	31820	1.85	38070	32.74	248.593	8.761
Average	49444	3	35265	30	45402	9

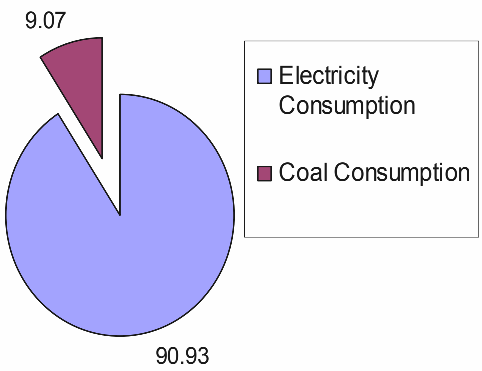

Figure 1.2 : Percentage of Coal and Electricity Consumption in Total Energy Consumption

Example 1.1

The energy audit data for a steel company for a typical month is :

Coal consumption = 74430 Kg

Electricity consumption = 34020 KWh

Steel production = 593.723 Tonne

Calorific value of coal = 5800 KCal/Kg

Determine the specific energy consumption.

Solution

Let us first convert coal and electricity consumption into a common unit, say KCal.

$$\text{Coal consumption} = 74430 \text{ Kg} \times 5800 \text{ KCal/Kg}$$

$$= 431.694 \times 10^6 \text{ KCal}$$

$$\text{Total consumption} = 431.694 \times 10^6 \text{ KCal} + 29.257 \times 10^6 \text{ KCal}$$

$$= 460.951 \times 10^6 \text{ KCal}$$

$$\text{Specific Energy Consumption} = \frac{\text{Energy Consumption}}{\text{Production}}$$

$$= \frac{460.951 \times 10^6 \text{ KCal}}{593.723 \text{ Tonne}} = 7.763 \times 10^5 \text{ KCal/Tonne}$$

> **SAQ 1**
>
> Differentiate between energy consumption and specific energy consumption.
>
> ....
>
> ....
>
> ....
>
> ....

1.4 ENERGY BALANCE

1.4.1 Electrical Energy Balance

In order to carry out electrical energy balance, you need the data regarding the total connected load of each device and their operating hours. The energy consumption is then evaluated and compared with the consumption recorded during audit. The connected load and energy consumption is given in Table 1.3.

Table 1.3 : Connected Load of Electricity

Device	H.P.	No.	KW	Operating Hrs./Day	KWh/Day
Hot Drying	250	1	186.5	6	1119
Shearing	25	1	18.65	3.5	65.28
Shearing	15	1	11.19	3.5	39.17
Twisting	15	1	11.19	3	33.57
Twisting	10	1	7.46	3	22.38
Blower	5	1	3.73	6	22.38
Pusher	5	1	3.73	6	22.38
Lathe	5	1	3.73	2	7.46
Shaper	3	1	2.24	2	4.48
Pump	5	1	3.73	6	22.38
Fan	2	1	1.49	6	8.94
Fan	1	2	1.47	6	8.94
FL Tubes (54 W)	-	20	1.08	6	6.48
Bulbs (100 W)	-	20	2.00	6	12.00
Total Energy Consumption					1394.86

The working days of the industry are 25 per month.

Total monthly consumption = 1394.86KWh/day × 25 days = 34872 KWh

Average monthly electrical consumption = 35265 KWh (Table 1.2)

The electrical energy balance may be worked as follows :

Average electricity consumption = Estimated electricity consumption

+ Unaccounted electricity consumption

or 35265 KWh = 34872 KWh + Unaccounted electricity consumption

or Unaccounted electricity consumption = 393 KWh which is about 11% of the average electricity consumption.

The difference of 393 KWh may be due to incorrect recording of operating hours of electricity consuming devices given in Table 1.3.

1.4.2 Thermal Energy Balance

Coal is the only source of energy used for thermal energy. It is used in a furnace, which is made up of fire bricks. The data used in developing thermal energy balance is given in Table 1.4.

Table 1.4 : Thermal Energy Balance

Energy Audit Data	Value
1. Coal flow rate	329.6 Kg/hr.
2. Calorific Value of coal	5800 KCal/Kg
3. Steel flow rate, M	2583.78 Kg/hr.
4. Specific heat of steel, C_t	0.116 KCal/Kg ºK
5. Air flow rate	3984.5 Kg/hr
6. Mass of flue gases = (1) + (5), m	4314.1 Kg/hr
7. Specific heat of flue gases	0.26 KCal/Kg ºC
8. Thermal Conductivity of M.S. block, C_f	46.1 KCal/m ºC hr
9. Thermal conductivity of fire brick	0.1204 KCal/m ºC hr
10. Flue gas temperature	300ºC
11. Ambient air temperature	30ºC
12. Furnace temperature	1400ºC

We will now estimate heat energy generated and then used for various applications :

A : Heat in = Coal consumption rate (Kg/hr) × calorific value of coal (KCal/Kg)

$$= 329.6 \times 5800 = 1911680 \text{ KCal/hr}$$

B : Heat taken by steel = $M \times C_t \times \Delta T$

$$= 2583.78 \times 0.116 \times (1400 - 30)$$

$$= 410614 \text{ KCal/hr}$$

You can now estimate the percentage share of this heat with the total heat released. Thus,

% share of heat used by the steel

$$= \frac{\text{Heat taken by steel}}{\text{Heat in}} = \frac{410614}{1911680} \times 100$$

= 21.5 % of heat in

C : Heat taken away by flue gases

$$= m\, C_f\, \Delta T$$

$$= 4314.1 \times 0.26 \times (300 - 30)$$

$$= 302850 \text{ KCal/hr}$$

% share = (302850/1911680) × 100

= 15.84 % of heat in

D : Heat lost through conduction, convection and radiation

The detailed analysis is beyond the scope of this Unit. We summarise the results below :

Heat loss through these processes

= 887890 KCal/hr

= 46.44 % of heat in.

Thus, thermal energy balance gives

Heat in = Heat out

1911680 (100 %) = 410614 (21.5 %) + 302780 (15.84 %) + 887890 (46.44 %)

+ Heat loss due to radiation when the blocks are open

or Heat loss due to radiation when the blocks are open = 16.22%.

Thus, the remaining 16.22 % of heat is lost through radiation when the blocks are open for coal feeding and for taking out red hot bars.

1.5 ENERGY CONSERVATION MEASURES

1.5.1 Electrical Energy Conservation Measures

Most of the electrical load is that of the motors. The loading of motors was tested by Tong tester. The measured data is shown in Table 1.5.

Table 1.5 : Performance Data of Motors

Devices	H.P.	Rated Current (Amp.)	Current at No Load (Amp.)	Current at Full Load (Amp.)
1) Hot Drawing	250	339	83	206
2) Shearing	25	36	21.3	26
3) Shearing	15	21	5.4	6
4) Blower	5	9	7	7.45
5) Lathe	5	9	2.57	3.7
6) Pump	5	9	2.89	3.84

It is clear from the above table that most of the motors are under loaded. Motors of correct size should be used so as to make optimal use of electrical energy.

1.5.2 Good Housekeeping Measures

You have read about good housekeeping measures. Some of the well known good housekeeping measures for lighting and cooling are :

In Lighting

- Turn off unnecessary lights wherever possible.
- Reduce lighting levels to minimum for task to be performed.
- Use energy efficient fluorescent/LED lighting fixtures

In Cooling

- Avoid direct sunshine on the outdoor heat exchanger of an air conditioner to improve its work efficiency by about10%.
- Remove regularly, obstructions from front of air conditioners or their grills and registers, to effect energy savings of the order of 5-15%.
- Clear air filter on room units and grills and registers of central unit, every 2-3 weeks. It can save energy up to 5-10%.
- Air leaks in air-conditioned rooms should be sealed for stopping energy wastage. This does not require much expenditure. This can lead to energy savings of the order of 5-20%.
- Clean and calibrate thermostats, this results in energy savings of the order of 5%.
- Select an energy efficient air-conditioning unit of the proper size for space to be cooled. It is wise to buy a slightly undersized unit, rather than oversized one.
- Follow the maintenance instructions suggested by the manufacture. Properly maintained air conditioning units consume 5-10% less energy.

Some of the energy conservation measures in air-conditioners are given in Table 1.6.

Table 1.6 : Energy Conservation Measures for Using Air-Conditioner

Conservation Measure	Frequency	Savings Potential (%)
Remove obstruction from front of air conditioner or their grills and registers	Regularly	5-15
Clean air filter on room units and grills and registers of central units	Every 2-3 weeks	5-10
Check for air leaks	Yearly	5-20
Balance the system	Yearly or as needed	5-10
Clean and calibrate thermostats	Yearly	5
Follow manufacturer's suggested maintenance	Regularly	5-10
Replace old unit with more efficient unit	-	Varies

1.6 LET US SUM UP

Various short term energy conservation measures have been discussed. Short term energy conservation are good housekeeping measures which require no expenditure or minimum expenditure but lead to huge savings.

1.7 ANSWERS TO SAQs

SAQ 1

In any energy consuming industry, the energy is consumed to produce the desired products. The energy consumption can be calculated either on daily basis, weekly, monthly or annual basis. Likewise the production data can also be calculated. The energy consumed per unit of production is called specific energy consumption.

UNIT 2 ENERGY AUDIT AND CONSERVATION IN A PHARMACEUTICAL INDUSTRY

Structure

2.1 INTRODUCTION

So far you have learnt about energy conservation in different industrial units like a printing press, an oil mill and a steel-manufacturing company. In this Unit we shall take up yet another case study of energy conservation in an industry.

The industry under consideration was a pharmaceutical company that manufactured pyrogen-free distilled water and dextrose powder. The former was based on what has come to be known as Heat Trap Technology. The set-up consisted of multi-column stills working on the principle of an inter-stage heat exchanger. The feed water was fed into a heat exchanger wherein 30% of it got converted under pressure into steam around 155ºC, enough to kill existing pyrogens.

The prevailing pressure pushed the steam produced as also the remaining feed water into the next column. High temperature bacteria-free steam helped vaporize the remaining feed water, and during the process got partially condensed into water due to cooling. There was thus an additional steam produced without any external source of heat. The process was repeated in up to three columns each working at a slightly lower pressure than the one before it.

The steam produced in the first column was condensed in the second. This was repeated column after column till the last column wherein it was condensed in a dual function condenser mainly by feed water and if needed, then by external cooling water. The condenser thus acts as both as pre-heater for feed water and cooler for the steam in the last column. Most of the steam produced was cooled within the system itself. The need of external water for cooling arose only for a part of the steam produced in the last column.

The steam required for the distilled water plant was supplied by a 1.5-ton rating boiler. It was designed for burning smaller size broken coal. The "as received" coal stored on soft earthy ground was fed into a hopper that fed it to a pounding equipment that broke the original coal into smaller size pieces. In this process inevitably some powdered coal was also produced. This jumble of powdered coal along with larger pieces of 15-20 mm size was pushed by a blower, delivering the mixture of primary air and coal to the burner in a semi-continuous operation.

The boiler did not has any provision for the removal of ash without opening the main furnace door, even while using the broken coal. The door had thus to be opened both for feeding the coal as well as for ash removal. This had to be done a number of times during an operational day. On each such occasion fully charged furnace of the boiler was suddenly cooled. Accumulative effect of this wasteful practice affected adversely the performance of the boiler resulting in very poor working efficiency.

Objectives

After studying this unit, you will be able to understand

- energy audit of a Pharmaceutical Company,
- energy conservation measures in Pharmaceutical Company, and
- areas where these measures may be effective.

2.2 PRELIMINARY ENERGY AUDIT

Coal and electricity were the only energy sources used in the plant. The former fed a 1.5-ton rating boiler which in turn supplied steam to the distillation and dextrose section. The block diagram of distribution of steam and distilled water in various sections of the plant is given in Figure 2.1. The coal was consumed at the rate of 1.5 ton per day. The electricity was used for lighting, running motors, pumps, fans and blowers, etc.

Scrutiny of electric bills for a period of one year showed penalties both due to maximum demand charges as well as due to low power factor. The total connected load in the plant was 132 KVA.

A preliminary energy audit of the plant helped in the identification of equipment and services where energy conservation was possible :

- The coal was stored on moist soft ground where there was a lot of scope of mixing of earth with the coal fines leading to carpet losses that could be up to 2-3%.
- There was no provision of periodic flue gas analysis nor control or fine tuning of primary air for combustion.
- There was a surplus of condensate with temperatures ranging between 60ºC and 70ºC, available at the ground level, arising due to the use of normal tap water for cooling in the distillation plant and about 150 liters of similar water form the sterilization plant and mixing this with the condensate. Its collection in right amount in one place and feeding it back into the feed water circuit needs careful attention.

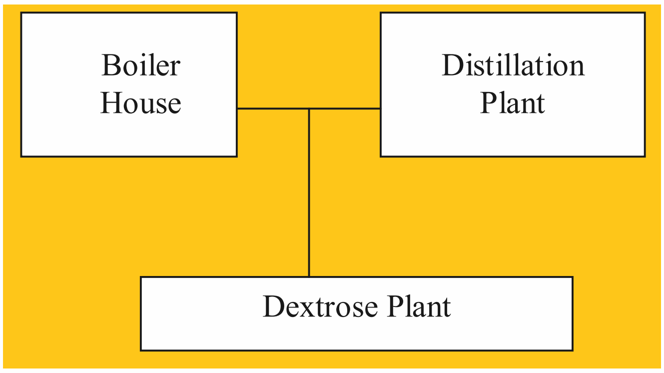

Figure 2.1 : Block Diagram of Steam Distribution

- The flue gases at high temperature were going out of the chimney without being passed through any heat recovery device. Detailed measurements indicated that they have temperature of about 270ºC.
- There existed a frequent problem of scaling of boiler surfaces. Fine tuning of boiler system and basic housekeeping include proper adjustment of combustion-control systems and a good maintenance programme for steam traps, lines and vents. Apart from this the energy conservation measure must include the maximum return of condensate, the most expensive water in a plant, and the use of flash tanks and heat exchangers to reclaim some of the energy wasted in boiler blow down. Excessive blow down to maintain TDS in boiler within prescribed safe limits was the largest single water related energy wastage.
- The efficiency of the cooling towers could be improved by replacing the existing fan with a FRP fan and lower HP motor.
- The maximum demand and low power factor needed careful attention. There were no separate meters installed to identify sections consuming more power than others; this information proves useful in controlling demand by shifting some of this load to off peak hours.
- Energy efficient lighting systems needed to be used.

2.3 ANALYSIS OF ENERGY USAGE

In order to identify energy conservation measures, it is necessary to prepare an energy balance. In this Section we shall discuss thermal energy balance.

The principle components of energy balance are :

- Carpet losses associated with storage of coal on the open on loose soft ground;
- Heat losses associated with dry flue gases;
- Heat losses arising due to the presence of water vapour in the flue gases;
- Energy taken up by the boiler to generate steam at the working efficiency of the boiler;
- Losses springing from the boiler not always working at its rated value or what has been called the load factor;
- Blow down losses, and
- Losses due to incomplete combustion and radiation from the body of the boiler and furnace mouth.

These losses are discussed in the following sections :

2.3.1 Carpet Losses

The coal required for the boiler furnace was stored behind the boiler house on open loose soft ground. This resulted in the mixing of the coal fines with loose earth and eventual loss that could be up to 3% or so.

2.3.2 Heat Losses in the Flue Gases

A graphical representation of the combustion in the boiler furnace is shown in Figure 2.2. C H O N S A W are the percentages of carbon, hydrogen, oxygen, nitrogen, sulfur, ash, and mechanical water present in the coal. This information is supposed to be obtained from the combustion products formed by the burning of coal. In addition to these components water vapour is also produced during combustion due to the presence of hydrogen in coal.

Heat losses in the flue gases can be estimated from the actual measurement of the constituents of flue gases. These measurements were taken several times with the help of IMR 300 (an instrument capable to measure all possible constituents of flue gases). The results for a typical test run are given in the Table 2.1.

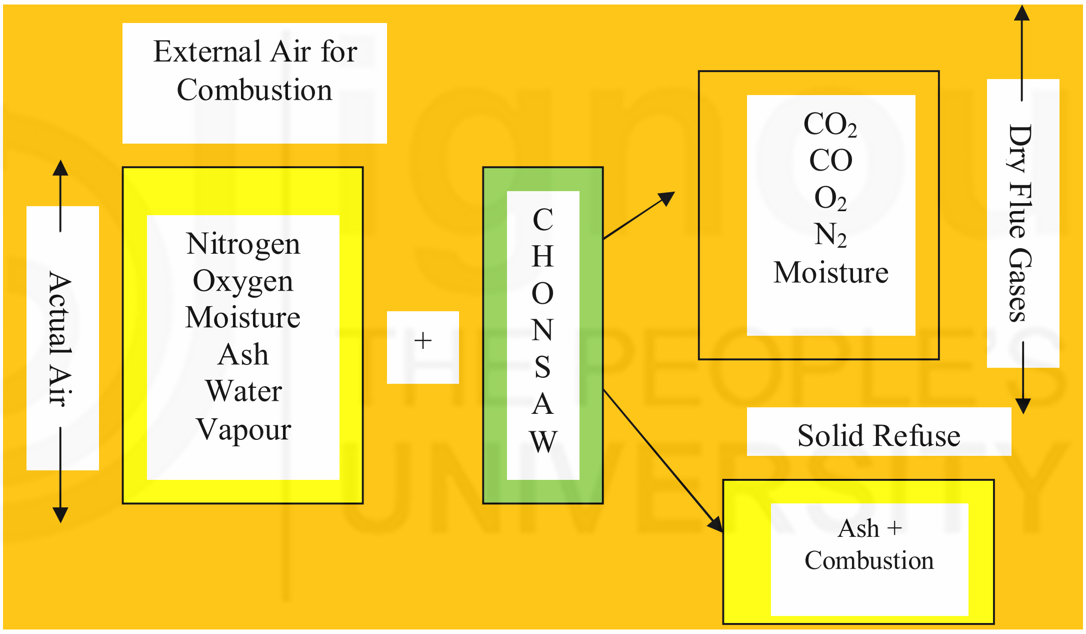

Figure 2.2 : Schematic Diagram of the Combustion in Boiler

These measurement figures are on volume basis. In order to make use of this data for quantitative analysis the parentages of flue gas components must be known on weight basis.

Table 21 : Flue Gas Analysis by IMR 300

Component	Value
CO_2	12.6%
Co	30 ppm (parts per million)
H_2S	0 ppm
NO	0 ppm
O_2	11.2%
SO_2	204 ppm
NO	116 ppm
Excess Air Factor	1.48

The heat losses associated with the flue gases were estimated from the coal consumption data provided by the management.

During energy audit, it was observed that there was no quantitative data available on the primary air being supplied for combustion. A 7.5 HP blower was used for pushing the mixture of coal and air and feeding it to the burner. Another supplementary 3 HP blower augmented the primary air supply occasionally. We have estimated air demand for combustion from theoretical air for coal and assuming a 50% excess air factor. A 7.5 HP blower has a discharge capacity of about 3700 kg/hr.

In the absence of a detailed composition of coal, the following relevant properties were assumed. The analysis was based on the data supplied by the management and also on the measurements reported above.

Ash + moisture content = 30%

Calorific value of coal = 4500 kCal/kg

Burning rate of coal = 1.5 Tonnes/day

= 62.5 kg/hour (assuming 24-hour operation)

Heat released per hour = 62.5 kg/hr × 4500 kCal/kg.

$= 2.81 \times 0^5$ kCal/hr

Specific heat of flue gases (C_p) = 0.24 kCal/kg^{o}C

Theoretical amount of air for coal = 11 kg/kg

Actual air being used up in view of the above excess air factor (see Table 2.1)

$= 11 \times 1.48 = 16.28$ kg/kg

Mass flux in the flue gases = $62.5 \times 16.28 + 62.5$

= 1080 kg/hour

Hence, Heat flux in the flue gases

$= m\ C_p\ \Delta T$

$= 1080 \times 0.24 \times (270 - 30)$

$= 62.21 \times 10^3$ kCal/kg.

Percentage of heat loss in the flue gases

$= 62.21 \times 10^3 / 2.81 \times 10^5$

= 22.1%

2.3.3 Heat Loss Associated with Water Vapour in the Flue Gases

The water vapour in the flue gases enters from the following three sources :

(1) Mechanical water present in the composition of coal.

(2) Water formed in the composition of coal due to the presence of hydrogen in coal.

(3) Water vapour that is a constituent of external air supplied for the combustion.

The components of first two categories are liquid water that get converted into water vapour when these are brought to the state of the flue gases. The amount of water vapour present will depend upon the dry and wet bulb temperatures of the air or on its relative humidity, and is obtainable from the psychometric charts.

Assuming hydrogen and external moisture in the coal to be 5% and 10% respectively, the amount of water formed per Kg of coal during combustion may be computed by using the following formula :

The amount of water formed per Kg of coal during combustion

$$= 9 \times 0.05 + 0.1 = 0.55 \text{ kg.}$$

Latent heat of water vapour = 546 kCal/kg

Hence, heat lost due to latent heat of vapourisation in the flue gases

$$= 0.55 \times 546 = 300.3 \text{ kCal}$$

Specific heat of water vapour = 0.48 kCal/kg ºC

Heat lost due to sensible heat of water vapour

$$= m\, C_p\, \Delta T$$

$$= 0.55 \times 0.48 \times (270 - 30) = 63.4 \text{ kCal/kg}$$

Assuming 40% relative humidity of the external air, the amount of water vapour present per kg of air is 0.008 kg. The amount of air being supplied for the combustion of one kg of coal is 16.26 kg.

Hence, the amount of water vapour present in the air required for the combustion of 1 kg. of coal

$$= 16.26 \times 0.0008 = 0.13 \text{ kg.}$$

The amount of heat spent to bring it to the state of the flue gases will be

$$= 0.13 \times (270\text{-}30) \text{ x } 0.48 = 15.0 \text{ kCal}$$

Thus, total heat loss associated with the water vapour in the flue gases

$$= 300.3 + 63.4 + 15 = 378.7 \text{ kCal/kg of coal burnt.}$$

Percentage loss due to water vapour

$$= \frac{62.5 \times 378.7 \times 100}{2.81 \times 10^5} = 8.4\%$$

2.3.4 Boiler Efficiency

The boiler efficiency η was determined to be equal to 48.9%.

The boiler was not found to be working at its rated capacity of 1.5 ton/hr. During the survey of the plant on several occasions, it was found to be operating on the average at less than 50% of the rated load. Figure 2.3 shows the reduction in the efficiency with varying loads. This is also one of the reasons for its low working efficiency.

2.3.5 Blow down Losses

In spite of pre-treatment, boiler feed water often contains some impurities, such as suspended and dissolved solids. The impurities can remain and accumulate inside the boiler over a period of time. The increasing concentration of suspended solids can form sludge, which reduces boiler efficiency. To avoid boiler problems, water must be periodically discharged or “blown down” from the boiler to control the concentrations of suspended and total dissolved solids in the boiler

The blow down was reportedly carried out three times in a shift of 12 hours or a total of six times is 24 hours. The resulting losses were estimated to be about 10%. Ideally, the blow down should be done once in a shift.

Thus to summarize the energy balance terms, we have

Carpet losses	= 3%
Process heat	= 48.9%
Heat loss in dry flue gases	= 22.1%
Heat loss due to water vapour in the flue gases	= 8.4%
Estimated blow down losses	= 10%
Total of clearly definable heat losses	= 92.4%

The remaining heat loss of 7.6% could be on account of incomplete combustion, fouling of heat transfer surfaces, radiation losses arising from the wasteful practices of frequently opening the door of the furnace for loading and ash removal.

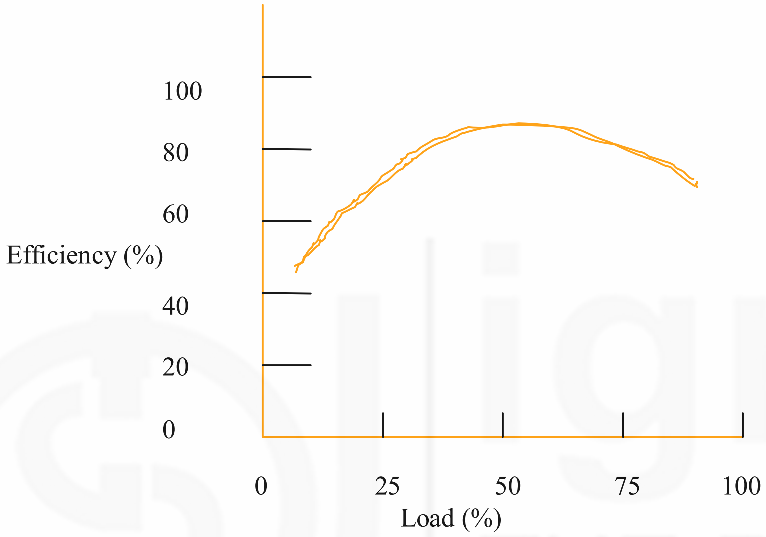

Figure 2.3 : Efficiency of Steam Boiler at Various Loads

2.3.6 Sankey Diagram

The above losses are represented in a Sankey diagram shown in Figure 2.4.

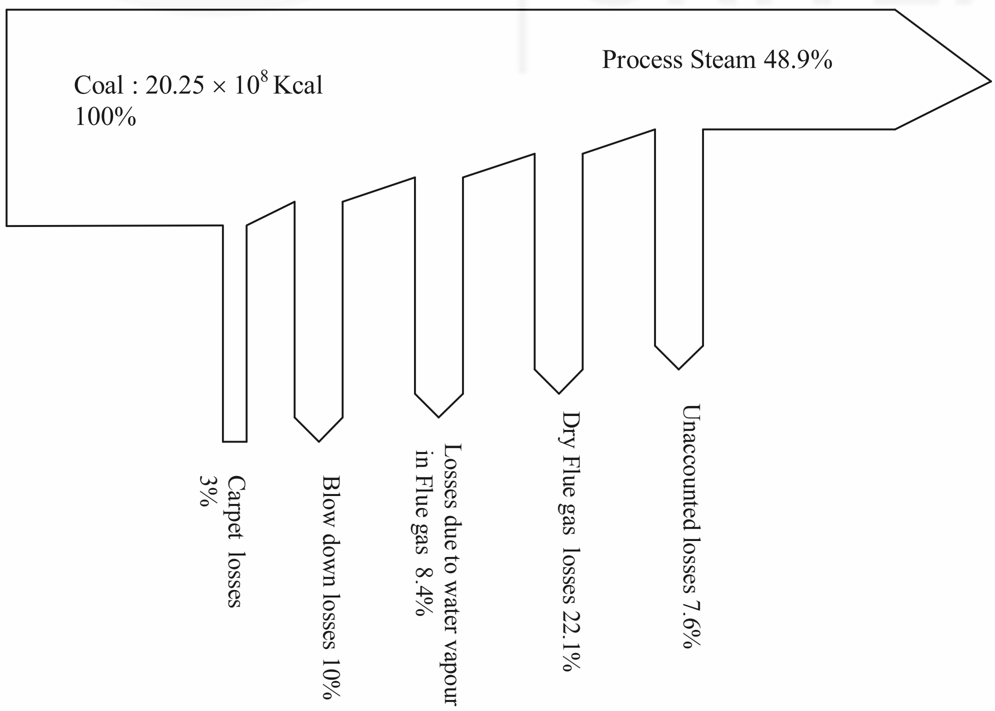

Figure 2.4 : Sankey Diagram : Thermal Energy

2.4 ENERGY CONSERVATION MEASURES

Based on the above observations relating to energy audit and energy balance, the following energy conservation measures may be identified. These are classified under three categories, namely short term, medium term and long term measures.

The following may be considered as the short term measures :

- Tuning of the boiler;
- Blow down control through estimation of TDS by measurement of conductivity or specific gravity of feed water, and
- Rephrasing of loads to escape penalty on account of exceeding maximum demand.

The medium term measures are

- Storing of coal on a concrete floor to avoid carpet losses;
- Management of condensate recovery;
- Installation of power capacitors;
- Use of energy efficient lighting systems, and
- The heat recovery device in the form of an air pre-heater.

The long term measures are

- Use of surplus condensate in future expansion plans, and
- Replacement of the existing fan of the cooling tower whenever it needs to be replaced.

2.5 SHORT TERM MEASURES

2.5.1 Tuning of the Boiler

In the operation of the boiler no attention was paid to the control of combustion air. There was no organized practice of controlling excess air through analysis of the flue gases. The excess air supplied to the furnace of the boiler was much more than the optimum required.

In the absence of on-line flue-gas analyzers, the only flue-gas characteristics that the boiler operator could use continuously were opacity and temperature. Or, he could look at the appearance of the flame, and use other subjective judgments to decide when the boiler was operating at the best excess-air level. However, through these techniques one could only make an approximate assessment. Use of flue-gas analyzers can provide accurate results.

All boilers need some excess air to ensure proper combustion of the fuel. While a range of sophisticated microprocessor based controls are available, their cost may not justify their installation on small boiler. In view of this it can be suggested that apart from depending on the wisdom and intuition of the operator, periodic checks once a day by a portable Orset apparatus be conducted to look for the optimum amounts of O_2 and CO_2 in the flue gases.

Oxygen content of the flue gas is roughly proportional to the amount of air blown into the furnace. It is directly proportional to excess air over the range 0-8% O_2.

Operators may be advised to keep O_2 above a level that is predetermined for the anticipated load. This would be feasible when this is practiced over a period of time.

More excess oxygen is needed at low loads, because of poorer mixing of air and fuel. A problem with O_2 monitoring that must be mentioned is that the reading is drastically distorted by air infiltration into the furnace and the convection passages downstream of the burners.

Carbon monoxide in the flue gas (measured in ppm of CO) stays at a fairly low constant level at high excess air, but rises sharply as excess air is reduced below the optimum level. Flue-gas carbon monoxide is unaffected by air infiltration, and thus gives a more certain indication of combustion. The CO level in the flue gas depends solely on combustion efficiency and not on the fuel, the burners, or the design of the boiler. However, with all these merits, its measurement is an expensive proposition.

Carbon dioxide in the flue gas increases to a maximum approximately at the ideal air/fuel ratio, and falls off both with increasing with decreasing excess air. However, it is not suitable as a primary control signal, because a peak value is less definitive than a present value. The peak value also varies with load, fuel, and boiler type and condition.

Unburned hydrocarbons in the flue gas provide the greatest threat of boiler-furnace explosion. They can be measured with the type of measuring gadget mentioned above. They are sometimes used to control combustion.

Oxides of nitrogen and sulfur in the flue gas are all increased with increased levels of excess air. Thus, a benefit of minimizing excess air to improve combustion efficiency is that pollutants are reduced, and sulfuric acid corrosion of stack equipment is minimized.

A couple of years old coal-fired boiler without any heat recovery or condensate recovery devices is expected to have an efficiency in the range of 60-70%. With the installation of heat recovery devices the efficiency can go up to 80%. In the present case, therefore, with appropriate control of air for combustion, based on daily testing as stated above, the efficiency of the boiler may be increased by at least 10%. This would amount to a saving of about 45 tonnes of coal or Rs. 56250. The only cost involved is that of the Orset apparatus that costs about Rs. 5000. This cost is recoverable within about 5 months.

2.5.2 Control of TDS in Feed Water

For a boiler of the size discussed above, the TDS (total dissolved solids) have to be about 3500 ppm. There was no provision for estimating this and maintaining it at the desired level. The manual conductivity measurement of feed water and adjustment of valve need to be carried out every four to six hours so as to maintain water conductivity in the range of 2400-2800 micromhom^{-1}. A simpler alternative exists in terms of specific gravity test. The resultant increase in boiler efficiency is expected to be about 5%.

2.5.3 Maximum Demand Control

It was found from the electricity bills of the company that they had incurred penalties arising from exceeding the contract demand at times. This could be avoided by shifting some of the load to non-peak hours, say night time.

2.6 LET US SUM UP

Coal and electricity are the only energy sources used in the plant. Coal is consumed at the rate of 1.5 ton per day. The electricity is used for lighting, running motors, pumps, fans and blowers, etc.

The principle components of energy balance are :

- Carpet losses associated with storage of coal in the open on loose soft ground;
- Heat losses associated with dry flue gases;
- Heat losses arising due to the presence of water vapour in the flue gases;
- Energy taken up by the boiler to generate steam at the working efficiency of the boiler;
- Losses springing from the boiler not always working at its rated value or what has been called the load factor;
- Blow down losses, and
- Losses due to incomplete combustion and radiation from the body of the boiler and furnace month.

Based on the energy audit and energy balance, the following energy conservation measures are recommended :

- Tuning of the boiler;
- Blow down control through estimation of TDS by measurement of conductivity or specific gravity of feed water, and
- Rephrasing of loads to escape penalty on account of exceeding maximum demand.

UNIT 3 MEDIUM AND LONG TERM ENERGY CONSERVATION MEASURES IN PHARMACEUTICAL INDUSTRY

Structure

3.1 INTRODUCTION

The rate at which the energy demand and energy prices are increasing, it may become difficult to sustain the present rate of development. The environmental implications of inefficient use of energy are causing serious concern. Greenhouse effect, acid rain, deforestation, shift in climatic conditions, etc. are some of the indicators of the environmental degradation. Setting up additional generating capacities to meet increasing energy demands is not only a very expensive but also a time-consuming alternative. Additional power plants also mean additional pollution and further degradation of the environment. Thus, energy conservation, besides being a quick and economical approach has the potential to provide an effective solution to emerging environmental concerns.

In any energy consuming industrial unit, there is a lot of scope for short, medium and long term energy conservation measures. In Unit 3.3.2, you have learnt about short term energy conservation measures in a pharmaceutical company. In this Unit we shall continue with the same case study and shall discuss medium-term and long-term energy conservation measures.

Objectives

After studying this unit, you will be able to

- understand medium term conservation measures,
- understand long term conservation measures, and
- evaluate the payback periods of these measures.

3.2 INSTALLATION OF CORRECTLY RATED MOTORS

There were a large number of electrical motors used in the plant for a variety of purposes as described in Table 3.1. During the energy audit, measurements of actual currents being drawn by the large sized motors (7.5 HP and above) were made by a tong tester and the findings are given in Table 3.1. It was found that some of them were running up to 65% below the rated current. You have learnt earlier, that an induction motor should always be loaded to its maximum capacity, as these motors are designed to be efficient at full rated load. The motor efficiency reduces drastically when the load factor on the motor is less than 50-60% of rated load. Hence, it was recommended that the measurement of currents of motors while in operation be made regularly. This data should be well documented over a period of time so as to cover all likely loads. On the basis of this information collected if some of the motors are found to consistently over rated these be replaced by adequately matched efficient motors.

Table 3.1 : Loading Pattern of Selected AC Motors

Sl. No	Section	Motor HP	Rated Full Load (Amp)	Actual Load (Amp)	Loading (%)
1.	Muddling Section	7.5	10.5	8.05	76.6
2.	Air compressor	7.5	11.57	7.07	61.1
		7.5	11.57	7.53	65.0
		7.5	11.0	5.0	45.4
3.	Dextrose Section	10.0	15.5	4.19	27.0
		7.5	10.5	3.0	28.6
		7.5	10.5	3.0	28.6
4.	Filling Room	5.0	7.6	3.76	49.5
5.	A.C. Room	20.0	N/A	21.5	--------
		10.0	14.5	9.47	65.3
6.	Tube Well	7.5	11.57	11.57	8.9
7.	Boiler Section	7.5	10.9	9.61	88.1
		10.0	14.4	9.70	67.4
8.	Centrifuge	55	230	45 (Without Load)	19.5

Any motor should give the required performance at the minimum cost. There are two costs involved, i.e. capital cost and running cost. The running cost of a motor depends upon its efficiency.

3.3 STORAGE OF COAL ON CONCRETE FLOOR

As discussed in the earlier Unit, the coal was being stored on loose moist soft ground, leading to carpet losses of about 2-3%, amounting to annual loss exceeding Rs. 15000. This could be avoided by constructing a concrete floor of

25 m^2 at a cost of about Rs. 10000. As you can see, this cost could be recovered in less than a year.

3.4 POWER FACTOR IMPROVEMENT

You have learnt about power factor in Block 1 of OEY-001. Power factor is the ratio of real power (watt) and apparent power (volt amp). In an electrical circuit having pure resistive loads, real power and apparent power are the same. However, in a circuit having inductors (as in motors) they are different. For example, if the real power is 1700 watt and the apparent power is 1200 volt amp, the power factor is 0.85. With low power factor load, the current flowing through the device components is higher than necessary to do the required work. This results in excess heating which may damage the device or reduce its life. Low power factor may also cause low-voltage conditions, which results in dimming of lights and sluggish motor operations.

The reactive load component (KVAr) must be reduced to improve the P.F. of a given load. The reactive power component lags the power component (KW) by 90º and therefore one way to reduce the effect of this component is to introduce another reactive power component that leads the power component by 90º. This can be done by power capacitor. The amount and location of the corrective capacitance may be determined from a survey of the distribution system and the source of the low power factor loads. In order to reduce the system losses, the power capacitors should be electrically located as close to the low power factor loads as possible or just across the load. The power factor capacitors are connected across the power lines in parallel with the low-power-factor loads.

The maximum demand, energy consumption, power factor and penalty due to low power factor found through an audit of a unit are given in Table 3.2.

Table 3.3 gives the multiplier to be applied to the KW load to determine the capacitive KVAr required for obtaining the desired corrected power factor.

The operating power factor during the survey period was 0.7, total connected load being 184 KW. The rating of power capacitors required to improve the power factor to 0.95 works out to be 127.5 KVAr, as shown below :

Original power factor is given by

$$Cos\,\varphi_1 = 0.7 = \frac{Real\ Power}{Apparent\ Power} = \frac{184}{Apparent\ Power}$$

$$Apparent\ Power = \frac{184}{0.7} = 262.86\,KVA$$

The reactive power is then given by

$$Reactive\ Power = \sqrt{262.86^2 - 184^2} = 187.72\,KVAr$$

For the improved power factor of 0.95, the apparent power and reactive power are given by

$$Apparent\ Power = \frac{184}{0.95} = 193.68\,KVA$$

$$Reactive\ Power = \sqrt{193.68^2 - 184^2} = 60.5\,KVAr$$

The rating of power capacitor required = 188 – 60.5 = 127.5 KVAr.

Assuming the average cost of the capacitor to be Rs. 125/KVAr, the cost of the capacitor to be connected comes out to be Rs. 15938.

Table 3.2 : Details of Electrical Loads

Month	Maximum Demand (KVA)	Energy Consumption (KWh)	Power Factor	Total Energy Charges (Rs.)	Low P.F. Charges (Rs.)
March	63.00	9510	0.66	8368.80	3071.73
April	61.50	10440	0.64	9187.20	3727.20
May	76.50	12420	0.71	10929.60	2955.96
June	102.75	24117	0.72	10560.00	4488.00
July	102.75	24117	0.72	21222.96	5329.86
August	106.50	192936	0.66	16977.84	6231.64
September	115.50	22079	0.64	19429.52	7822.20
October	151.50	27138	0.62	33387079	14090.26
November	99.00	15555	0.57	16954.95	8710.80
December	132.75	16943	0.54	29444.00	16797.00
January	139.50	25827	0.56	29665.44	15785.28
February	139.50	31610	0.58	36061.26	21317.76

Table 3.3 : Power Factor Correction Factors

Existing Power Factor (%)	Corrected Power Factor				
	100%	95%	90%	85%	80%
50	1.732	1.403	1.247	1.112	0.982
52	1.643	1.314	1.158	1.023	0.893
54	1.558	1.229	1.073	0.938	0.808
56	1.479	1.150	0.994	0.859	0.799
58	1.404	1.075	0.919	0.784	0.654
60	1.333	1.004	0.848	0.713	0.583
62	1.265	0.936	0.780	0.645	0.515
64	1.201	0.872	0.716	0.581	0.451
66	1.139	0.810	0.654	0.519	0.389
68	1.078	0.749	0.893	0.458	0.328
70	***10.20***	***0.691***	***0.535***	***0.400***	***0.270***
72	0.964	0.635	0.479	0.344	0.214
74	0.909	0.580	0.424	0.289	0.195
76	0.855	0.526	0.370	0.235	0.105
78	0.802	0.473	0.370	0.235	0.105
80	0.750	0.421	0.265	0.130	0.052
82	0.698	0.369	0.213	0.078	-
84	0.646	0.317	0.161	-	________
86	0.594	0.265	0.109	-	________
88	0.540	0.211	0.055	-	________
90	0.485	0.156	-	-	________

The penalty on low power factor during the month of energy audit was Rs. 21317. If we take the average penalty, it comes out to be Rs. 18551/per month or Rs. 222600 per year.

The estimated payback period is less than two months.

Connecting the power capacitors to the motor terminals and switching the capacitors with the motor load is a very effective method for correcting the power factor. The benefits of this type of installation are the following :

- No extra switches or protective devices are required.
- Line losses are reduced from the point of connection back to the power source.
- Corrective capacitance is supplied only when the motor is operating. In addition, the correction capacitors can be sized based on the motor nameplate information, as previously discussed.

Example 3.1

Determine the rating of power capacitor required in the above case by using Table 3.3.

Solution

You need three things. The connected load (KW), existing power factor and new power factor. In the above case, these are

Connected load = 184 KW

Existing power factor = 0.7

New power factor = 0.95

From Table 3.3, the multiplier factor is 0.691. The capacitor rating required to increase power factor from 0.7 to 0.95 is 0.691 × 184 = 127.14 KV Ar which is close to 127.5 calculated above.

3.5 CONDENSATE RECOVERY FROM BOILER FEED WATER

Recovery and collection of the condensate from different points in the network and pumping it back into the feed water tank is an attractive proposition (see Figure 3.1). Estimated temperature of the condensate is in the range of 60-70ºC. Assuming that about 75% of the condensate can be retrieved, average steam demand being 625 Kg per hour, an estimated 469 Kg of condensate can be pumped back into the feed water circuit. Normally this would put a demand of the make-up water of about 256 Kg/hr. Instead 400 Kg of DM water used as cooling water in place of normal tap water plus about 150 Kg/hr from the sterilization plant was being pumped into the condensate tank every hour. This was the total water source, there being no other make-up water. Thus, there is an excess of condensate of DM water to the extent of 300 Kg per hour being added to the source tank, i.e. the condensate tank. This excess hot water could be used for various productive purposes. Following steps would help conserve energy :

(i) It should be covered to avoid heat losses from the water surface.

(ii) The sides of the tank should be insulated to avoid conduction losses to the ground.

Estimated minimum rise in water temperature by (i) and (ii) is 10ºC.

The heat saved by this measure is 625 × 10 × 1 = 6250 KCal/hr.

Equivalent coal saving is = 1.39 Kg/hr or roughly 10 tons in a year. The resulting annual saving is Rs. 13500.

The estimated cost of (i) and (ii) is about Rs. 10000/-. Thus, the cost is recoverable in about a year.

The condensate collected in the properly insulated covered tank should be pumped to the feed water tank before being fed to the boiler.

Rate of water to be pumped = 700Kg/hr

The height to which it has to be pumped = 5 m

Rate of doing work = 3500 Kg m/hr

One HP = 44760 J/minute

This works out to be roughly 0.5 KW. At 50% efficiency the power required for the pump is about 1 KW.

Capital cost of the pump = Rs. 2500

Running cost @ Rs. 2/- per KWh = Rs. 48 per day

= Rs. 14400 in a year.

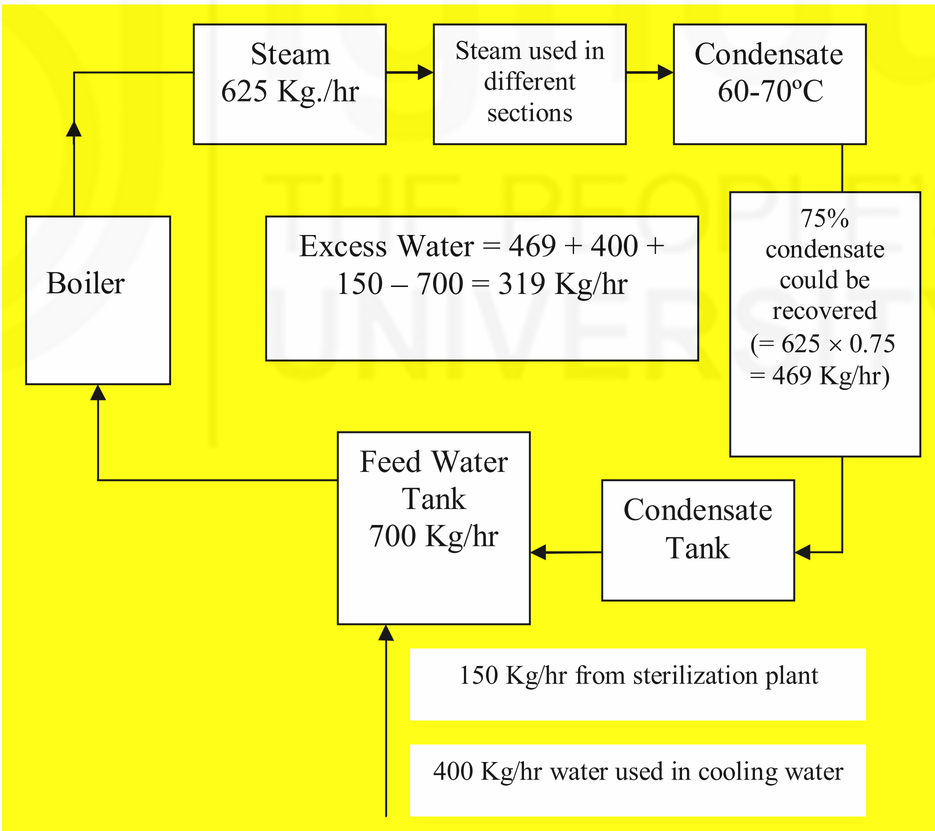

Figure 3.1 : Condensate Recovery

Rate of condensate available = 625 Kg/hr

Temperature of the condensate = 70ºC

Equivalent heat saved = 625 × (70 − 30) × 1

= 25000 KCal/hr

Coal saved in a year = (25000/4500) × 7200

= 40000 Kg

Annual savings @ Rs. 1250 per ton = Rs. 50000

Thus, the capital and the running cost is recoverable in less than a year.

3.6 WASTE HEAT RECOVERY

Use of heat recovery device based on exploitation of the heat contained in the flue gases is another attractive option. It has been shown that an air pre-heater is very cost effective leading to an annual saving of about Rs. 62,000/- with a payback period of less than two years. A layout of waste heat recovery system is outlined in Figure 3.2.

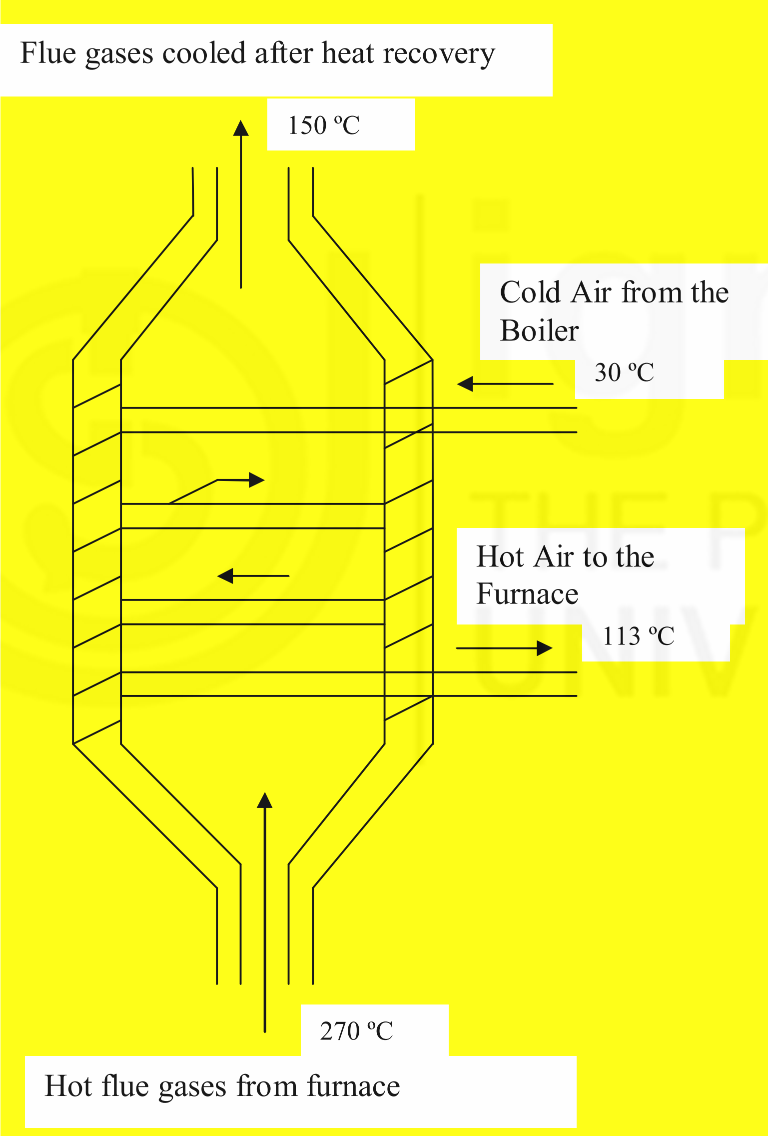

Figure 3.2 : Cross Sectional View of Waste Heat Recovery

The flue gases coming out of the chimney have a temperature of about 270ºC. The fuel being used was coal which was likely to have sulfur as an impurity. In fact the flue gas analysis showed the presence of 204 ppm of SO_2, which when dissolved in water vapour in the flue gases would lead to the formation of sulfuric acid. This in turn set a limit up to which the flue gases could be cooled, due to corrosion problems connected with condensation of sulfuric acid. The safe limit chosen in such cases was temperature T_2 = 150ºC. Thus the flue gases can be cooled by about 120ºC. The heat flux available in the flue gases may be calculated from the rate of burning of coal and allied data as discussed below :

Rate of burning of coal = 62.5 Kg/hr

Estimated air required for burning = 16.28 Kg./Kg

Mass flux of air required for combustion = 16.28 * 62.5 = 1017 Kg./hr

Initial temperature of external air, T_o = 30ºC

Initial temperature of flue gases, T_1 = 270ºC

Specified heat of flue gases = 0.24 KCal/Kg ºC

Outlet temperature of external air, T_o = 113ºC

The area of the heat exchanger comes out to be = 13 m^2

Estimated cost of the heat exchanger is about Rs. 70000.

Coal saved per hour is given by 35156.5/4500 = 7.8 Kg.

Coal saved in a year = 7.8 × 24 × 300 = 56.16 tons

Saving in a year with coal cost of Rs. 1250/- per ton is about Rs. 70200 that gives a pay back period of about a year.

3.7 USE OF ENERGY EFFICIENT LIGHTS

There were 100 numbers of 40 W fluorescent tubes operating 16 hrs. per day. The tubes were fitted with conventional chokes which consume about 12 W of power. Thus for 300 operational days in a year, the annual consumption is given by:

$$\text{Annual consumption } E_1 = \frac{100 \times 52 \times 300 \times 16 \text{ KWh/yr}}{1000}$$

$$= 24960 \text{ KWh/yr}$$

These tubes can be replaced by compact fluorescent lamps (CFL) of 11 W and electronic chock which consume about 4 W of power. The annual consumption would be

$$\text{Annual consumption } E_2 = \frac{100 \times 15 \times 300 \times 16 \text{ KWh/yr}}{1000}$$

$$= 7200 \text{ KWh/yr}$$

The savings in annual electricity consumption = $E_1 - E_2$ = 17760 KWh/yr.

The cost of electricity saved @ Rs. 2/KWh = 17760 × 2 = Rs. 35520.

The capital cost for one complete fixture would be about Rs. 300.

The payback period = (300 × 100/35520) × 12 = 10 months.

3.8 EXCESS DEMAND

During the survey it was found that the total connected load as per the name plate rating of various devices was 184 KW. In terms of an average PF of 0.75, the corresponding KVA works out to be 245, the contract demand being 132 KVA, the scrutiny of electric bills showed exceeding this demand at times leading to penalties.

The solution lies either in shifting the working hours from peak load hours or asking for increased contract demand.

3.9 LET US SUM UP

We have discussed energy conservation measures in a pharmaceutical company. The energy conservation measures are in the area of lighting, power factor improvement, waste heat recovery, condensate recovery, etc.

The medium term measures are

- Shoring of coal on a concrete floor to avoid carpet losses.
- Management of condensate.
- Installation of power capacitors.
- Replacement of lights by fluorescent tubes.
- The heat recovery device in the form of an air pre-heater.

The long term measures are

- Use of surplus condensate in future expansion plans.
- Replacement of the existing fan of the cooling tower whenever it needs to be replaced.