Palestine Polytechnic University

College of Engineering and Technology
Mechanical Engineering Department

Graduation Project

Energy Auditing for an Industrial Premises

Project Team

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Palestine Polytechnic University
(PPU)
Hebron-Palestine

PROJECT NAME

Energy Auditing for an Industrial Premises

Project Team
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According to the project supervisor and according to the agreement of the Testing committee members, this project is submitted to the Department of Mechanical Engineering at college of engineering and technology in partial fulfillment of the requirements of (B.SC) degree.

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June, 2009

Dedication

To our parents who
spent nights and days doing their best
to give us the best...

To all students and who
Wish to look for
the future...

To who love the knowledge and
Looking for the new
in this world...

To who carry candle of science
To light his avenue
of life...

To our beloved country Palestine...

To all of our friends…

Amjad A Qasrawi
Talat N Yasin

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So again thanks to:

Our great Palestine Polytechnic University (PPU)

Our College of Engineering and Technology (CET)

Our Mechanical Department (MD)

Abstract

In order to attain the best energy efficiency in an industrial plant, an energy audit is a prerequisite process for identifying the general energy consumption condition and to hence identify the measures that need to be taken to save the cost of excessive energy consumed and later to retrofit the faults that were observed. The case study presented in this paper is a medium industry plant located in Hebron. The audit methodology, observation, and audit results will be presented and discussed with the recommendation drawn.

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References

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- G. J. Hughes, Electricity & Buildings, 1984, Peter Peregrinus Ltd, London, UK, Short Run Press Ltd, England, ISBN 0-86341-015-4.

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- Energy Management Handbook, six edition, Wayne C. Turner Steve Doty

Internet

www.energyefficiencyasia.org

Appendix A

Table A.1 Typical Reflectance Values

	Ceiling	Walls	Floor
Air Conditioned Office	0.7	0.5	0.2
Light Industrial	0.5	0.3	0.1
Heavy Industrial	0.3	0.2	0.1

Table A.2: Utilization Factor

Room utilisation factor										
Luminaries ceiling mounted Reflectances p										
Ceiling	0.8	0.8	0.8	0.5	0.5	0.8	0.8	0.5	0.5	0.3
Wall	0.8	0.5	0.3	0.5	0.3	0.8	0.3	0.5	0.3	0.3
Surface	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1
Room factor k	Room utilisation factor in %									
0.6	73	46	37	44	36	66	36	42	35	35
0.8	82	57	47	54	46	74	45	51	44	44
1.0	91	66	56	62	54	80	53	59	52	51
1.25	98	75	65	70	62	85	61	66	60	59
1.5	103	82	73	76	69	89	67	72	66	65
2.0	109	91	82	84	78	94	75	78	73	72
2.5	114	98	90	90	84	97	81	83	79	77
3.0	117	103	96	95	90	99	86	87	83	82
4.0	120	109	103	100	95	101	91	91	88	86
5.0	122	113	107	103	98	103	93	93	91	89

Table A.3 Light Loss Factor

Air Conditioned Office	0.8
Clean Industrial	0.7
Dirty Industrial	0.6

Table A.4 Some Type of Motors

Type	Advantages	Disadvantages	Typical Application	Typical Drive
AC Induction (Shaded Pole)	Least expensive Long life high power	Rotation slips from frequency Low starting torque	Fans	Uni/Poly-phase AC
AC Induction (split-phase	High power high starting	Rotation slips from frequency	Appliances	Uni/Poly-phase AC

capacitor)	torque			
AC Synchronous	Rotation in-sync with freq long-life (alternator)	More expensive	Clocks Audio turntables tape drives	Uni/Poly-phase AC
Stepper DC	Precision positioning High holding torque	Requires a controller	Positioning in printers and floppy drives	Multiphase DC
Brushless DC electric motor	Long lifespan low maintenance High efficiency	High initial cost Requires a controller	Hard drives CD/DVD players electric vehicles	Multiphase DC
Brushed DC electric motor	Low initial cost Simple speed control (Dynamo)	High maintenance (brushes) Low lifespan	Treadmill exercisers automotive starters	Direct (PWM)

1

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1.1 Overview

Energy is the common approach for the experts and scientists in all over the world, since it's the basic operating agent for any service producing help and support for the human.

It's the underlying "currency" of our lives. It is necessary for everything that we do, and using it wisely is critical to our economy and to our environment. Yet for most of us, our only experience with the vast network that supplies our energy is flipping the switch that turns on the lights (or other appliances).

Energy literate citizens have the knowledge and skills to make informed choices on energy use and to understand local, state, national, and international energy issues. Energy literate citizens are essential to the economic and environmental future and energy education in our schools is fundamental to ensuring that future generations are literate energy consumers and decision makers.

As known, energy is considered as the working agent in buildings, which means that electricity, fuel and gas are used in order to operate any power producing machine, so the consumption of these sources should be conserved to avoid energy run out.

This initiate all the attention to calculate the amount of energy consumed to produce output power that is familiar to the user , and calculate the actual value of energy consumption effectively .

1.2 Energy Management

Part of the building's normal operations, energy efficiency programs that are designed to reduce the energy used by specific end-use systems. This includes Energy Auditing and Building Energy Management.

Saving money in energy bills is attractive to businesses, industries and individuals alike. Customers, whose energy bills use up a large part of their income, especially those customers whose energy bills represent a substantial fraction of their company's operating costs, having a strong motivation to initiate and continue an ongoing energy cost control program. No-cost or very low cost operational changes can often save a customer or an industry to about 10-20% of utility bills; capital cost programs with payback times of two years or less can often save an additional 20-30%.

In many cases those energy cost control programs will also result in both reduced energy consumption and reduced emissions of environmental pollutants.

The energy audit is one of the first tasks to be performed for the accomplishment of an effective energy cost control program.

1.2.1 Objectives of Energy Management

There are several targets for energy management, such as:

- Minimization of fuel consumption.
- Energy conservation, through the monitoring and control of the amounts of electricity, gas and other fuels used in the workplace.
- Reduced costs.
- Reduced damage to the environment.
- Improved energy usage.

1.3 Energy Audit

Energy Auditing is simply defined as calculating the amount of energy consumed to produce output power that is familiar to the user, and to calculate the actual value of energy consumption effectively.

In order to execute the energy audit in a building, there should be a test for the consumption of the equipments and systems used, and differentiate between the input and output power in each system individually.

In other words; Energy Audit is an examination of energy consuming equipments, and systems, to ensure that energy is being used efficiently. In many ways, this is similar to financial accounting. Building manager examines the energy account of energy consuming equipments and systems, checks the way energy is used in its various components, checks for areas of inefficiency or that less energy can be used and identifies the means for improvement.

1.3.1 Objectives of Energy Audit Process

Energy audit is a top-down initiative. Its importance represented as the following:

- Commitment on energy conservation and environmental protection.
- Anticipation on the energy savings achievable.
- Aspiration of the improvement to corporate image by promoting energy efficiency and conservation.

1.3.2 Preparing for the Audit Visit

Some preliminary work must be done before the auditor makes the actual energy audit visit to a facility.

Data should be collected on the facility's use of energy through examination of utility bills, and some preliminary information should be compiled on the physical description and operation of the facility. This data should then be analyzed so that the auditor can do the most complete job of identifying Energy Conservation Opportunities during the actual site visit to the facility

1.3.3 Energy Use Data

The energy auditor should start the work by collecting data on energy use, power demand and cost for at least the previous 12 months. Twenty-four months of data might be necessary to adequately understand some types of billing methods. Bills for gas, oil, coal, electricity, etc. should be compiled and examined to determine both the amount of energy used and the cost of that energy. This data should then be put into tabular and graphic forms to see what kind of patterns or problems appear from the tables or graphs. Any anomaly in the pattern of energy use raises the possibility for some significant energy or cost savings by identifying and controlling that anomalous behavior. Sometimes an anomaly on the graph or in the table reflects an error in billing, but generally the deviation shows that some activity is going on that has not been noticed, or is not completely understood by the customer.

1.3.4 Energy Audit Team

In order to make harmony on this project, Energy audit team consists of two students from the following branches in the mechanical engineering department:

- Mechatronics Engineering.
- Automotive Engineering.

1.4.1 Project Scheduling

1.4.1 Estimation of Time Plan for the First Semester:

Table 1.1: Time plan for the first semester

Week / **activity**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Choose the project																
Selecting the desired industrial																
Visit the industrial to make the survey process																
Calculating the amount of electrical consumption																
Printing final report																
Documentation																

1.4.2 Estimation of Time Plan for the Second Semester:

Table 1.2: Time plan for the second semester

Week / activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Load Calculation	■	■	■	■	■											
Conducting Site Inspection and Measurement				■	■	■	■	■	■							
Analyzing Data Collected						■	■	■	■	■	■					
Comparison between theoretical & actual data										■	■	■	■			
Find the opportunity of energy audit											■	■	■	■		
Economic study													■	■	■	
Printing final report															■	
Documentation			■	■	■	■	■	■	■	■	■	■	■	■	■	

1.5 The Budget:

Table 1.3 Budget

Activity	Cost ($)
Telecommunications	70
Transportation	150
Printing	130
Total	**350**

2.1 Introduction

The project deals with Al-Zaghal Investment & Industrial Group, the plant located at Al-Hawouz, near Al-Tahreer Fuel Station. The factory is responsible of producing two main categories of products serving and covering the local community, those products are plastic glasses and shoes.

Figure 2.1: Outside view of the factory

2.2 General Description of the Factory Building

The industrial plant consists of three flats with an external yard, that yard consists of a separate office with a parking and a store for storing raw materials. It includes also a standby system (Electric Generator), a compressor and an additional cooling device serving the activities of the plastic glasses manufacturing section.

The first flat is divided into three sections, the first section is a shoes gallery from the factory's own production, the second section also is divided into two different subsections, the first has two production lines for producing plastic glasses, and the second manipulates the defected units of produced glasses, in other words, it has a recycling process.

The third section of the first flat is restricted for producing shoes, and it is considered as one part of the whole shoes production process in the whole factory.

The second flat serves the process of almost whole production criteria of shoes, and so, this flat is exclusively used for shoes production, in addition to a small section for labors and workers for cloth changing and bathrooms.

And the last flat is used for plastic glasses and shoes inventory (Products Stock). Also there is a roof that comes at once after the third floor; it has a compressor for plastic glasses manufacturing section and a main cooling device (Cooler).

The total area of the whole factory with the around location is about 1,878 m^2. The building configuration with volume and dimensions appear in Table2.1 Below:

Table 2.1: The building configuration with volume and dimensions

Flat No.	**Area (m^2)**	**Volume (m^3)**
First flat	755	3322
Second flat	755	2272
Third flat	755	2272
Total	**2,265**	**7866**

2.3 Description of Manufacturing Section

The factory section is divided into two types as follows:

2.3.1 Plastic Glasses Manufacturing Section

This section has two subsections of the technological process, the first is used for initial preparation of required material, that there begins the process of supplying the raw material which is usually a polymer substance, then that material is melted at quiet high temperature by means of a heater with a specified power, then the melted substance passes through a bench roll machine that forces the material to be formed in the shape of plastic rolls, this is what about the first subsection of Glasses manufacturing.

The second subsection is designed to deal with those produces plastic rolls which in turn takes the trouble of producing plastic glasses into two parallel production lines that comes after the first subsection as a cascade or sequence technological process as noticed in other filed of industry and other industrial plants. Hence; the sizes or shapes of produced glasses can be change according to a change in plastic molds acquired within the same machine.

Its important to mention here, that within the second subsection, there is a process of removing and cutting of some roll parts to attain the required roll size serving a required glasses size, those removed sides or parts are then to be transferred to the recycling subsection to remanufacture the defected plastic into a useful material so as to be used again.

2.3.2 Shoes Manufacturing Section

- Sewing machines: this section has about three sewing machines serving different usages especially for leather joint and connection to each other.
- Clips skin.
- Material mixing machines: this machine is used for mixing raw materials to produce general shapes of shoes molds.

- Material melting oven: the solid materials are to be collected and poured into an oven for a melting process to convert those solids into liquid materials.
- Casting machines: those are used for the casting operation of melted materials into special type of molds as the usage required with the size required, and then the melted material are to be pressed to be shaped in the form of the used mold at each process. Hence; the factory has two machines of that type.

  The previous machine consists of four main components as follows:

  - Control panel: that controls all machine operations including power on, off, emergency stop, swiveling, etc.
  - Storage tanks: where two distinct materials are stored then to be transferred to the third component.
  - Mixing unit: where the previous mentioned substances are to be mixed together to form a one uniform material.
  - Casting unit: the melted material is poured into molds, and then dried by means of a compressor and then pressed to be formulated in the shape of the mold.
- Foot bottom side cover shaping machine: this can be accomplished with the presence of two main elements which are heat and pressure.
- Trade mark printing Machine: same as in the previous point.
- Perforation machine: this takes the trouble of making holes in the bottom side cover of shoes where the upper shell is to be fixed.
- Coloring machine: to achieve the process of painting used leather with the intended preferred color.
- Pulling machine: this machine combines both the bottom foot cover with the upper shell (Joint).

2.4 Machines Power in the Glasses Manufacturing

Glasses manufacturing machine composed of two main parts, the first is called Extruder, and the second is called Thermoforming, and those two parts are isolated from each other and both of them works independently, both also are related to a PLC program.

2.4.1 Extruder Machine

This machine takes the trouble of melting raw materials manufactured from plastic and forming it in the shape of plastic rolls, those rolls are formulated as required or demand, either by changing color, thickness and other plastic specifications. The Extruder is usually connected to many important and additional instruments.

Figure 2.2: The first section of extruder machine

Figure 2.3: The second section of extruder machine

The power consuming parts included within this machine part are basically Motors and Heaters.

2.4.1.1 Motors Power in the Extruder

The extruder contains a number of motors that have specified tasks within the machine. Those tasks are as the following:

Main Motor: this one is used for recirculation raw materials, so as to make the operation of melting easy so far. The main motor is connected to a gear box in a way to reduce speed and increasing the torque.

Shell Roll Motor (Pressure Motor): this one is used for controlling the thickness of plastic rolls, also to achieve cooling requirements of the previous mentioned rolls, in hand with occurring of a smooth surface. That is simply done by controlling the rotation of three cylinders by means of a hydraulic system.

Pull Roll Motor: Tensile the plastic rolls

Winder Motor (A and B): Working on the completion of the final product

Blower Motor: this motor is used for melted raw materials temperature controlling process, that is; it uses the cooling technique by means of a fan that rotates due to the presence of that motor. The Extruder has about five Blower Motors.

Crane Motor: it is used for lifting the plastic rolls and transferring them from the extruder region to another one for storage or any other activities that serves the whole process.

Table 2.2 General Data Description of motors in the extruder

Electrical Motors	**No. of Motors used**	**Power of single Motors (kW)**	**Total power of Motors (kW)**
Main Motor	1	44.742	44.742
Shell Roll Motor (Pressure Motor)	1	5.5	5.5
Pull Roll Motor	1	2.2	2.2
Winder Motor (A and B)	1	1.5	1.5
Blower Motor	5	0.155	0.775
Crane Motor	1	1.02	1.02
Total Power			**55.737**

2.4.1.2 Heaters Power in the Extruder

The extruder contains a number of Heaters, those heaters are as follows:

- **Extruder Parrel Zone:** each connected to a blower motor, the extruder contains five units of these parallel zone's, and each unit composes three heaters.
- **Adaptor Heater Zone(6).**
- **Screen Changer (7):** this one contains four heaters.
- **Die Zone (8).**
- **Die Zone (9).**
- **Die Zone (10).**
- **Lip Zone (11)**
- **Lip Zone (12).**

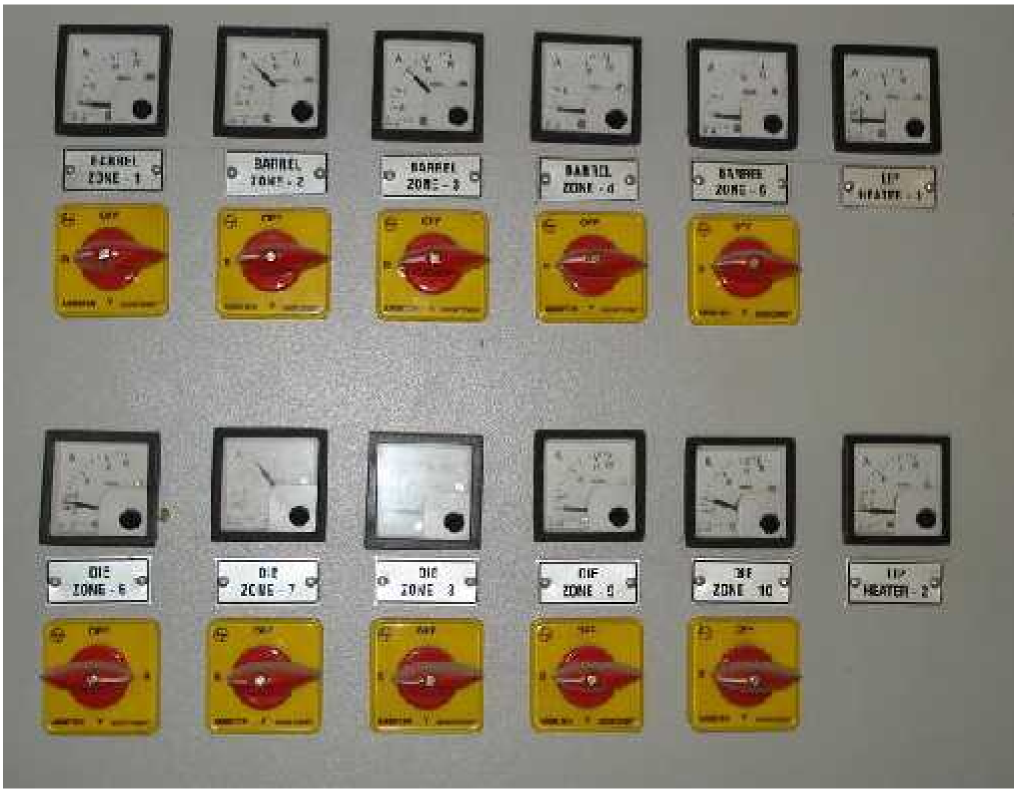

Figure 2.4: Control panel of zone heaters

Table 2.3 General Data Description of heaters in extruder

Electrical Heaters	No. of Heaters used	Power of single Heaters (kW)	Total power of Heaters (kW)
Extruder Parallel Zone(1-5)	3 * 5	0.65	9.75
Adaptor Zone (6)	1	1	1
Screen Changer (7)	4	0.65	2.6
Die Zone (8)	1	0.65	0.65
Die zone (9)	1	0.65	0.65
Die zone (10)	1	0.65	0.65
Lip zone (11)	1	13.13	13.13
Lip zone (12)	1	13.13	13.13
Total Power			**41.56**

The previous mentioned zone's are divided into groups, each group is responsible of formulating the case of material within the process (Liquid, solid, etc.).

2.4.2 Thermoforming Machine

This machine is used for the formulation of plastic glasses and bottles, and finalizes the ready final product. This machine is dependent on the output plastic rolls from the extruder.

Figure 2.5: Thermoforming Machine

This machine has two molds, top and bottom ones, and they are both take the trouble of forming the plastic bottles. In addition to that, they may be changed as the required final product. The product that gets out from the molds is transferred by means of conveyor belts, then to be transferred to the isolation step for separating good and bad plastic bottles each other, and finally to the storage section.

The previous tasks are achieved due to the presence of a number of heaters and motors, each has a specified task. Those motors and heaters are as follows:

2.4.2.1 Motors Power in the Thermoforming

Un-winder Motor: this one serves the task of plastic rolls pulling operation and passing them into the thermoform machine.

Index Motor: it is a servo motor that is used for moving chains; those chains are used for pulling the plastic rolls after the material is being connected to the chain.

Main Motor: used for moving the bottom mold either up or down, and hence; it is a servo motor.

Plug Motor: this is used for moving the top mold using cranks. Also this one is a servo motor type.

Scrap Motor: used for rolling rubbish plastic then to be again recycled.

Stucker Motor: this motor is used for moving the conveyor belt.

Isolator Motor: it is used for moving plastic blades; those blades are for isolating the defected bottles from the good ones.

Table 2.4 General Data Description of motors in thermoforming

Electrical Motors	Total power of Motors (kW)
Un-winder Motor	0.75
Index Motor	1.9952
Main Motor	0.68944
Plug Motor	0.8618
Scrap Motor	0.37
Stucker Motor	0.37
Isolator Motor	1.5
Total Power	**6.53644**

2.4.2.2 Heaters Power in the Thermoforming

Piereing Heaters: the machine contains two heaters; these are used for softening the edges of the plastic rolls so as to enable the chains to get into them easily.

Zone Heater: they are nine, each composed of fourteen heaters, those are used for softening the plastic rolls and then to be transferred to the pressing molds.

Table 2.5 General Data Description of heaters in thermoforming

Electrical Heaters	No. of Heaters	Power of single Heaters (kW)	Total power of Heaters (kW)
Piereing Heaters	2	0.45	0.9
Zone Heater	9 * 14	0.45	56.7
Total Power			**57 .6**

2.4.3 Additional Machines

On the other hand, the extruder contains a number of additional parts, those parts can be summed as the following:

2.4.3.1 Cooling Machine

This machine is connected to the extruder, for achieving the process of cooling shell roll cylinders by means of a cyclic water source. This machine composed of three motors having the same specifications and used for water pumping.

Figure 2.6: Cooling Machine

Table 2.6 General Data Description of cooling motors

Electrical Motors	No. of Motors	Power of single Motors (kW)	Total power of Motors (kW)
Cooling Motors	3	1.48	4.44
Total Power			**4.44**

2.4.3.2 Crusher Machine

This one serves the activity of recycling the rubbish plastic occurred by plastic rolls, and hence; this machine works on parallel with the extruder, in addition to that, this machine contains three motors. Those motors are:

Main Motor: for grinding the rubbish plastic mentioned in the point above to be recycled and used again.

Staking Motor: is used for pulling the rubbish plastic which is in the form of two tapes in order to access the grinding room.

Blower Motor: this one is used for the suction operation of grinded rubbish and placing it in a container of special type.

Figure 2.7: Crusher Machine

Table 2.7 General Data Description of crusher motors

Electrical Motors	Total power of Motors (kW)
Main Motor	1.64054
Staking Motor	0.25
Blower Motor	0.75
Total Power	**2.64054**

2.4.3.3 Air Compressor and Chillers

Figure 2.8: Air compressor

2.8 General Data Description of air compressor motors

Electrical Motors	Total power of Motors (kW)
Cooling Motor	2.2
Main Motor	30
Total Power	**32.2**

Figure 2.9: Chillers

2.9 General Data Description of chillers

Items	Power (kW)
Chillers	26.0995
Pump	3.4
Total Power	**29.4995**

2.4.4 Grinding Machines

The factory contains three machines of this type, two are made in a company, and the third is made in a different one, but all serves the same activity.

The two same manufactured machines are to grind the defected bottles, each composed of two motors, one is for grinding and the other is for suction.

Figure 2.10: Grinding Machines

The different one is used for grinding rubbish plastic rolls and contains three motors, one is for grinding, the second is for suction and the thirds is for roll pulling.

2.10 General Data Description of grinding motors

Electrical Motors	Total power for Motors (KW)
Grinding Motors(1)	22.371
Grinding Motors(2)	22.371
Grinding Motors(3)	22.371
Suction Motors(1)	0.7457
Suction Motors(2)	0.7457
Suction Motors(3)	1.4914
Roll pulling Motors	2.2371
Total power	72.3329

2.5 Lighting System

The building has a number of activities running during the day; these activities need a good lighting intensity and lighting distribution that must be suitable for the area of the floors.

Many types of lighting systems are used to achieve the comfort lighting for the human; these types are distributed according to specific usage in each area. Each floor has special board to supply the lights.

Tables 2.11, 2.12, 2.13 illustrate the amount of lights and power in each floor.

2.11 Lights in the first flat

No. of sections	Type of light	No. of Lights	Power (W)	Total Power (W)
Office	**Tungsten tube**	10 * 2	36	720
	Osram dulux	41 * 1	13	533
	Osram dulux	13 * 2	9	234
Plastic Glasses manufacturing	**Tungsten tube**	50 * 2	36	3600
recycle	**Tungsten tube**	3 * 2	36	216
Clips skin	**Tungsten tube**	8 * 2	36	576
Sewing machines	**Tungsten tube**	5 * 2	36	360
Entrance	**Tungsten tube**	12 * 2	36	864
Total Power in the floor				**7103**

1.12 Light in second flat

No. of sections	Type of light	No. of Lights	Power (W)	Total Power (W)
Section #1	**Tungsten tube**	55 * 2	36	3960
Section #2	**Tungsten tube**	20 * 2	36	1440
Section #3	**Tungsten tube**	12 * 2	36	864
Section #4	**Tungsten tube**	16 * 2	36	1125
Section #5	**Tungsten tube**	12 * 2	36	864
Total Power in the floor				**8253**

2.13 Light in third flat

No. of sections	Type of light	No. of Lights	Power (W)	Total Power (W)
Section #1	**Tungsten tube**	10 * 2	36	720
Section #2	**Tungsten tube**	15 * 2	36	1080
Section #3	**Tungsten tube**	14 * 2	36	1008
Total Power in the floor				**2808**

2.6 Electric energy consumption audit

The factory depends basically on electrical energy and not on other forms of energy like solar or gas or whatever else. In this project, bills of electric energy annual consumption had been conducted and studied extensively, the year was 2008, and the results were as in the following table:

Table 2.14: Electric consumption data of 2008

Month	**Power (kWh)**	**Cost (NIS)**
January	78480	45535
February	56000	32498
March	70400	40850
April	74624	43300
May	86291	50067
June	83840	48645
July	93760	54399
August	84720	51697
September	82960	50624
October	69150	42181
November	76640	46767
December	38400	23442
Total	**895315**	**530005**

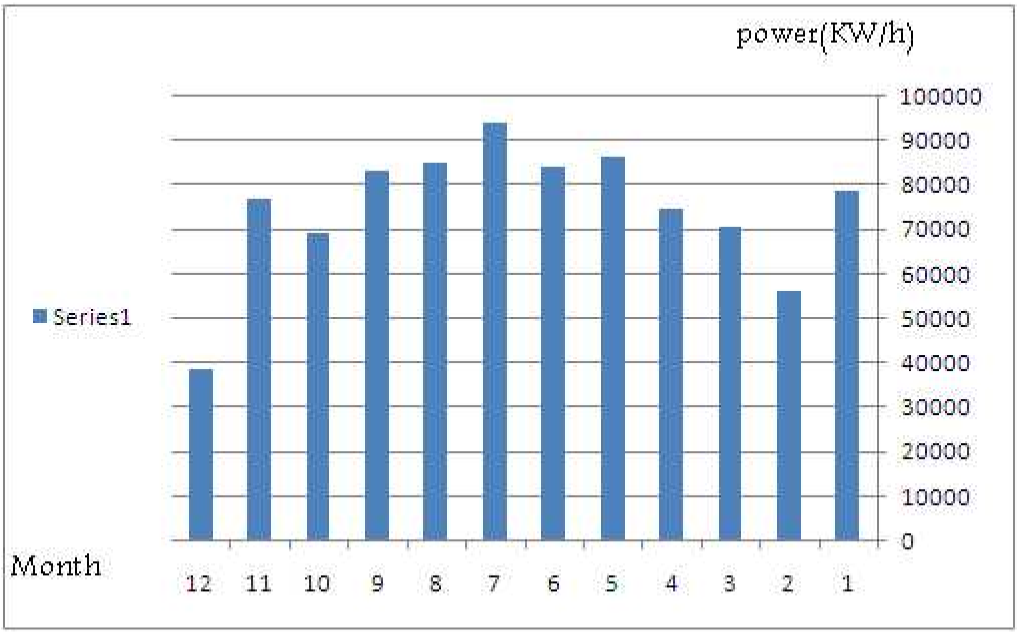

Figure 2.11: Energy consumption rates of 2008

From the previous graph, it can be concluded that highest consumption naturally be with the summer period, because it is usually known that the highest industrial activities are in the summer, and so, as clear from the graph, the highest consumption rate was in July, and the least was in December.

In the first eight months of the intended year, the electric tariff was about 0.58 NIS, but from the ninth month till the end of the year it was about 0.6099 NIS.

3.1 Methodology of Energy Study

3.1.1 Monitoring of Electrical Devices

Monitoring equipment can be useful to measure the actual operating parameters of various energy equipment and compare them with the design parameters to determine if energy efficiency can be improved.

The most common Parameters that are often monitored during an energy assessment are:
Basic electrical parameters in AC & DC systems: voltage (V), current (I), power factor, active power (kW), maximum demand (kVA), reactive power (kVAr), energy consumption (kWh), frequency (Hz), harmonics.
This module provides information for various monitoring equipment that are often used during Energy assessments in industry:

- Electrical measuring instruments
- Thermometers
- Lux meters

For each type of monitoring equipment the following information is given:

- What the monitoring equipment does.
- Where the monitoring equipment is used.
- How to operate the monitoring equipment.
- Precautions and safety measures necessary for the monitoring equipment.

3.1.2 Electrical Measuring Instruments

3.1.2.1 What electrical measuring instruments do

Electrical measuring instruments include clamp-on or power analyzers and are used to measure main electrical parameters such as KVA, kW, PF, Hertz, KVAr, Amps and Volts. Some of these instruments also measure harmonics. Instant measurements can be taken with hand- held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals. There are several models available in the market from different companies. One such instrument is the MAGNELAB- Clamp-on Power Hitester.

Electrical specifications

- Output 0.333V at rated current.
- Accuracy ±0.01.
- Phase angle <2degrees (valid for 150A or higher).
- Rated accuracy at 10% to 130% of rated current.

3.1.2.2 Where Electrical Measuring Instruments are used

These instruments are applied on-line to measure various electrical parameters of motors, transformers, and electrical heaters. There are no needs to stop the equipment while taking the measurements.

3.1.2.3 How to Operate Electrical Measuring Instruments

The instrument has three leads (wires), which are connected to the crocodile clips at the end. The three leads are yellow, black and red. Figures (3.1, 2) give illustrate the measurement method for various conditions. However, operating procedures may vary for different types of clamp-on or power analyzers. For the correct operation procedure the operator should always check the instruction manual supplied with the instrument.

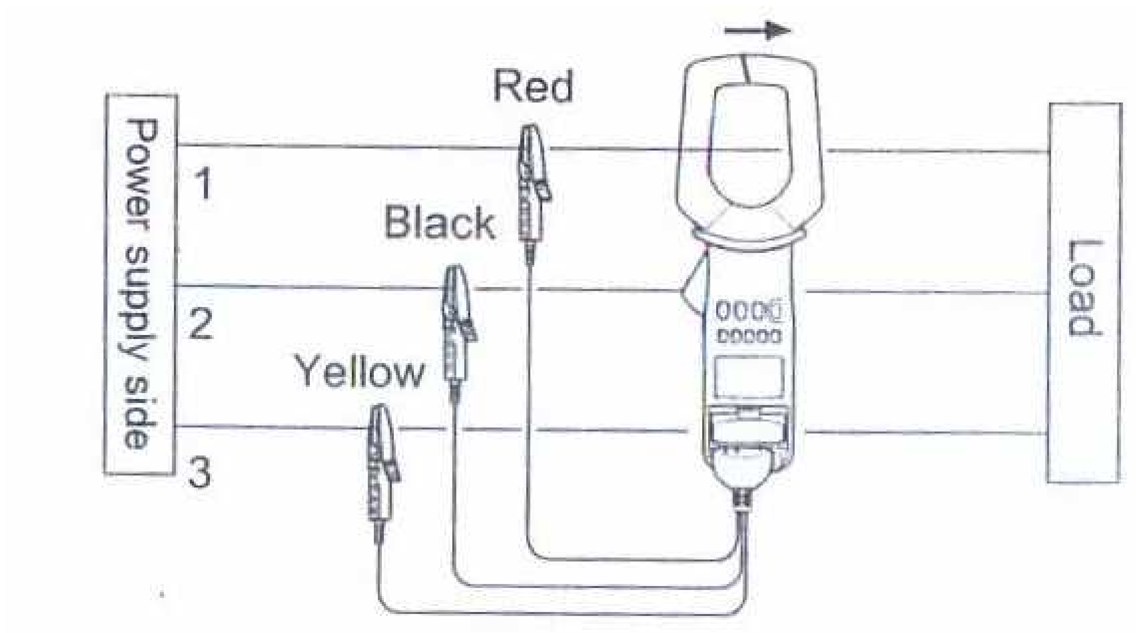

Figure 3.1: switching on clamp-meter for 3 phase

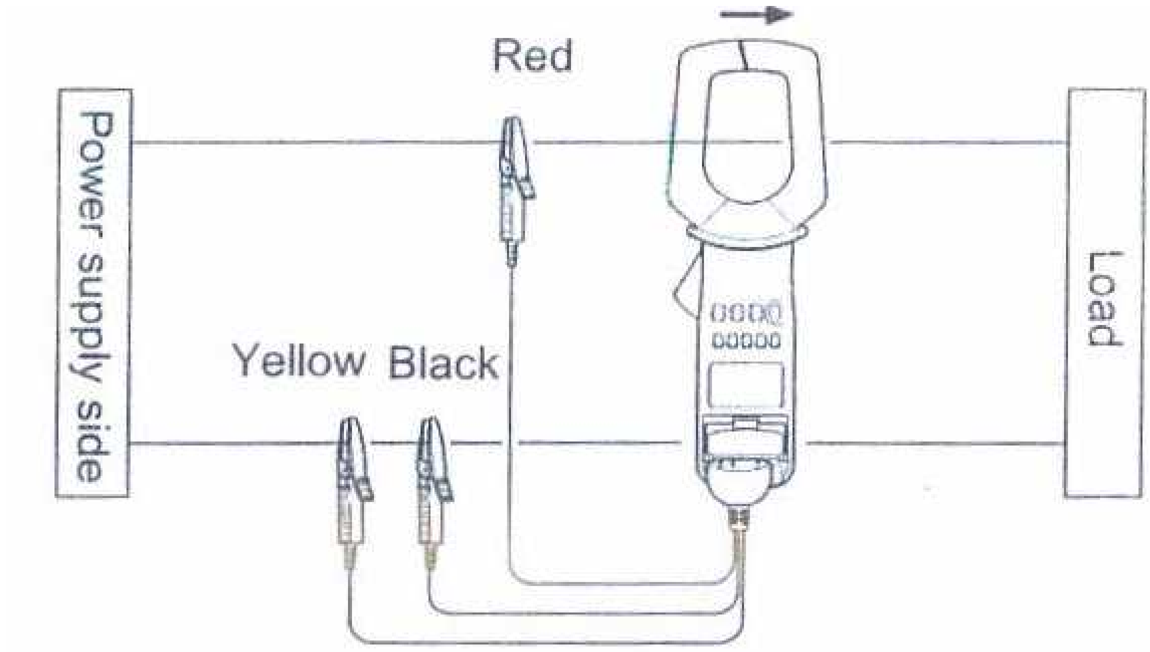

Figure 3.2: switching on clamp-meter for single phase

3.1.2.4 Precautions and Safety Measures

Some precautions and safety measures to be taken while using clamp-on and power analyzers are:

- To avoid short circuits and potentially life-threatening hazards, never attach the clamp to a circuit that operates at more than the maximum rated voltage, or over bare conductors.
- The clamp-on probe should be connected to the secondary side of a breaker, so the breaker can prevent an accident if a short circuit occurs.
- While using the instrument, use rubber hand gloves, boots, and a safety helmet, to avoid electrical shocks, and do not use the instrument when hands are wet.
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

3.1.3 Thermometer

3.1.3.1 What a Thermometer does

Thermometers are instruments used to measure the temperature of fluids, surfaces or gases, for example of the flue gases after combustion has taken place. Thermometers are classified as Contact thermometers or non-contact or infrared thermometers and are described below.

3.1.3.1.1 Contact Thermometer

There are many types of contact thermometers. A simple clinical thermometer is the best known example of a contact thermometer. However, for the purpose of energy audits in an industrial plant we generally use thermocouples for measuring temperatures with a high accuracy. It consists of two dissimilar metals, joined together at one end. The thermocouple metal alloys are commonly available as wire. A thermocouple is available in different combinations of metals or calibrations. The four most common calibrations are J, K, T and E. There are high temperature calibrations R, S, C and GB. Each calibration has a different temperature range and environment, although the maximum temperature varies with the diameter of the wire used in the thermocouple. Although the thermocouple calibration dictates the temperature range, the maximum range is also limited by the diameter of the thermocouple wire.

3.1.3.1.2 Non-contact or infrared thermometer

A non-contact or infrared thermometer allows the measurement of temperatures without physical contact between the thermometer and the object of which the temperature is determined. The thermometer is directed at the surface and immediately gives a temperature reading. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc. Infrared thermometer allows users to measure temperature in applications where conventional sensors cannot be used or cannot produce accurate temperature readings.

3.1.3.2 Where the Thermometer is used

In energy audits, the temperature is one of the most important parameters to be measured in order to determine the thermal energy loss or to make a thermal energy balance. Temperature Measurements are taken for the audit of air conditioning units, boilers, furnaces, steam systems, Waste heat recovery systems, heat exchangers, etc. During the audits, the temperature can by:-

- Ambient air
- Chilled water in refrigeration plants
- Inlet air into the Air Handling unit of AC plant
- Cooling water inlet and out let at the Cooling Tower
- Surfaces of steam pipelines, boilers, kilns
- Input water to the boiler
- Exhaust gases
- Condensate returned
- Pre heated air supply for combustion
- Temperature of the fuel oil

3.1.3.3 How to Operate a Thermometer

The thermocouple (contact thermometer) consists of two dissimilar metals, joined together at one end. When the junction of the two metals is heated or cooled a voltage is produced that can be correlated back to the temperature. A probe is inserted into a liquid or gaseous stream to measure the temperature of, for example, flue gas, hot air, or water. A leaf type probe is used to measure surface temperatures. In most of the cases the thermocouple directly gives the reading in the desired units (Centigrade or Fahrenheit) on a digital panel. The operation of a non-contact or infrared thermometer is simple. The infrared thermometer (gun) is pointed towards the surface where the temperature must be measured. The measurement result is read directly from the panel.

3.1.3.4 Precautions and safety measures

The following precautions and safety measures apply when using a thermometer:

- The probe must be immersed in the fluid and the measurement must be taken after 1-2 minutes, i.e. after the stabilization of the readings.
- Before using the thermocouple, the temperature range for which the thermocouple is designed for should be checked.
- The probe of the thermocouple should never touch the bare flame.
- Before using a non-contact thermometer the emissivity should be set in accordance with the surface where the temperature is to be measured.
- Check the operating manual of the monitoring equipment for more detailed instructions on safety and precautions before using the equipment.

3.1.4 Luxmeter

3.1.4.1 What lux Meters do

Lux meters are used to measure illumination (light) levels. Most lux meters consist of a body, a sensor with a photo cell, and a display panel as shown in figure (3.3). The sensor is placed under the light source. The light that falls on the photo cell has energy, which is transferred by the photo cell into electric current. The more light is absorbed by the cell, the higher the generated current. The meter reads the electrical current and calculates the appropriate value of either Lux or Foot candles. This value is shown on the display panel.

A key thing to remember about light is that it is usually made up of many different types (colors) of light at different wavelengths. The reading, therefore, is a result of the combined effects of all the wavelengths. A standard color can be referred to as color temperature and is expressed in degrees Kelvin. The standard color temperature for calibration of most light meters is 2856 degrees Kelvin, which is more yellow than pure white. Different types of light bulbs burn at different color temperatures. Lux meter readings will, therefore, vary with different light sources of the same intensity. This is why some lights seem "harsher" or “softer” than others.

Figure 3.3: Lux meter

3.1.4.2 Where lux Meters are used

Lux meters are used to measure illumination levels in offices, factories etc.

3.1.4.3 How to Operate a lux Meters

This instrument is very simple to operate. The sensor is to be placed at the work station or at the place where intensity of the light is to be measured, and the instrument will directly give the reading on the display panel.

3.1.4.4 Precautions and Safety Measures

The following measures should be taken when working with lux meters:

- The sensor is to be properly placed on the work station to obtain an accurate reading
- Due to the high sensitivity of sensor it should be stored safely

Check the operating manual of the monitoring equipment for more detailed instructions on Safety and precautions before using the equipments.

3.1.5 Noise Meter

The Noise Meter or "sound level meter" is designed to accurately measure the noise that you can hear, putting a real value to something that is so affected by perception.

Figure 3.4: Noise Meter

As this noise meter has auto-ranging, it can measure from 30 to 130 dB, without the need to select the correct range beforehand. The meter also features Fast and Slow time response as well as Maximum, Minimum and Display Hold. This is useful for monitoring machinery or vehicle noise limits.

The Noise Meter has been one of our most popular noise measurement products, satisfying customers in the following areas:

- Police Departments (vehicle noise, community noise)
- Factories and industrial complexes
- Housing associations
- Fire alarms and other alarm systems
- Sound system installation

3.1.6 Ultrasonic flow meter

An ultrasonic flow meter measures the velocity of a liquid or gas through a pipe using ultrasonic transducers. The results are slightly affected by temperature, density or viscosity of the flowing medium. Maintenance is inexpensive because there are no moving parts. Some may be able to measure liquid level as well. With the level measurement and pipe size, flow rate and total discharge can be calculated.

Figure 3.5: Ultrasonic Flow Meter

Ultrasonic flow meters work with at least three different types:

- Transmission (contra propagating transit-time) flow meters
- Reflection (Doppler) flow meters
- Open-channel flow meters

Transmission flow meters can be distinguished into:

- In-line flow meters (intrusive, wetted)
- Clamp-on flow meters (non-intrusive)

3.1.6.1 Transit-Time Flow meters (general)

The most commonly used ultrasonic flow meter is the transit-time flow meter which is used for liquids and gases.

Transit-time flow meters work by measuring the time of flight difference between an ultrasonic pulse sent in the flow direction and an ultrasound pulse sent opposite the flow direction. This time difference is a measure for the average velocity of the fluid along the path of the ultrasound beam. By using the absolute transit time and the distance between the ultrasound transducers, the current speed of sound is easily found. The measuring effect can be adversely affected by many things including gas and solid content.

By using at least 3 transducers, an "ultrasonic anemometer" measures wind speed and direction in open air, with no moving parts.

3.1.6.2 Transit-Time Clamp-On Flow meters (non-intrusive)

For clamp-on flow meter, the ultrasonic transducers are mounted (clamped) on the outside of the pipe wall. For accurate flow computation, the transducer distance, the pipe dimensions and the pipe material has to be known. The sound speed of the flowing medium is needed for initial transducer positioning but is updated during the flow measurement.

3.1.7 Anemometer

An anemometer is a device that is used for measuring wind speed, and is one instrument used in a weather station. The term is derived from the Greek word anemos, meaning wind. The first known description of an anemometer was given by Leon Battista Alberti in around 1450.

Anemometers can be divided into two classes: those that measure the wind's velocity, and those that measure the wind's pressure; but as there is a close connection between the pressure and the velocity, an anemometer designed for one will give information about both.

Figure 3.6: Anemometer

4.1 lighting system

4.1.1 Background

From the dawn of civilization until recent times, human beings created light solely from fire, though it is more a source of heat than light. We are still using the same principle in the 21st century to produce light and heat through incandescent lamps. Only in the past few decades have lighting products become much more sophisticated and varied. Estimates indicate that energy consumption by lighting is about 20 - 45% of a commercial building's total energy consumption and about 3 - 10% in an industrial plant's total energy consumption. Most industrial and commercial energy users are aware of energy savings in lighting systems. Often significant energy savings can be realized with a minimal investment of capital and common sense. Replacing mercury vapor or incandescent sources with metal halide or high pressure sodium will generally result in reduced energy costs and increased visibility. Installing and maintaining photo-controls, time clocks, and energy management systems can also achieve extraordinary savings. However, in some cases it may be necessary to consider modifications of the lighting design in order to achieve the desired energy savings. It is important to understand that efficient lamps alone would not ensure efficient lighting systems.

4.1.2Basic Theory of Light

Light is just one portion of the various electromagnetic waves flying through space. These waves have both a frequency and a length, the values of which distinguish light from other forms of energy on the electromagnetic spectrum.

4.1.3 The Importance of Lighting

Lighting consumes a tremendous amount of energy and financial resources. Lighting accounts for approximately 17 percent of all electricity sold in the United States. Energy star estimates that if efficient lighting were used in all locations where it has been shown to be profitable throughout the country, the nation's demand for electricity would be cut by more than 10 percent. This could save nearly $17 billion in ratepayer bills and result in the following annual pollution reductions:

• 202 million metric tons of carbon dioxide, the primary cause of global climate change. This would be the equivalent of taking 15 million cars off the road.

• More than 1.3 million metric tons of sulfur dioxide, which contributes to acid rain.

• 600,000 metric tons of nitrogen oxides, which contribute to smog.

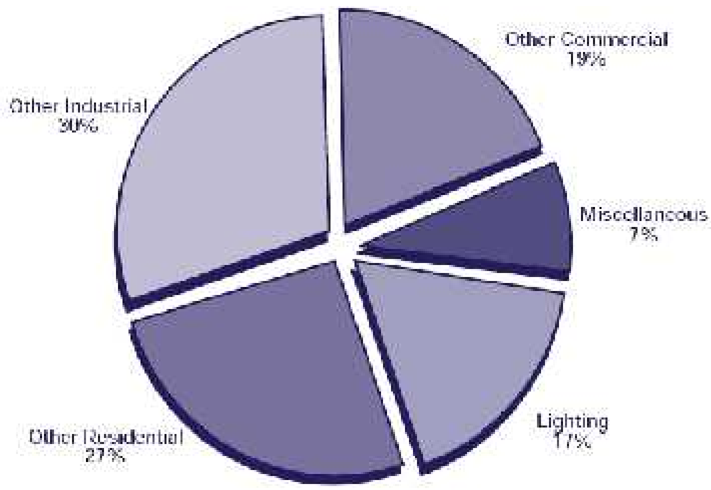

Figure 4-1: Lighting Share of All Electric Energy Use

Lighting is also a significant expense in operating buildings. Lighting is the largest cost component of a commercial building's electricity bill (see Figure (4-1)) and a significant portion of its total energy bill.

4.1.4 Lighting and the Building

4.1.4.1 Reduce Heat Gain

In addition to visible light, all lighting systems produce heat. Lighting is typically the largest source of waste heat, often called "heat gain," inside commercial buildings.

Improving lighting efficiency reduces heat gain, which affects your buildings in two ways. Waste heat is a useful supplement when the building requires heat, it must be removed by the HVAC system when the building needs to be cooled. The impact of this tradeoff the penalty for increased heating costs versus the bonus for reduced cooling costs—depends on your building type, its geographic location, and its HVAC system. Although heating costs may rise, they will rarely exceed the resultant cooling savings, even in buildings in northern climates that use electric resistance heat.

By reducing internal heat gain, efficient lighting also reduces your building's cooling requirements. Consequently, your existing cooling system may be able to serve future added loads, or may be appropriate for "rightsizing". Given the large impact lighting upgrades can have on your HVAC system requirements and the high cost of cooling equipment, you should always quantify HVAC and lighting interactions. There are simplified methods available for calculating the impacts of lighting upgrades on heating and cooling systems.

Lighting also affects the power quality of your building's electrical distribution system. Poor power quality is a concern because it wastes energy, reduces electrical capacity, and can harm equipment and the electrical distribution system itself. Upgrading to lighting equipment with clean power quality (high power factor and low harmonic distortion) can improve the power quality in your building's electrical system. Furthermore, upgrading with higher efficiency and higher power factor lighting equipment can also free up valuable electrical capacity. This benefit alone may justify the cost of a lighting upgrade.

The relationship of lighting to task performance and visibility is well understood. Improved lighting enhances visual comfort, reduces eye fatigue, and improves performance on visual tasks. Well-designed lighting is likely to improve performance, increase productivity, and reduce absenteeism. Because costs associated with your employees greatly outweigh the other building costs, any lighting changes that improve your occupants' workspaces are worth investigating.

Lighting also contributes to the safety of occupants and the security of buildings. Emergency lighting must be available during power outages, and minimum levels of light must be available at night when most lighting is turned off. In addition, safety codes require exit signs to highlight escape routes during fires or other emergencies. Outside lighting and indoor night lighting deters crime by exposing intruders' movements and permitting occupants to move safely through the building or to cars. Although such effects are difficult to quantify, comfort, mood, productivity, health, safety, and other impacts on people should be considered as part of every lighting upgrade.

Light is emitted from the body due to any of the following phenomena:

1- **Incandescence** Solids and liquids emit visible radiation when they are heated to temperatures about 1000K. The intensity increases and the appearance become whiter as the temperature increases.

2- **Electric Discharge**: When an electric current is passed through a gas the atoms and molecules emit radiation whose spectrum is characteristic of the elements present.

3- **Electro luminescence**: Light is generated when electric current is passed through certain solids such as semiconductor or phosphor materials.

4- **Photoluminescence:** Radiation at one wavelength is absorbed, usually by a solid, and re-emitted at a different wavelength. When the re-emitted radiation is visible the phenomenon may be termed either *fluorescence* or *phosphorescence*.

4.1.5 Definitions and Commonly Used Terms

Luminaire: A luminaire is a complete lighting unit, consisting of a lamp or lamps together with the parts designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply.

Lumen: Unit of luminous flux; the flux emitted within a unit solid angle by a point source with a uniform luminous intensity of one candela. One lux is one lumen per square meter.

The lumen (lm) is the photometric equivalent of the watt, weighted to match the eye response of the “standard observer”. 1 watt = 683 lumens at 555 nm wavelength.

Lux: This is the metric unit of measure for illuminance of a surface. Average maintained illuminance is the average of lux levels measured at various points in a defined area. One lux is equal to one lumen per square meter. The difference between the lux and the lumen is that the lux takes into account the area over which the luminous flux is spread. 1000 lumens, concentrated into an area of one square meter, lights up that square meter with an illuminance of 1000 lux. The same 1000 lumens, spread out over ten square meters, produce a dimmer illuminance of only 100 lux.

Rated luminous efficacy: The ratio of rated lumen output of the lamp and the rated power consumption expressed in lumens per watt.

Room Index: This is a ratio, which relates the plan dimensions of the whole room to the height between the working plane and the plane of the fittings.

Utilization factor (UF): This is the proportion of the luminous flux emitted by the lamps, reaching the working plane. It is a measure of the effectiveness of the lighting scheme.

4.2 Methodology of Lighting System Energy Efficiency Study

A step by step approach to assessment of improvement options in lighting at any facility would involve the following likely steps.

Step 1: Inventory the lighting system elements & transformers in the facility as per following typical format.

Step 2: With the aid of a lux meter, measure and document the lux levels at various plant locations at working level, as daytime lux and night time lux values alongside the number of lamps “ON” during measurement.

Step 3: With the aid of portable load analyzer, measure and document the voltage and power consumption at various input points, namely the distribution boards or the lighting voltage transformers at the same as that of the lighting level audit.

Step 4: Compare the measured lux values with the standard. Use the values as a reference and identify locations of under lit and over lit areas.

Step 5: Analyze the failure rates of lamps, ballasts and the actual life expectancy levels from the past data.

4.3 Designing of Lighting System

4.3.1 How much light is needed

Every task requires some lighting level on the surface of the body. Good lighting is essential to perform visual tasks. Better lighting permits people to work with more productivity. Typical book reading can be done with 100 to 200 lux.

These recommended values have since made their way into national and international standards for lighting design see Table (4.1).

Table 4.1 Illuminance Levels for different Areas of Activity

Building/Space Type	Guideline Illuminance Range (footcandles)
Commercial interiors	
Art galleries	30-100
Banks	50-150
Hotels (rooms and lobbies)	10-50
Offices	30-100
-Average reading and writing	50-75
-Hallways	10-20
-Rooms with computers	20-50
Restaurants (dining areas)	20-50
Stores (general)	20-50
Merchandise	100-200
Institutional interiors	
Auditoriums/assembly places	15-30
Hospitals (general areas)	10-15
Labs/treatment areas	50-100
Libraries	30-100
Schools	30-150
Industrial interiors	
Ordinary tasks	50
Stockroom storage	30
Loading and unloading	20
Difficult tasks	100
Highly difficult tasks	200
Very difficult tasks	300-500
Most difficult tasks	500-1000
Exterior	
Building security	1-5
Floodlighting (low/high brightness or surroundings)	5-30
Parking	1-5

4.3.2 Lighting design for interiors

The step by step process of lighting design is illustrated below with the help of an example. Figure (4.2) shows the parameters of a typical space.

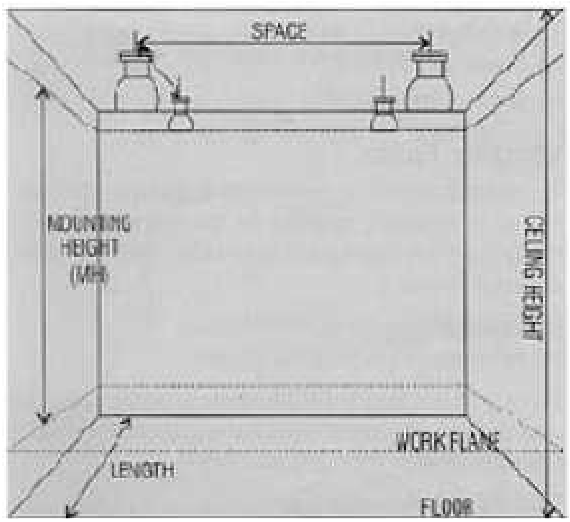

Figure 4.2: Room with dimensions

Step 1: Decide the required Illuminance on work plane, the type of lamp and luminaries.

A preliminary assessment must be made of the type of lighting required, a decision most often made as a function of both aesthetics and economics. For normal office work, illuminance of 200 lux is desired.

For an air-conditioned office space under consideration, we choose 36 W fluorescent tube lights with twin tube fittings. The luminaries are porcelain-enameled, suitable for the above lamp. It is necessary to procure utilization factor tables for these luminaries from the manufacturer for further calculations.

Step 2: Collect the room data in the format given in table (4.2).

Table 4.2: Data for Plastic Glasses Manufacturing Section

Region	Length (m)	Width (m)	High (m)	Area (m^2)	Room Index
Plastic glasses manufacturing	27.6	13.9	4.4	383.64	2.1009

Step 3: Calculate room index.

$$\text{Room Index} = \frac{\text{Length} \times \text{Width}}{\text{Hight} \times (\text{Length} + \text{Width})} \qquad (4\text{-}1)$$

Step 4: Calculating the Utilization factor.

Utilization factor is defined as the percent of rated bare-lamp lumens that exit the luminaries and reach the work plane. It accounts for light directly from the luminaries as well as light reflected off the room surfaces. Manufacturers will supply each luminaries with its own CU table derived from a photometric test report. Using tables available from manufacturers, it is possible to determine the utilization factor for different light fittings if the reflectance of both the walls and ceiling is known, the room index has been determined and the type of luminaries is known.

Step 5: Calculate the number of fittings required by applying the following formula.

$$N = \frac{E \times A}{F \times UF \times LLF} \qquad (4\text{-}2)$$

Where:

N = Number of fittings

E = Lux level required on working plane

A = Area of room (L x W)

F = Total flux (Lumens) from all the lamps in one fitting

UF = Utilization factor from the table for the fitting to be used

LLF = Light loss factor. This takes account of the depreciation over time of lamp output and dirt accumulation on the fitting and walls of the building.

4.4 Sample of calculations

In Plastic Glasses Manufacturing Section, by referring to equation 4.1, we get the following result:

Room index= $\frac{27.6*13.9}{4.4(27.6+13.9)}$ =2.1009

From table (A-1) in appendix (A), with general reflectance's for walls, ceiling and surface of the floor then:

UF (Utilization Factor) = 0.75 ………….. (Using interpolation from table A-3)

LLF = 0.6 from table (A-2) in appendix (A).

Flux = 2300(Lumen)

1 footcandle = 10.76391 lux

After that, number of fittings can be calculated via equation 4.2, and the result is:

N= $\frac{10*10.763*383.64}{2300*0.75*0.6}$ =39.89

Table 4.3: Difference between the actual and measured values.

Calculated Number of Fittings	Actual Number of Fittings	Recommended flux (fc)	Measured flux (fc)
39.89	40	10	10.35

The difference between the actual and recommended number of fittings forms the amount of energy that can be achieved in the space, the previous note confirmed by instrumentation using lux meter as illustrated in table (4.3).

To compute the energy loss:

The number of excess Lightings= Actual Number of Fittings - Calculated Number of Fittings

The number of excess Lightings= 40-39.89 = 0.11

Energy loss per hour = total amount of lighting Power × Time light turns off per day

Energy loss per hour = 0.11*36 *18 hour= 0.07128 kWh

$$Energy\ loss\ per\ year = P_{loss}\ kW * \frac{No.hours}{Day} * \frac{day}{month} * \frac{month}{year} \quad (0.3)$$

Energy loss per year = 0.07128 * 26 * 12 = 22.23 (kW/year)

$$The\ Cost \text{ of energy loss} = \frac{22.23 * 0.58}{4} \ (\$/year)$$

$$The\ Cost \text{ of energy loss} = 3.22 \ (\$/year)$$

4.5 Maximizing Efficiency and Quality

A comprehensive lighting upgrade achieves your qualitative lighting objectives while maximizing efficiency and profitability. With rewards beyond the sum of its parts, this process integrates equipment replacement with deliberate design, operation, maintenance and disposal practices. This whole-system approach takes what is frequently regarded as a complex system of individual decisions and unites them into a strategic approach that ensures that each opportunity is addressed and balanced with other objectives (see Figure (4.3)).

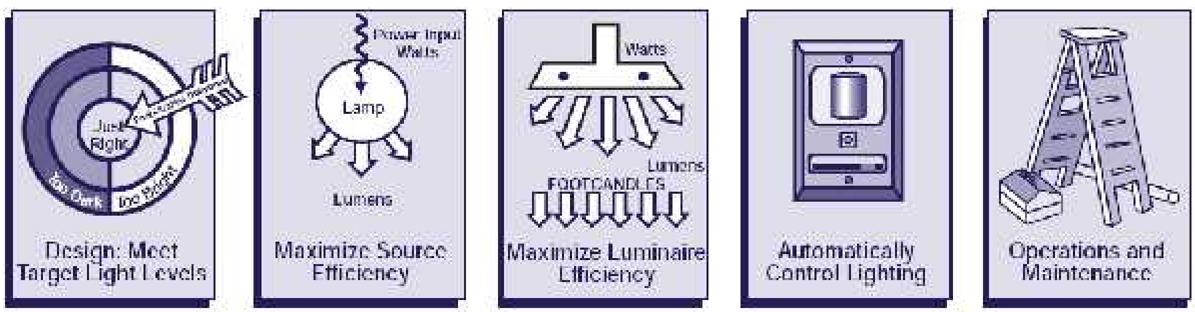

Figure 4.3: Different opportunity

4.5.1 Automatically Control Lighting

Reducing the connected load (wattage) of the lighting system represents only half of the potential for maximizing energy savings. The other half is minimizing the use of that load through automatic controls. Automatic controls switch or dim lighting based on time, occupancy, lighting-level strategies, or a combination of all three. In situations where lighting may be on longer than needed, left on in unoccupied areas, or used when sufficient daylight exists, you should consider installing automatic controls as a supplement or replacement for manual controls.

4.5.2 Time-Based Controls

The most basic controlling strategies involve time-based controls, best suited for spaces where lighting needs are predictable and predetermined. Time-based controls can be used in both indoor and outdoor situations. Common outdoor applications include automatically switching parking lot or security lighting based on the sunset and sunrise times. Typical indoor situations include switching lighting in production, manufacturing, and retail facilities that operate on fixed, predefined operating schedules. Time-based control systems for indoor lighting typically include a manual override option for situations when lighting is needed beyond the scheduled period. Simple equipment, such as mechanical and electronic time clocks and electromechanical and electronic photocells, can be independent or part of a larger centralized energy-management system.

4.5.3 Occupancy-Based Controls

Occupancy-based strategies are best suited to spaces that have highly variable and unpredictable occupancy patterns. Occupancy or motion sensors are used to detect occupant motion, lighting the space only when it is occupied. For both initial and sustained success in using occupancy sensors, the sensor must be able to see the range of motion in the entire space while avoiding either on or off false triggering. This requires proper product selection, positioning, and testing. Occupancy sensors should first be selected based on the range of body motion expected to occur throughout the entire lighted space. Controls for hallways, for example, need only be sensitive to a person walking down a narrow area, while sensors for offices need to detect smaller upper body motion, such as typing or reaching for a telephone. Once sensitivity and coverage area is established, sensors are selected from two predominant technology types. Passive infrared sensors detect the motion of heat between vertical and horizontal fan pattern detection zones. This technology requires a direct line of sight and is more sensitive to lateral motion, but it requires larger motion as distance from the sensor increases. The coverage pattern and field of view can also be precisely controlled. It typically finds its best application in smaller spaces with a direct line of sight, warehouses, and aisles as shown in Figure (4.4).

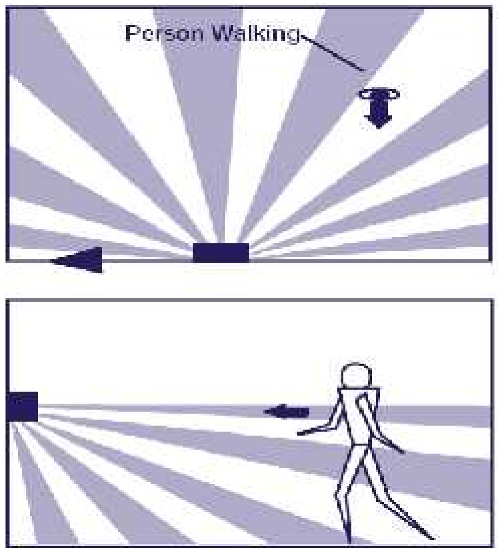

Figure 4.4: Infrared Sensor Coverage Patterns

Ultrasonic sensors detect movement by sensing disturbances in high-frequency ultrasonic patterns. Because this technology emits ultrasonic waves that are reflected around the room surfaces, it does not require a direct line of sight, is more sensitive to motion toward and away from the sensor, and its sensitivity decreases relative to its distance from the sensor (see Figure (4.5)). It also does not have a definable coverage pattern or field of view. These characteristics make it suitable for use in larger enclosed areas that may have cabinets, shelving, partitions, or other obstructions. If necessary, these technologies can also be combined into one product to improve detection and reduce the likelihood of false on or off triggering. To achieve cost-effective, user-friendly occupancy sensor installations, both types of technologies need to be carefully commissioned at installation to make sure that their position, time delay, and sensitivity are properly adjusted for the space and tasks. To ensure proper performance, the position of both wall- and ceiling-mounted sensors needs to be evaluated carefully. Ultrasonic sensors, for example will respond to strong air movement and need to be located away from ventilation diffusers. Infrared sensors should have their line of sight checked to ensure that it is not blocked by room furnishings. Both types of technologies should be positioned and adjusted so that their coverage area is not allowed to stray outside of the intended control area. All sensors have an adjustable time delay to prevent the lights from switching off when the space is occupied but there is little activity. Some infrared and all ultrasonic sensors also have an adjustable sensitivity setting. Customizing these settings to the application is necessary to balance energy savings with occupant satisfaction.

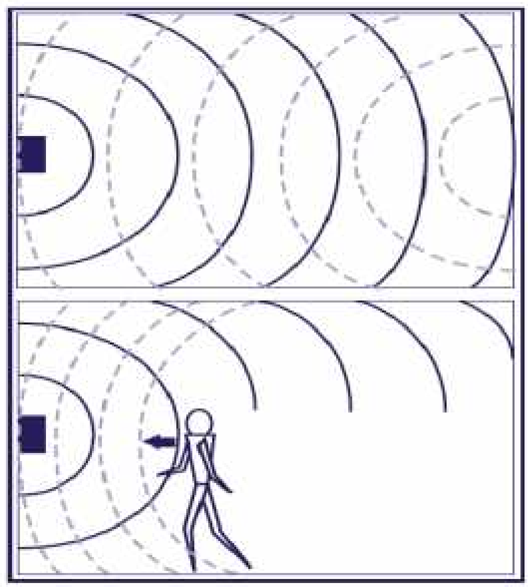

Figure 4.5: Ultrasonic Sensor Coverage Patterns

Although increasing time delays will reduce the possibility of the lighting being switched off while the space is occupied, it will also reduce the energy savings. Setting the sensitivity too high may turn the lighting on when the room is unoccupied, wasting energy. Similarly, setting the sensitivity too low will create occupant complaints, as the lighting may turn off when the room is occupied. Evaluating the potential savings from an occupancy sensor installation should, and can, go beyond guesswork or speculation. Although sensors primarily affect energy use, they also affect energy demand, load on HVAC system, and lamp life. Evaluating the economic feasibility of an installation is best done by monitoring lighting and occupancy patterns. The use of inexpensive loggers will indicate the total amount of time the lights are on when the space is vacant, the time of day the savings take place, and the frequency of lamp cycling.

4.5.4 Lighting Level-Based Controls

Lighting level-based strategies take advantage of any available daylight and supply only the necessary amount of electric light to provide target lighting levels. In addition to saving energy, lighting level controls can minimize over lighting and glare and help reduce electricity demand charges. The two main strategies for controlling perimeter fixtures in day-lighted areas are daylight switching or daylight dimming.

Daylight switching involves switching fixtures off when the target lighting levels can be achieved by utilizing daylight. To avoid frequent cycling of the lamps and to minimize distraction to occupants, a time delay, provided by a dead band, is necessary. Several levels of switching are commonly used to provide for flexibility and a smooth transition between natural and electric lighting.

Daylight dimming involves continuously varying the electric lighting level to maintain a constant target level of illumination. Dimming systems save energy by dimming fluorescent lights down to as low as 10 to 20 percent of full output, with the added benefit of maintaining consistent lighting levels. Because HID sources cannot be frequently switched on and off, they are instead dimmed for time, occupancy, and lighting level-based control strategies.

4.5.5 Calculating the amount of energy saving

When an occupancy sensor based on ultrasonic or infrared principle is used, the power consumed with non occupied space is saved since the lamp is turned off in this time interval, so the lighting use will be more controllable than the previous state i.e. without using this sensor.

Let Plastic Glasses Manufacturing Section as an example for using occupancy sensor then the amount of energy saved can be calculated sing equation (4-3):

Energy saving per hour = total amount of lighting Power × Time light turns off per day

Energy saving per hour = 1*36*40*1 hour = 1.440 kWh

Since the hours of operation are 7 hours in the day, we can calculate the energy consumed per year. And the energy saved by the occupancy sensor can be calculate as the difference between 6 and 7 hours of operation since we have at least one hour of losing energy in the missing turning on of lights in a space.

Then, the total energy saving per year can be calculated using equation (4.3):

Total energy saving = 449.28 kWh/year

This cost of energy saving is due to the glasses factory region as a sample for the whole study.

$$\text{Energy saving costs} = \frac{449.28*0.58}{4} = 65.1456\ \$/year$$

Now, the savings attained by using the occupancy sensors are to be calculated, and hence; those occupancy sensors are proposed to be fastened in regions where there is a big number of lighting devices, because it’s not sense to use this system in locations which have a slight number of lighting devices.

For the first flat, the energy savings attained are to be calculated in each; plastic and clips skin, the calculations with results are as follows:

Energy saving per hour = 1*36*51*1 hour = 1.836 kWh

Using equation 4.3:

Annual energy savings = 572.83 kWh/year

$$\text{Energy saving costs} = \frac{572.83*0.58}{4} = 83.06\ \$/year$$

For the second flat, the energy savings attained are to be calculated in the first section of the five sections that composes the second floor, because the number of lighting devices in the other sections are slight and there is no need to used occupancy sensors as mentioned before. The savings is:

Energy saving per hour = 1*36*39*1 hour = 1.404 kWh

Using equation 4.3 we get that:

Annual energy saving = 438.04 kWh/year

$$\text{Energy saving costs} = \frac{449.28*0.58}{4} = 63.51\ \$/year$$

For the third flat which is composed of three sections, energy savings are to be calculated in all sections due to the presence of a large number of lighting devices, and hence; the result calculated here is the total summation of the three sections together.

Energy saving per hour = 1*36*50*1 hour = 1.8 kWh

Using equation 4.3, we get:

Annual energy savings = 561.6 kWh/year

$$\text{Energy saving costs} = \frac{449.28*0.58}{4} = 81.432\ \$/year$$

It would make sense, if the total savings for whole the factory is calculated by summing all lighting devices of whole together.

Total energy saving costs (for the whole plant) = 83.06 + 63.51 + 81.432 = 228.1$/year

To calculate the Cost-recovery time, it should be included here the number of occupancy sensors to be used, and t he number is six sensors (two in the first flat, 1 in the second flat and 3 in the third flat), taking into account, that the cost of the sensors is about $ 50 for each.

$$\text{Cost-recovery time} = \frac{50*6\,\$}{228.1\,\$} = 1.3 \text{ year} = 16 \text{ months}$$

4.6 Noise

4.6.1 Introduction

It's a physical aspect as a source of quick frequency or movement of somebody, and that frequency results in movement or fluctuation of air particles in the around atmosphere, also results in air particles diffusion in the form of sound wave. In this sound wave there are regions of either high or low densities, in t he high one there is precipitated a high pressure and vice versa.

If the level of noise was very high it in fact results in harmful problems to the hearing sense of human beings.

Level of noise can be measured using what is known by Noise Meter, which measures in the units of Decibel (dB).

Each body has a certain level of sound noise in dB's, and it has been founded that its for factories and industrial plants in the range of 100 dB.

In the case that sound noise was about 85 dB in hand with that this noise lasted for a long time, it is in fact results in harmful effects to hearing sense as mentioned before.

4.6.2 Noise in the plant

Noise level in the industrial plant was measured by means of what is called: Noise Meter, and the results found were as illustrated in the table below.

Table 4.4: Noise level in plastic glasses manufacturing systems

place	Noise (dB)	Note
Entrance	89	Affects on the long term
Clips skin	78	So slight influence
Grinding	106	Very high value and needs safety requirements
extruder	92	Large influence on the long term
thermoforming	86	Affects on the long term

In the region where the grinding machines are exist, the level of noise is very high, so that; when occurring people are near to these machines, it is recommended that they use occupational safety devices such as headphones to protect ears and the sense of hearing, in hand with insulating the area, and there is no need to save long times in that work region. Same story is in the region of the extruders.

5.1 Electric motors

5.1.1 Introduction

An electric motor is a device using electrical energy to produce mechanical energy, nearly always by the interaction of magnetic fields and current-carrying conductors. The reverse process that of using mechanical energy to produce electrical energy is accomplished by a generator or dynamo. Traction motors used on vehicles often perform both tasks.

Electric motors are found in myriad uses such as industrial fans, blowers and pumps, machine tools, household appliances, power tools, and computer disk drives, among many other applications. Electric motors may be operated by direct current from a battery in a portable device or motor vehicle, or from alternating current from a central electrical distribution grid. The smallest motors may be found in electric wristwatches. Medium-size motors of highly standardized dimensions and characteristics provide convenient mechanical power for industrial uses. The very largest electric motors are used for propulsion of large ships, and for such purposes as pipeline compressors, with ratings in the thousands of kilowatts. Electric motors may be classified by the source of electric power, by their internal construction, and by application.

The physical principle of production of mechanical force by the interaction of an electric current and a magnetic field was known as early as 1821. Electric motors of increasing efficiency were constructed throughout the 19th century, but commercial exploitation of electric motors on a large scale required efficient electrical generators and electrical distribution networks.

There are three types of motor loads; those are illustrated in the following table:

Table 5.1: Motor load's types

Motor loads	description	example
Constant torque load	Out put power varies but torque is constant	Rotary kilins, constant displacement pumps
Variable torque load	Torque varies with square of operation speed	Centrifugal pump's fans
Constant power loads	Torque change inversely with speed	Machines tools

Electric motors in general are of two main types, AC and DC motors. All surveyed motors within the factory were AC motor type, and so all the speech from now on will be about AC motors only.

5.1.2 AC motors

An AC motor is an electric motor that is driven by an alternating current. It consists of two basic parts, an outside stationary stator having coils supplied with alternating current to produce a rotating magnetic field, and an inside rotor attached to the output shaft that is given a torque by the rotating field.

5.1.2.1 Types of AC motors

- Synchronous motor, which rotates exactly at the supply frequency or a submultiples of the supply frequency. The magnetic field on the rotor is either generated by current delivered through slip rings or by a permanent magnet.

- Induction motor, which turns slightly slower than the supply frequency. The magnetic field on the rotor of this motor is created by an induced current.

An induction motor (IM) is a type of asynchronous AC motor where power is supplied to the rotating device by means of electromagnetic induction. Another commonly used name is squirrel cage motor because the rotor bars with short circuit rings resemble a squirrel cage (hamster wheel).

Figure 5.1: Induction motor

An electric motor converts electrical power to mechanical power in its rotor (rotating part). There are several ways to supply power to the rotor. In a DC motor this power is supplied to the armature directly from a DC source, while in an induction motor this power is induced in the rotating device. An induction motor is sometimes called a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. Induction motors are widely used, especially polyphase induction motors, which are frequently used in industrial drives.

Induction motors are now the preferred choice for industrial motors due to their rugged construction, absence of brushes (which are required in most DC motors) and - thanks to modern power electronics - the ability to control the speed of the motor.

A synchronous electric motor is an AC motor distinguished by a rotor spinning with coils passing magnets at the same rate as the alternating current and resulting magnetic field which drives it. Another way of saying this is that it has zero slip under usual operating conditions. Contrast this with an induction motor, which must slip in order to produce torque. Synchronous motor is like an induction motor except the rotor is excited by a DC field. Slip rings and brushes are used to conduct current to rotor. The rotor poles connect to each other and move at the same speed hence the name synchronous motor.

Figure 5.2: Synchronous motor

The basic difference between an induction motor and a synchronous AC motor is that in the latter a current is supplied onto the rotor. This then creates a magnetic field which, through magnetic interaction, links to the rotating magnetic field in the stator which in turn causes the rotor to turn. It is called synchronous because at steady state the speed of the rotor is the same as the speed of the rotating magnetic field in the stator.

By way of contrast, the induction motor does not have any direct supply onto the rotor; instead, a secondary current is induced in the rotor. To achieve this, stator windings are arranged around the rotor so that when energized with a polyphase supply they create a rotating magnetic field pattern which sweeps past the rotor. This changing magnetic field pattern induces current in the rotor conductors. These currents interact with the rotating magnetic field created by the stator and in effect causes a rotational motion on the rotor.

However, for these currents to be induced, the speed of the physical rotor and the speed of the rotating magnetic field in the stator must be different, or else the magnetic field will not be moving relative to the rotor conductors and no currents will be induced. If by some chance this happens, the rotor typically slows slightly until a current is re-induced and then the rotor continues as before. This difference between the speed of the rotor and speed of the rotating magnetic field in the stator is called slip. It is unit-less and is the ratio between the relative speed of the magnetic field as seen by the rotor (the slip speed) to the speed of the rotating stator field. Due to this an induction motor is sometimes referred to as an asynchronous machine.

5.1.2.2 Efficiency of electric motors

Motor losses in general can be categorized in some main aspects such as: Fixed losses, Rotor losses, Stator losses, Friction losses, Stray load losses.

However; efficiency can be affected due to many factors like: Age, Capacity, Speed, Type, Temperature, Rewinding, Loads.

For motors to insure indirect energy saving there are some main procedures that should be taken into account, those are illustrated in table 5.2.

Table 5.2: Indirect energy saving methodologies in motors

NO	Items to be checked	Notes
1	Note the technical characteristics of the units from their name plates	Motor parameters (voltage, current, speed, torque, power)
2	Consult each motor’s instructions for maintenance guidelines. Motors are not all the same. Be careful not to think that what is good for one is good for all. For example, some motors require a periodic greasing of the bearings and some do not.	Periodic maintenance if required
3	Clean motor surfaces and ventilation openings periodically, preferably with a vacuum cleaner. Heavy accumulations of dust and lint will result in overheating and premature motor failure	Periodic cleaning required
4	Facility managers should inventory all motors in their facilities, beginning with the largest and those with the longest run-times. This inventory enables facility managers to make informed choices about replacement either before or after motor failure. Field testing motors prior to failure enables the facility manager to properly size replacements to match the actual driven load	Inventory management
5	Turn off or sequence unnecessary motors.	Use necessary motors only as required
6	Check packing for wear and repack as necessary. Consider replacing packing with mechanical seals.	Check packing periodically
7	Align the motor coupling to allow for efficient torque Transfer to the pump.	Align Coupling
8	Check and secure all motor mountings	Motor mountings

		check
9	Tighten connection terminals as necessary	Check for motor connections
10	Inspect bearings and drive belts for wear. Adjust, repair, or replace as necessary.	Check bearings periodically
11	Check the condition of the motor through temperature or vibration analysis to assure long life.	Check temperature periodically
12	Unbalanced power can shorten the motor life through excessive heat build up.	Insure balanced supply voltages (balanced three phase systems)
13	Over- or under-voltage situations can shorten the motor life through excessive heat build up.)	Insure healthy supply voltages

5.1.2.3 Methodologies to calculate the energy losses of motors

To compute the lost energy in a motor, we have to compute the efficiency of that motor. In order to do that we must know the input and output power. The difference between the two powers is the lost energy.

The input and output powers calculations depend on the type of the motor. The motors used in the factory are different types such that: one phase AC motors, three phase AC motors, servo motors and others. So each motor has different calculations.

To increase the efficiency of the motor, we must study the losses and try to reduce them as possible.

Generally:

$$P_{in} = \sqrt{3} * I * V * PF \quad (5.1)$$

$$P_{out} = \tau\omega \quad (5.2)$$

$$\eta = {}^{P_{out}}\!/_{P_{in}} \quad (5.3)$$

Where: P_{in}: input power (kW)

P_{out}: output power (kW)

I: input current (Amperes)

V: input voltage (Volts)

PF: Power Factor

η: Efficiency

ω: Angular speed (rpm)

τ: Torque (N.m)

to calculate the power losses in the plant, the input current in amp's, and the input voltage in volts were measured using Clamp meter and a voltmeter respectively. Calculating the input power requires also the value of the Power Factor (PF), this value had been founded from the motor's name-plate and was 0.9. now the input power can be calculated using equation 5.1:

$$P_{in} = \sqrt{3} * 4.8 * 415 * 0.9 = 3.1\ kW$$

The output power also can be found on the motor's name-plate, and was 2.2 kW. Hence; the output power should have been calculated in terms of speed and torque, but unfortunately, to measure the values of them requires special types of measuring instruments, and couldn't find them, so here the output power on the name-plate which is considered theoretical, was considered here as an actual value.

Efficiency can be calculated referring to equation 5.3, that gives:

$$\eta = \frac{2.2}{3.1} = 0.71 = 71\%$$

In any system in the nature, if it is to find the losses, losses usually equal the difference between the inputs and the outputs of those systems. Applying this concept, leads to the following formula:

$$P_{losses} = Pin – Pout \quad (5.4)$$

Then;

$$P_{losses} = 3.1 – 2.2 = 0.9\ kW$$

Note; P_{losses} for all the motors in the industrial plant are mentioned in the appendices (Appendix B).

5.1.2.4 Calculating the amount of energy saving

Energy loss per hour = total amount of motor loss Power × Time motor turns off per day

Energy loss per hour= 0.9 kW*1hour = 0.9 kWh

Since the daily operational hours are twelve, thirty days monthly and twelve months annually, the annual energy losses can be calculated as follows:

$$Energy\ loss\ per\ year = P_{loss}\ kW * \frac{No.hours}{Day} * \frac{Day}{Month} * \frac{Month}{Year}$$

Then;

$$Energy\ loss\ per\ year = 0.9 kW * 12 * 16 * 12 = 2360\ kW\ yearly$$

Then, the total energy saving per year can calculated using equation

$$\textit{The Cost} \text{ of energy loss} = \frac{2304 * 0.58}{4} \ (\$/year)$$

$$\textit{The Cost} \text{ of energy loss} = 334 \ (\$/year)$$

5.2 Electric heater

5.2.1 Introduction

Electric heating is any process in which electrical energy is converted to heat. Common applications include heating of buildings, cooking, and industrial processes .

An electric heater is an electrical appliance that converts electrical energy into heat. The heating element inside every electric heater is simply an electrical resistor, and works on the principle of Joule heating: an electric current through a resistor converts electrical energy into heat energy.

Alternatively, a heat pump uses an electric motor to drive a refrigeration cycle, drawing heat from a source such as the ground or outside air and directing it into the space to be warmed. Such systems can deliver two or three units of heating energy for every unit of electricity purchased.

5.2.2 Economic aspects

The operation of electric resistance heaters to heat an area for a long period of time is generally considered to be costly. However intermittent or partial day use can be more cost efficient than whole building heating since there savings due to superior zonal control.

Economically, electric heat is very efficient, and can be compared to other sources of home heating by calculating the cost per kilowatt hour multiplied by the efficiency of the heater, and then multiplied by the number of kilowatts the heater uses.

5.2.3 Industrial electric heating

Advantages of electric heating methods over other forms include precision control of temperature and distribution of heat energy, combustion not used to develop heat, and the ability to attain temperatures not readily achievable with chemical combustion. Electric heat can be accurately applied at the precise point needed in a process, at high concentration of power per unit area or volume. Electric heating apparatus can be built in any required size and can be located anywhere within a plant. Electric heating processes are generally clean, quiet, and do not emit much byproduct heat to the surroundings. Electrical heating equipment has a high speed of response, lending it to rapid-cycling mass-production equipment.

The limitations and disadvantages of electric heating in industry include the higher cost of electrical energy compared to direct use of fuel, and the capital cost of both the electric heating apparatus itself and the infrastructure required to deliver large quantities of electrical energy to the point of use. This may be somewhat offset by efficiency gains in using less energy overall to achieve the same result.

Design of an industrial heating system starts with assessment of the temperature required, the amount of heat required, and the feasible modes of transferring heat energy. In addition to conduction, convection and radiation, electrical heating methods can use electric and magnetic fields to heat material.

Industrial heating processes can be broadly categorized as low-temperature (to about 400 C (730 F)), medium temperature (between 400 C and 1150 C (730-2100 F)), and high temperature (beyond 1150 C (2100 F)).

Low temperature processes include:

- Baking and drying,
- Curing finishes,
- Soldering,
- Molding and shaping plastics.

Medium temperature processes include:

- Melting plastics and some non-metals for casting or reshaping,
- Annealing,
- Stress-relieving, and
- Heat-treating.

High-temperature processes include:

- Steelmaking,
- Brazing and welding,
- Ferrous and other metal casting,
- Cutting,
- Smelting,
- Preparation of some chemicals.

3.4.2.1 Energy losses of heater

In the plant, the extruder is used for melting the plastic by means of heaters, those heater's temperatures can be calibrated on a desired value via a control unit, and when the heater reaches the required temperature; it stops working in a way for energy saving. But; the occurrence of ventilation systems (fans), causes some kind of devices temperature impact, that is fans takes out the warm air and in lets colder air instead, the new air absorbs part of heaters temperature (Temperature balance – from hottest to coldest), this forces the heaters to be automatically switched on again due to temperature loss. The problem here; is that it had been found that successive ON-OFF operations of heaters for short period of times, is same as operating heaters an additional one hour daily, which means additional energy consumption (Additional costs), in addition to that, it is known that successive ON-OFF operations reduces the machines life.

In the factory, the percentage of power losses in zones six through twelve is much larger than that of zones one through five, because the heaters used in zones one through five are using an insulating system, where the others of the rest of zones are not.

- From zone one to zone five the time operation loss are 30 minutes

Energy loss per hour= 9.75 *0.5 hour = 4.875 kWh

$$Energy\ loss\ per\ year = P_{loss}\ kW * \frac{No.hours}{Day} * \frac{Day}{Month} * \frac{Month}{Year}$$

$$Energy\ loss\ per\ year = 4.875 kWh * 16 * 12 = 532 kW\ yearly$$

Then, the total energy saving per year can calculated using equation

$$The\ Cost \text{ of energy loss} = \frac{936 * 0.58}{4}\ (\$/year)$$

$The\ Cost$ of energy loss = 135.72 $(\$/year)$

- From zone six to zone twelve the time operation loss are one hour

Energy loss per hour=31.81 *1 hour = 4.875 kWh

$Energy\ loss\ per\ year = 31.81 kWh * 16 * 12 = 2?1?3.1?\ kW\ yearly$

$The\ Cost$ of energy loss = $\frac{6107.52 * 0.58}{4} = 885.6\ (\$/year)$

$Total\ energy\ losses = 1?1.3?2 + 441.2? = 1021 (\$/year)$

6.1 Pumps

6.1.1 Introduction

Hydraulics is defined as the science of the conveyance of liquids through pipes. The pump is often used to raise water from a low level to a high level where it can be stored in a tank. Most of the theory applicable to hydraulic pumps has been derived using water as the working fluid, but other liquids can also be used. In this chapter, we will assume that liquids are totally incompressible unless otherwise specified. This means that the density of liquids will be considered constant no matter how much pressure is applied. Unless the change in pressure in a particular situation is very great, this assumption will not cause a significant error in calculations. Centrifugal and axial flow pumps are very common hydraulic pumps. Both work on the principle that the energy of the liquid is increased by imparting kinetic energy to it as it flows through the pump. This energy is supplied by the impeller, which is driven by an electric motor or some other drive.

6.1.2 Pumping system characteristics

6.1.2.1 Resistance of the system head

Pressure is needed to pump the liquid through the system at a certain rate. This pressure has to be high enough to overcome the resistance of the system, which is also called “head”. The total head is the sum of static head and friction head:

a) Static head

Figure (6.1) shows the Static head is the difference in height between the source and destination of the pumped liquid. Static head is independent of flow. The static head at a certain pressure depends on the weight of the liquid and can be calculated with this equation (6-1):

$$\text{Head (feet)} = \frac{\text{Pressure (Psi)} \times 2.31}{\text{specific grafity}} \tag{6-1}$$

Static head consists of:

- Static suction head (h_s): resulting from lifting the liquid relative to the pump center line. The h_s is positive if the liquid level is above pump centerline, and negative if the liquid level is below pump centerline (also called “suction lift)
- Static discharge head (h_d): the vertical distance between the pump centerline and the surface of the liquid in the destination tank.

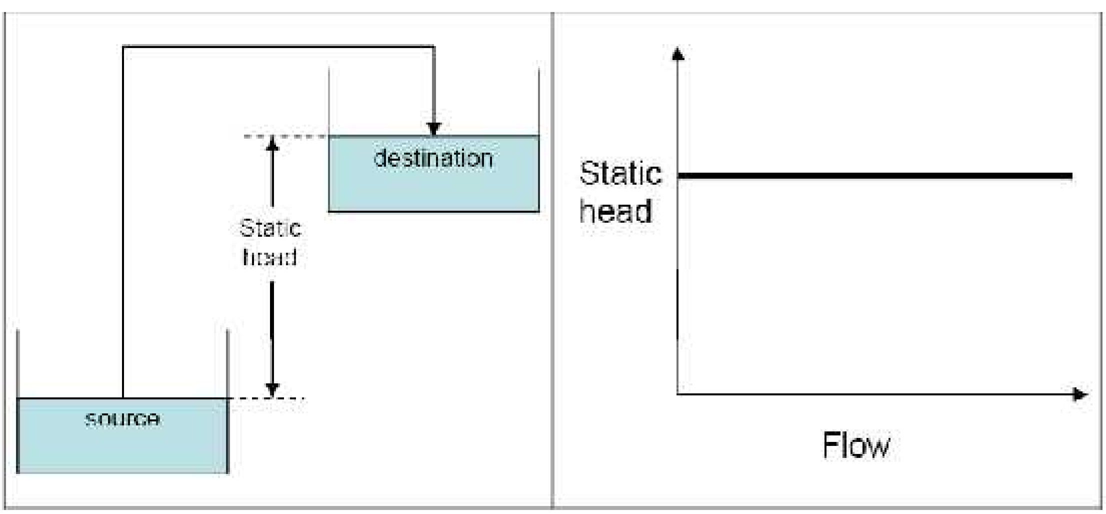

Figure 6.1: Static head

b) Friction head (h_f)

This is the loss needed to overcome that is caused by the resistance to flow in the pipe and fittings. It is dependent on size, condition and type of pipe, number and type of pipe fittings, flow rate, and nature of the liquid. The friction head is proportional to the square of the flow rate as shown in figure (6.2). A closed loop circulating system only exhibits friction head (i.e. not static head).

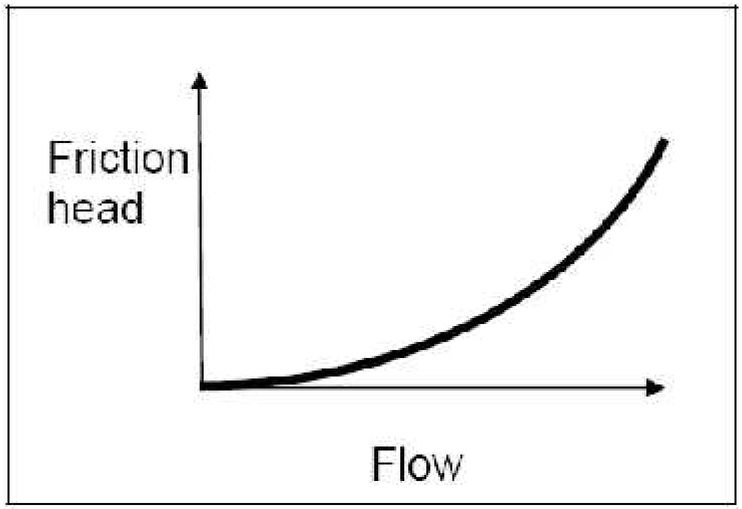

Figure 6.2: Frictional Head versus Flow

6.1.2.2 Pump performance curve

The head and flow rate determine the performance of a pump, which is graphically shown in Figure (6.3) as the performance curve or pump characteristic curve. The figure shows a typical curve of a centrifugal pump where the head gradually decreases with increasing flow. As the resistance of a system increases, the head will also increase. This in turn causes the flow rate to decrease and will eventually reach zero. A zero flow rate is only acceptable for a short period without causing to the pump to burn out.

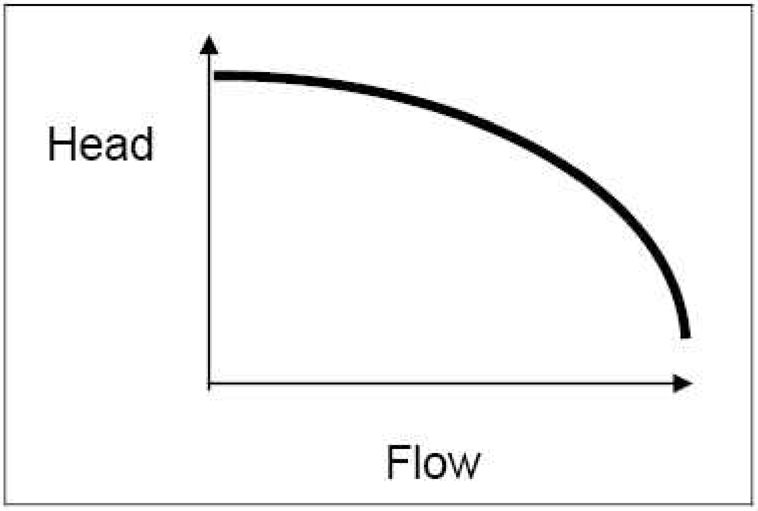

Figure 6.3: Performance curve

6.1.2.3 Pump operating point

The rate of flow at a certain head is called the duty point. The pump performance curve is made up of many duty points. The pump operating point is determined by the intersection of the system curve and the pump curve as shown in Figure (6.4).

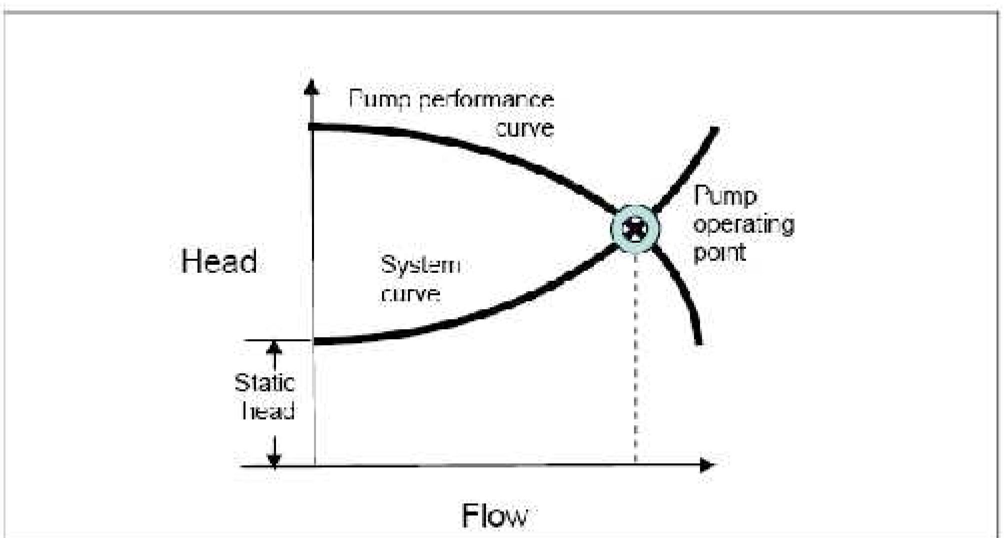

Figure 6.4: Pump operating point

6.1.2.4 Pump suction performance (NPSH)

Cavitations or vaporization is the formation of bubbles inside the pump. This may occur when at the fluid's local static pressure becomes lower than the liquid's vapor pressure (at the actual temperature). A possible cause is when the fluid accelerates in a control valve or around a pump impeller. Vaporization itself does not cause any damage. However, when the velocity is decreased and pressure increased, the vapor will evaporate and collapse. This has three undesirable effects:

- Erosion of vane surfaces, especially when pumping water-based liquids
- Increase of noise and vibration, resulting in shorter seal and bearing life

Partially choking of the impeller passages, this reduces the pump performance and can lead to loss of total head in extreme cases. The Net Positive Suction Head Available (NPSHA) indicates how much the pump suction exceeds the liquid vapor pressure, and is a characteristic of the system design. The NPSH Required (NPSHR) is the pump suction needed to avoid cavitations, and is a characteristic of the pump design.

6.1.3 TYPE OF PUMPS

This section describes the various types of pumps. Two Pumps come in a variety of sizes for a wide range of applications. They can be classified according to their basic operating principle as dynamic or positive displacement pumps as shown in Figure (6.5).

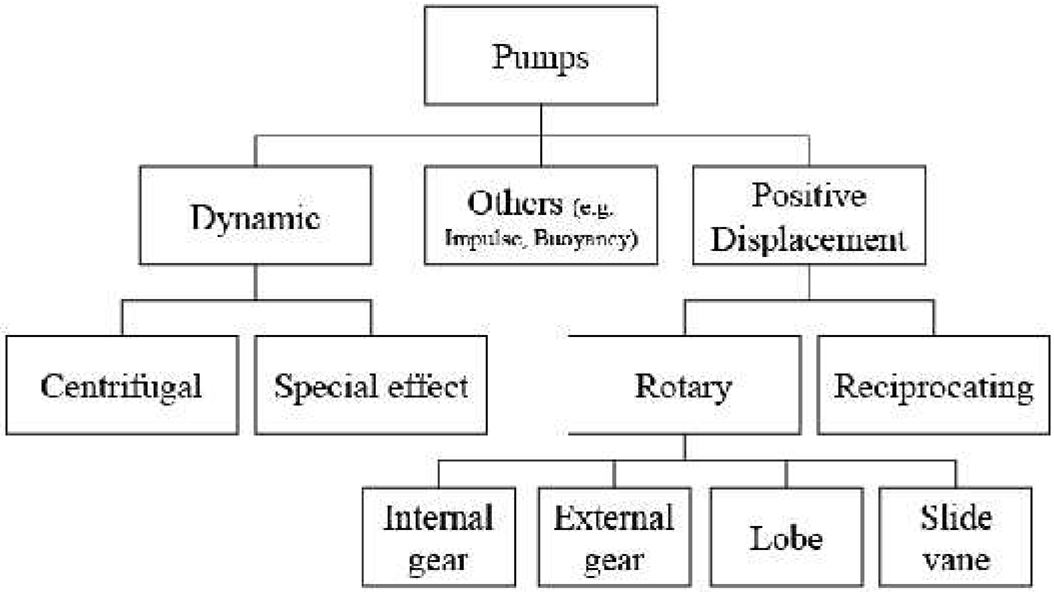

Figure 6.5: Different types of pumps

In principle, any liquid can be handled by any of the pump designs. Where different pump designs could be used, the centrifugal pump is generally the most economical followed by rotary and reciprocating pumps. Although, positive displacement pumps are generally more efficient than centrifugal pumps, the benefit of higher efficiency tends to be offset by increased maintenance costs.

6.1.3.1 Dynamic pumps

Dynamic pumps are also characterized by their mode of operation: a rotating impeller converts kinetic energy into pressure or velocity that is needed to pump the fluid. There are two types of dynamic pumps:

- Centrifugal pumps are the most common pumps used for pumping water in industrial applications. Typically, more than 75% of the pumps installed in an industry are centrifugal pumps. For this reason, this pump is further described below.

- Special effect pumps are particularly used for specialized conditions at an industrial site.

6.1.3.2 How a centrifugal pump works

- A centrifugal pump is one of the simplest pieces of equipment in any process plant. Figure (6.6) shows how this type of pump operates:
- Liquid is forced into an impeller either by atmospheric pressure or in case of a jet pumps by artificial pressure. The vanes of impeller pass kinetic energy to the liquid, thereby causing the liquid to rotate. The liquid leaves the impeller at high velocity.
- The impellers are surrounded by a volute casing or in case of a turbine pump a stationary diffuser ring. The volute or stationary diffuser ring converts the kinetic energy into pressure energy.

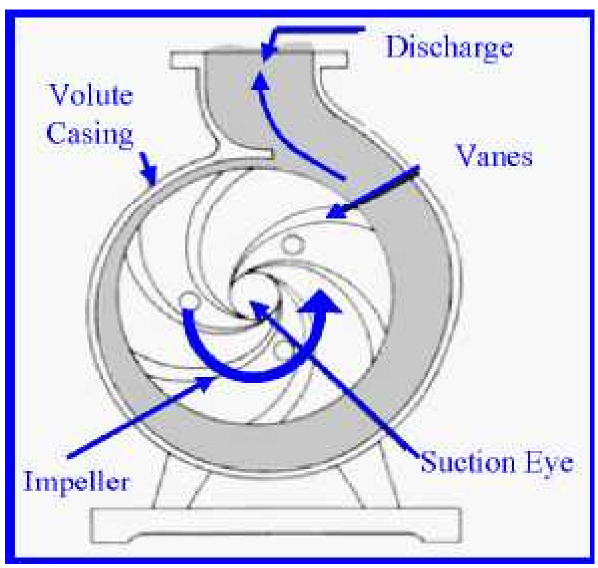

Figure 6.6 : Liquid Flow Path of a Centrifugal Pump

6.1.3.3 Components of a centrifugal pump

The main components of a centrifugal pump are shown in Figure (6.7) and described below:

- Rotating components: an impeller coupled to a shaft.
- Stationary components: casing, casing cover, and bearings.

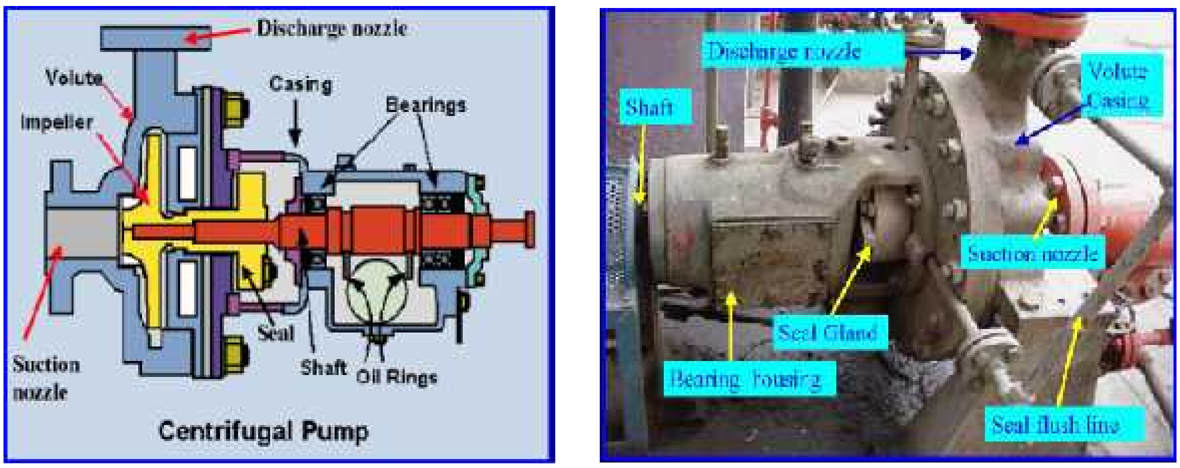

Figure 6.7: Main Components of a Centrifugal Pump

Pump output, water horsepower or hydraulic horsepower (hp) is the liquid horsepower delivered by the pump, and can be calculated as follows in equation (6-2):

Hydraulic power:

$$\text{Hydraulic Power (W)} = {}^{\circ} gQH \tag{6-2}$$

Where:

Q = flow rate (m^3/s)

H = benefit head (m)

ρ = density of the fluid (Kg/m^3)

g = acceleration due to gravity (m/s^2)

the efficiency of the pump is calculated using the following relation (6-2):

$$\text{Pump Efficiency} = \frac{\rho g Q H}{IV} \qquad (6\text{-}3)$$

6.1.3.4 PUMP LOSSES

The following are the various losses occurring during the operation of a centrifugal pump. Losses in the suction and delivery pipe are known as hydraulic losses.

6.1.3.4.1 Theory and Analysis

In this study, it is necessary to obtain the volumetric flow rate, Q. Volumetric flow rate, put simply, is the time, t it takes for a certain volume, V to fill , and is given in units of ($meters^3$ / seconds). It is obtained through the use of the following equation (6-4):

$$Q = \frac{V}{t} \qquad (6\text{-}4)$$

Where:

Q: is the volumetric flow rate (m^3/s)

V: is the volume of water flow into the measuring cylinder (m^3)

t: is the time taken for the flow (sec)

The cross-sectional area, (A) area of all of the pipes is a circle; it can be obtained from the known diameter, D of each pipe using equation (6-5).

$$A = \pi \frac{D^2}{4} \qquad (6\text{-}5)$$

Where:

A: is the cross-sectional area of the pipe (m^2).

D: is the diameter of the pipe (m)

The Continuity Equation (shown below) states that the flowing velocity, V is related to the volumetric flow rate, Q and the cross-sectional area of the pipe A. The units of Velocity are in (meters / seconds) using calculation (6-6).

$$V = \frac{Q}{A} \tag{6-6}$$

Where:

V: is the flowing velocity (m/s).

Q: is the volumetric flow rate (m^3/s)

A: is the cross-sectional area of the pipe (m^2).

The Reynolds number, Re, is very useful in the determination of the friction factor, and can be determined by relating the flowing velocity, V, the fluid's density, _ (given as a lowercase Greek rho), the pipe's diameter, D, and the fluid's dynamic viscosity, μ (given by a lowercase Greek mu). The density of a fluid is a number stating how much mass can fit into a certain volume for a specific substance. In this case, the fluid is water. The dynamic viscosity explains how easily a fluid can flow when taking the friction of the walls of the pipe into account. The density and dynamic viscosity are given in the units of kilograms / meters3 and kilograms / (meters x seconds). A quick analysis of the units involved shows that they cancel each other out through division, and thusly, the Reynolds number, Re, is dimensionless. It is important to note that both density and dynamic viscosity vary with temperature. This does not apply to this case however because the temperature of the testing area was held constant substituting all values in equation (6-7).

$$Re = \frac{\rho V D}{\mu} \tag{6-7}$$

Where:

Re is the Reynolds number for the flow (non dimensional) ρ: is the density of fluid (kg/m^3)

μ: is the dynamic viscosity of the fluid (kg/m.s)

V: is the flowing velocity (m/s)

D: is the diameter of the pipe (m).

There are two major ways to describe the flowing of a fluid. A steady, even flow is called a laminar flow, and a flow that moves violently or roughly is called a turbulent flow. The easiest way to show that a flow is laminar is to first determine the Reynolds number; if the value obtained is below 2000 then the flow is laminar, and if the value is above 4000 then the flow is turbulent. For values of the Reynolds number between 2000 and 4000, the fluid is called a transitional flow and shows characteristics of both types.

The friction factor, f, allows us to determine a variety of information regarding pipe flows. For a laminar flow only, it is determined by the Reynolds number using equation (6-8). Note that the friction factor is also dimensionless.

$$f = \frac{64}{Re} \qquad (6\text{-}8)$$

Where

f: is the friction factor.

Re: is the Reynolds number for the flow.

For turbulent flow, the friction factor, f is determined from the Moody chart (see attached at the end of this report) as a function of Reynolds number, Re and the relative roughness, r of the pipe. The relative roughness for the pipe is related to the pipe’s surface roughness, _ (given by a lowercase Greek epsilon) and the diameter, D. Both values of roughness describe the ability of a fluid to flow past without “sticking” to the sides, and the friction factor, f is determined by matching the lines for relative roughness to the grid for Reynolds number and locating the value for the friction factor at the corresponding point. Although there are advanced equations that can determine the friction factor without the use of the Moody chart, it is a generally accepted method for easily determining the value.

In fluid mechanics, it is often helpful to define the head of a fluid in a system as a height of fluid in the vertical direction; this value can then be used to define more intricate values for different aspects of the flow. The head can be measured directly through the use of a *manometer*. In the case where two manometers are set up at opposing ends of a pipe, we can measure the total head loss, Δh as illustrated in equation (6-9) of the flow of the pipe. Corresponding to the experimental setup, this is merely the difference of manometer heights h1 and h2 and is measured in meters.

$$\Delta h = h_2 - h_1 \qquad (6\text{-}9)$$

Where

Δh: The total head loss.

h1 is the height of the fluid in manometer 1.

h2 is the height of the fluid in manometer 2.

Although there are many reasons for the change in the size of the head, Δh, from one end of the pipe to the other, the largest factor involved is the head loss due to friction, hf. This is explained through relation with friction factor, f, the overall pipe length, L, the flow velocity, V, the acceleration due to gravity, g, and the pipe diameter, D. The units of head loss due to friction are the same as the total head loss; namely, in meters. The pipe's length is also given in meters. The acceleration due to gravity is a constant on the Earth's surface, and is given as 9.81 (meters / seconds^2). It is important to note that the pipe length is given as the length that the fluid must pass through to reach the other end; this is an important concept in analyzing pipes with bends or elbows as opposed to straight sections then the losses in the pipe due to friction can be calculated using equation (6-9).

$$h_f = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right) \qquad (6\text{-}9)$$

Where:

hf :is the head loss due to friction. (m)

L: is the length of the pipe. (m)

g :is the value of acceleration due to gravity. (m/s^2)

f :is the friction factor (non dimensional)

V: is the velocity of the flow. (m/s)

D: is the diameter of the pipe. (m)

In the analysis of test sections with bends or elbows, we must add the effects of bends to the total head loss. The head loss due to bends, h_b, is also denoted in meters, and is related to the velocity, V, the acceleration due to gravity, g, and the bend resistance coefficient, K_b , which is dimensionless. The following relation (6-10) is used. Take care to remember that the velocity, V referred to in this equation is the fluid velocity determined from the volumetric flow rate, Q, and not the mean velocity, V_{mean}.

$$h_b = K_b \frac{V^2}{2g} \qquad (6\text{-}10)$$

Where:

h_b :is the head loss due to the elbow/bend. (m)

K_b: is the bend resistance coefficient. (non dimensional)

V: is the velocity of the fluid. (m/s)

g: is the acceleration due to gravity. (m/s^2)

The relation used to obtain a value for bend resistance coefficient, Kb, requires several additional values, one of which is the velocity head, hv. This is another head describing the features of pipe flow, and like velocity, V it is also given in meters / seconds. This number is related to velocity and the acceleration due to gravity, g, and is given by the equation (6-11) below. Once again, the value of velocity used is the standard velocity obtained from the volumetric flow rate, Q, not the mean velocity, V_{mean}.

$$h_v = \frac{V^2}{2g} \qquad (6\text{-}11)$$

Where:

hv: is the velocity head. (m)

V: is the velocity. (m/s)

g :is the acceleration due to gravity.(m/s^2).

6.1.3.5 Sample of calculation for the circular tank

First of all, the Perimeter of the tank should measured using a measuring tape, then the occurring result can be used to calculate the diameter of the tank, and so, the flow rate within seven minutes can be found.

$$L=2\circledR r \longrightarrow r = \frac{4.67}{2\times 3.14} = 0.743 \text{ m}$$

$$D = r * 2 = .743 * 2 = 1.5 \text{ m}$$

$$\Delta v = \left(\frac{\pi}{4}\right)(1.5)^2\,(0.45) = 0.794\ (m^3)$$

To calculate the flow rate for seven minutes, equation 6.4 is used here:

$$Q = \frac{0.794}{7*60} = 0.0019\ (m^3/sec)$$

The velocity is calculated referring to equation 6.6:

$$V = \frac{4\times Q}{\circledR \times D^2} = 0.9383\ (m/s)$$

Now, Reynolds Number can be calculated using equation 6.7 as follows:

$$Re = \frac{\rho V D}{\mu} = \frac{1000 * 0.9383 * 3\ 0.02547}{(1.277 * 10^{-3})} = 56143 > 4000 \text{ Turbulent}$$

f = from Moody chart with 0.0008547 surface roughness = 0.02

for calculating the head friction losses, equation 6.9 is used:

$$h_f = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right) = 0.02\left(\frac{33.4}{3*0.02547}\right)\left(\frac{0.9383^2}{2*9.81}\right) = 0.41\ (m)$$

And equation 6.10 is used for calculating the head elbow and reducer losses as follows:

$$h_b = \text{(N of fittings, Elbows)}\ (K_b)\ \left(\frac{V^3}{2g}\right) = (7)\ (0.9)\ \left(\frac{0.9383^3}{2 * 981}\right) = 0.3\ \text{(m)}$$

$$h_b = \text{(N of fittings, Reducer)}\ (K_b)\ \left(\frac{V^3}{2g}\right) = (3)\ (0.15)\ \left(\frac{0.9383^3}{2 * 9.81}\right) = 0.02\ \text{(m)}$$

$$h_{loss}\ (TOTAL) = 0.41 + 0.3 + 0.02 = 0.73\ \text{(m)}$$

$$P_{loss} = \rho\ g\ Q\ h_{loss} = 1000 * 9.81 * 0.0019 * 0.73 = 0.0136\ \text{(KW)}$$

$$\text{Benefit power} = \rho\ g\ Q\ h_d = 1000 * 9.81 * 0.0019 * 14 = 260.9\ \text{(W)}$$

The pumps distribute the water to the groups of tanks according to the own head of the tank, all pipes losses discussed in Table (6.1).

Table 6.1: Pipes losses

	Diameter (m)	(Main supplier) (3 Inch diameter pipe supply line)
Flow rate. (m^3/s)	**Q**	0.0019
Velocity of the fluid. (m/s)	**V**	0.9383
Head loss due to pipe friction (m)	h_f	0.41
Head loss due to bend (m)	h_b	0.32
Delivery head. (m)	h_d	14
Suction head. (m)	h_s	5
Power loss in pipes & elbows. (kW)	$P_{Loss\ in\ pipes}$	0.0136
Benefit power .(kW)		260.9

The efficiency of the pump can be determined using the characteristic curve of its operation by matching the delivered head with the flow rate as shown in Figure (6.8).

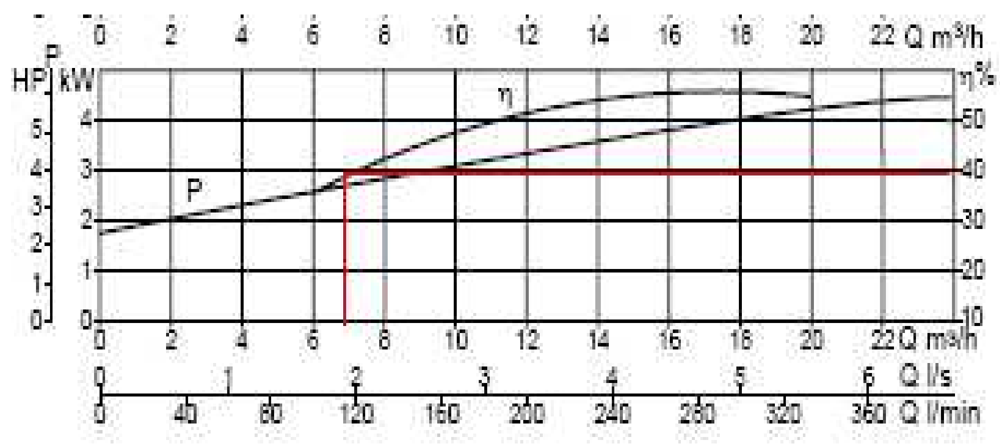

Figure 6.8: characteristic curve for Dap Pump

Flow rate = 6.84 m^3/h

Head = 14 m

η= 40%

6.1.3.6 Pump selection

It has been noticed that the pump's power in the factory is higher than needed, this result had been found referring to the flow rate and the head required, so that there should be another pump with different power rating to be used, and the specifications can be determined referring to the performance curve below.

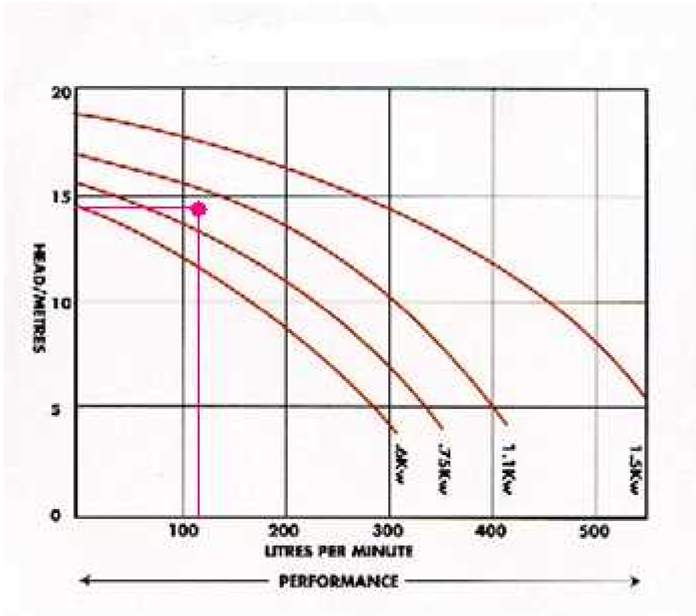

Figure 6.9: Performance curve of pumps

The previous curve illustrates the relation between the flow rate (Liters) and the head (Meter) for every single minute, and referring to the intersection between the flow rate (at about 1.9 Liters) and the head (which is 14 Meters), the required power for the new pump should be within 1 kW.

So; energy saving can be calculated as the following:

$$\text{Total energy saving} = 3 - 1 = 2 \text{ kW}$$

$$\text{Energy saving per } year = P_{saved}(kW) * \frac{No.hours}{Day} * \frac{day}{month} * \frac{month}{year}$$

$$\text{Energy saving per } year = 2 * 0 * 22 * 12$$

$$\text{Energy saving per } year = 2052 \text{ (kW/year)}$$

$$\text{The Cost of energy saving} = \frac{2496 * 0.58}{4} = 361.92 \text{ (\$/year)}$$

6.2 FANS AND BLOWERS

6.2.1 INTRODUCTION

Most manufacturing plants use fans and blowers for ventilation and for industrial processes that need an air flow. Fan systems are essential to keep manufacturing processes working, and consist of a fan, an electric motor, a drive system, ducts or piping, flow control devices, and air conditioning equipment (filters, cooling coils, heat exchangers, etc.). The US Department of Energy estimates that 15 percent of electricity in the US manufacturing industry is used by motors. Similarly, in the commercial sector, electricity needed to operate fan motors composes a large portion of the energy costs for space conditioning (US DOE, 1989).

Fans, blowers and compressors are differentiated by the method used to move the air, and by the system pressure they must operate against. The American Society of technical Engineers (ASME) uses the specific ratio, which is the ratio of the discharge pressure over the suction pressure, to define fans, blowers and compressors .Conversely, resistance decreases as flow decreases. To determine what volume the fan will produce, it is therefore necessary to know the system resistance characteristics. In existing systems, the system resistance can be measured. In systems that have been designed, but not built, the system resistance must be calculated.

6.2.2 Important terms and definitions

Before types of fans and blowers are described it is important to first understand terms and definitions.

6.2.2.1 System characteristics

The term "system resistance" is used when referring to the static pressure. The system resistance is the sum of static pressure losses in the system. The system resistance is a function of the configuration of ducts, pickups, elbows and the pressure drops across equipment, for example bag filter or cyclone. The system resistance varies with the square of the volume of air flowing through the system. For a given volume of air, the fan in a system with narrow ducts and multiple short radius elbows is going to have to work harder to overcome a greater system resistance than it would in a system with larger ducts and a minimum number of long radius turns.

Long narrow ducts with many bends and twists will require more energy to pull the air through them. Consequently, for a given fan speed, the fan will be able to pull less air through this system than through a short system with no elbows. Thus, the system resistance increases substantially as the volume of air flowing through the system increases; square of air flow.

6.2.3 Type of fans and blowers

This section briefly describes different types of fans and blowers.

6.2.3.1 Types of fans

There exist two main fan types. Centrifugal fans used a rotating impeller to move the air stream. Axial fans move the air stream along the axis of the fan.

- **Centrifugal fans**

Centrifugal fans increase the speed of an air stream with a rotating impeller. The speed increases as the reaches the ends of the blades and is then converted to pressure. These fans are able to produce high pressures, which makes them suitable for harsh operating conditions, such as systems with high temperatures, moist or dirty air streams, and material handling.

- **Axial fans**

Axial fans move an air stream along the axis of the fan. The way these fans work can be compared to a propeller on an airplane: the fan blades generate an aerodynamic lift that pressurizes the air. They are popular with industry because they are inexpensive, compact and light. The main types of axial flow fans (propeller, tube-axial and vane-axial).

6.2.4 Methodology of fan performance assessment

Before the fan efficiency can be calculated, a number of operating parameters must be measured, including air velocity, pressure head, temperature of air stream on the fan side and electrical motor kW input. In order to obtain correct operating figures it should be ensured that:

- Fan and its associated components are operating properly at its rated speed
- Operations are at stable condition i.e. steady temperature, densities, system resistance etc.

The calculation of fan efficiency is explained in 3 steps

- measure the air velocity and calculate average air velocity

The air velocity can be measured with a pitot tube and a manometer, or a flow sensor (differential pressure instrument), or an accurate anemometer. The total pressure is measured using the inner tube of Pitot tube and static pressure is measured using the outer tube of Pitot tube. When the inner and outer tube ends are connected to a manometer, we get the velocity pressure (i.e. the difference between total pressure and static pressure). For measuring low velocities, it is preferable to use an inclined tube manometer instead of U-tube manometer. See the chapter on Monitoring Equipment for explanation of manometers.

- Calculate the volumetric flow

1. The second step is to calculate the volumetric flow as follows:
2. The diameter of fans can be estimated).

$$\text{Volumetric Flow Rate} = \text{Velocity} \times \text{Area} \qquad (6\text{-}12)$$

$$Q = V \times A$$

Where:

Q = volumetric flow rate. (m^3/s)

V = velocity of the fluid.(m/s)

A = Area of the diameter or duct (m^2)

- measure the power of the drive motor

The power of the drive motor (kW) can be measured by a load analyzer. This kW multiplied by motor efficiency gives the shaft power to the fan.

6.2.5 Difficulties in assessing the performance of fans and blowers

In practice certain difficulties have to be faced when assessing the fan and blower performance, some of which are explained below:

- Non-availability of fan specification data: Fan specification data are essential to assess the fan performance. Most of the industries do not keep these data systematically or have none of these data available at all. In these cases, the percentage of fan loading with respect to flow or pressure can not be estimated satisfactorily. Fan specification data should be collected from the original equipment manufacturer (OEM) and kept on record.
- Difficulty in velocity measurement: Actual velocity measurement becomes a difficult task in fan performance assessment. In most cases the location of duct makes it difficult to take measurements and in other cases it becomes impossible to traverse the duct in both directions. If this is the case, then the velocity pressure can be measured in the center of the duct and corrected by multiplying it with a factor 0.9.
- Improper calibration of the pitot tube, manometer, anemometer & measuring instruments: All instruments and other power measuring instruments should be calibrated correctly to avoid an incorrect assessment of fans and blowers. Assessments should not be carried out by applying correction factors to compensate for this.
- Variation of process parameters during tests: If there is a large variation of process parameters measured during test periods, then the performance assessment becomes unreliable.

6.2.6 Fan losses

Table 6.2: parameters of fans calculation

D (m)	Q(m^3/s)	V (m/s)	h_v (m)
0.7	0.21	0.545	0.3

$$h_v = \frac{V^2}{2g}$$

$$h_v = \frac{0.545^2}{2 * 9.81} = 0.015 \text{ m}$$

$$A = \frac{\pi}{4} D^2 = 0.384\ m^2$$

$$Q = V * A \quad m^3/s$$

$$Q = 0545 * 0.384 = 0.21\ m^3/s$$

P_{loss} = ρ g Q h_v = 1.125 * 9.81 * 0.923 * 0.15 = 0.154 (W) (Hydraulic power)

6.3 Chiller

6.3.1 introduction

A chiller is a machine that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. A vapor-compression water chiller comprises the 4 major components of the vapor-compression refrigeration cycle (compressor, evaporator, condenser, and some form of metering device). These machines can implement a variety of refrigerants. Absorption chillers utilize water as the refrigerant and rely on the strong affinity between the water and a lithium bromide solution to achieve a refrigeration effect. Most often, pure water is chilled, but this water may also contain a percentage of glycol and/or corrosion inhibitors; other fluids such as thin oils can be chilled as well.

Chilled water is used to cool and dehumidify air in mid- to large-size commercial, industrial, and institutional (CII) facilities. Water chillers can be either water cooled, air-cooled, or evaporatively cooled. Water-cooled chillers incorporate the use of cooling towers which improve the chillers' thermodynamic effectiveness as compared to air-cooled chillers. This is due to heat rejection at or near the air's wet-bulb temperature rather than the higher, sometimes much higher, dry-bulb temperature. Evaporatively cooled chillers offer efficiencies better than air cooled, but lower than water cooled.

Water cooled chillers are typically intended for indoor installation and operation, and are cooled by a separate condenser water loop and connected to outdoor cooling towers to expel heat to the atmosphere.

Air Cooled and Evaporatively Cooled chillers are intended for outdoor installation and operation. Air cooled machines are directly cooled by ambient air being mechanically circulated directly through the machine's condenser coil to expel heat to the atmosphere. Evaporatively cooled machines are similar, except they implement a mist of water over the condenser coil to aid in condenser cooling, making the machine more efficient than a traditional air cooled machine. No remote cooling tower is typically required with either of these types of packaged air cooled or evaporatively cooled chillers.

Where available, cold water readily available in nearby water bodies might be used directly for cooling, or to replace or supplement cooling towers. The Deep Lake Water Cooling System in Toronto, Canada, is an example. It dispensed with the need for cooling towers, with a significant cut in carbon emissions and energy consumption. It uses cold lake water to cool the chillers, which in turn are used to cool city buildings via a district cooling system. The return water is used to warm the city's drinking water supply which is desirable in this cold climate. Whenever a chiller's heat rejection can be used for a productive purpose, in addition to the cooling function, very high thermal effectivenesses are possible.

6.3.2 Use in industry

In industrial application, chilled water or other liquid from the chiller is pumped through process or laboratory equipment. Industrial chillers are used for controlled cooling of products, mechanisms and factory machinery in a wide range of industries. They are often used in the plastic industry in injection and blow molding, metal working cutting oils, welding equipment, die-casting and machine tooling, chemical processing, pharmaceutical formulation, food and beverage processing, vacuum systems, X-ray diffraction, power supplies and power generation stations, analytical equipment, semiconductors, compressed air and gas cooling. They are also used to cool high-heat specialized items such as MRI machines and lasers.

The chillers for industrial applications can be centralized, where each chiller serves multiple cooling needs, or decentralized where each application or machine has its own chiller. Each approach has its advantages. It is also possible to have a combination of both central and decentral chillers, especially if the cooling requirements are the same for some applications or points of use, but not all.

Decentral chillers are usually small in size (cooling capacity), usually from 0.2 tons to 10 tons. Central chillers generally have capacities ranging from ten tons to hundreds or thousands of tons.

6.3.3 Industrial chiller technology

Industrial chillers typically come as complete packaged closed-loop systems, including the chiller unit, condenser, and pump station with recirculating pump, expansion valve, no-flow shutdown, internal cold water tank, and temperature control. The internal tank helps maintain cold water temperature and prevents temperature spikes from occurring. Closed loop industrial chillers recirculate a clean coolant or clean water with condition addititives at a constant temperature and pressure to increase the stability and reproducibility of water-cooled machines and instruments. The water flows from the chiller to the application's point of use and back.

If the water temperature differentials between inlet and outlet are high, then a large external water tank would be used to store the cold water. In this case the chilled water is not going directly from the chiller to the application, but goes to the external water tank which acts as a sort of "temperature buffer." The cold water tank is much larger than the internal water tank. The cold water goes from the external tank to the application and the return hot water from the application goes back to the external tank, not to the chiller.

The less common open loop industrial chillers control the temperature of a liquid in an open tank or sump by constantly recirculating it. The liquid is drawn from the tank, pumped through the chiller and back to the tank. An adjustable thermostat senses the makeup liquid temperature, cycling the chiller to maintain a constant temperature in the tank.

One of the newer developments in industrial water chillers is the use of water cooling instead of air cooling. In this case the condenser does not cool the hot refrigerant with ambient air, but uses water cooled by a cooling tower. This development allows a reduction in energy requirements by more than 15% and also allows a significant reduction in the size of the chiller due to the small surface area of the water based condenser and the absence of fans. Additionally, the absence of fans allows for significantly reduced noise levels.

Most industrial chillers use refrigeration as the media for cooling, but some rely on simpler techniques such as air or water flowing over coils containing the coolant to regulate temperature. Water is the most commonly used coolant within process chillers, although coolant mixtures (mostly water with a coolant additive to enhance heat dissipation) are frequently employed.

6.3.4 Industrial chiller selection

Important specifications to consider when searching for industrial chillers include the power source, chiller IP rating, chiller cooling capacity, evaporator capacity, evaporator material, evaporator type, condenser material, condenser capacity, ambient temperature, motor fan type, noise level, internal piping materials, number of compressors, type of compressor, number of fridge circuits, coolant requirements, fluid discharge temperature, and COP (the ratio between the cooling capacity in KW to the energy consumed by the whole chiller in KW). For medium to large chillers this should range from 3.5-4.8 with higher values meaning higher efficiency. Chiller efficiency is often specified in kilowatts per refrigeration ton (kW/RT).

Process pump specifications that are important to consider include the process flow, process pressure, pump material, elastomer and mechanical shaft seal material, motor voltage, motor electrical class, motor IP rating and pump rating. If the cold water temperature is lower than -5ºC, then a special pump needs to be used to be able to pump the high concentrations of ethylene glycol. Other important specifications include the internal water tank size and materials and full load amperage.

Control panel features that should be considered when selecting between industrial chillers include the local control panel, remote control panel, fault indicators, temperature indicators, and pressure indicators.

Additional features include emergency alarms, hot gas bypass, city water switchover, and casters.

6.3.5 Type and size of chiller

The type and size of contingency cooling required by a facility are determined by several factors. In turn, the choice of chiller determines how the facility is prepared. Examples of parameters that determine the chiller are:

- Electrical requirements

- Ease of installation
- Location or available space for mobile chillers
- Comfort cooling / air conditioning or process cooling

6.3.6 Location of chiller equipment

Location can be a major factor in contingency planning. When selecting the location of the temporary equipment it is important to consider:

- Water and electrical connections location
- Sound sensitive areas in the facility
- Location easily accessible to service staff
- Equipment separated from the public
- Ambient conditions

6.3.7 Calculation Coefficient of performance

Current and voltage were measured by the clamp-meter, water flow rate was measured by the ultrasonic flow meter and temperature was measured by the thermometer

Table 6.3: parameter of Coefficient of performance

$\dot{m}$(Kg/s)	C_p (KJ/Kg.C)	T_{in}(C)	T_{out}(C)	I(A)	V(v)	PF
1.5	4.1813	29.6	19.5	48.6	410	0.9

$$COP = \frac{\text{Desired Output}}{\text{Required Input}}$$

Out put power = $\dot{m}$ * C_p * ΔT

Input power = I * V * √3 * PF

$$COP = \frac{\dot{m} * C_{p} * \Delta T * t}{I * V * \sqrt{3} * PF * t}$$

COP: Coefficient of performance

m : Flow rate water (Kg/s)

C_p: Specific heat for hot water. (KJ/kg.k)

ΔT: Input temperature – output temperature

t: time(s)

I: input current (A)

V: Voltage (v)

PF: Power factor

p_{in}= √3 * I * V * PF

p_{in} = 48.6 * 410 * √3 * 0.9 = 31.06 KW

p_{out}= $\dot{m}$ * C_p * ΔT

p_{out} = 1.5 * 4.1813 * (29.6 – 19.5) = 63.34 kW

$$COP = \frac{p_{out}}{p_{in}} = \frac{63.34}{31.06} = 2$$

7.1 Results And Conclusions

In the plant, the extruder is used for melting the plastic by means of heaters, those heater's temperatures can be calibrated on a desired value via a control unit, and when the heater reaches

(1) According to the lighting in the plant, there are some regions where larger number of lighting devices than required occurs, whereas there are other regions having minimized lighting level than the desired levels.

(2) Using occupancy sensors, saves energy by a rate of about 449.28 kWh/year which means a cost of about 65$/year.

(3) Pumps in the plant having energy losses of about 2496 (kW/year)which means a cost of about 361.92 ($/year) Due to using pumps of inappropriate power ratings.

(4) Fans in the plant have energy losses due to the friction with air (windage).

(5) Chillers have energy losses of about 25% from total energy.

(6) Motors have energy losses of about 2304 kW yearly Which means a cost of about 334 ($/year).

(7) Heaters also have energy losses of about 6107.52 kW yearly Which means a cost of about 1021($/year).

7.2 Project's Problems

(1) The inexistence of the Data logger instrument which is used for measuring power, relative humidity and other stuff.

(2) The problem of measuring the actual output power of motors due to the inexistence of torque and speed meters.

(3) The presence of defected lighting devices which in turn results in inaccuracy when making calculations and measurements.

(4) The difficulty of measuring voltages and currents of some motors due to the difficulty to reach to the wires and connections.

7.3 Recommendations

(1) Insuring the usage of occupancy sensors in lighting systems as a step for achieving energy saving.

(2) Using cooling towers instead of chillers due to same service offered with less power consumption.

(3) The necessity of insulating extruders using an insulation system to keep the temperatures levels as required.

(4) Using reliable control systems for controlling the operations of fans to keep temperatures within the desired levels, such as PLC, Microcontroller, ….etc.

Table (A-1) Typical reflectance values

	Ceiling	Walls	Floor
Air Conditioned Office	0.7	0.5	0.2
Light Industrial	0.5	0.3	0.1
Heavy Industrial	0.3	0.2	0.1

Table (A-2) Typical LLF Values

Air Conditioned Office	0.8
Clean Industrial	0.7
Dirty Industrial	0.6

Table (A-3) Room Utilization Factor

Room utilisation factor										
Luminaries ceiling mounted Reflectances ρ										
Ceiling	0.8	0.8	0.8	0.5	0.5	0.8	0.8	0.5	0.5	0.3
Wall	0.8	0.5	0.3	0.5	0.3	0.8	0.3	0.5	0.3	0.3
Surface	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1
Room factor k	Room utilisation factor in %									
0.6	73	46	37	44	36	66	36	42	35	35
0.8	82	57	47	54	46	74	45	51	44	44
1.0	91	66	56	62	54	80	53	59	52	51
1.25	98	75	65	70	62	85	61	66	60	59
1.5	103	82	73	76	69	89	67	72	66	65
2.0	109	91	82	84	78	94	75	78	73	72
2.5	114	98	90	90	84	97	81	83	79	77
3.0	117	103	96	95	90	99	86	87	83	82
4.0	120	109	103	100	95	101	91	91	88	86
5.0	122	113	107	103	98	103	93	93	91	89

Table (A-4) Room Index Tables

1- First floor

Region #	Length (m)	Width (m)	High (m)	Area (m^2)	Room Index (RI)
Entrance	8.3	10.5	4.4	87.15	1.0535
Plastic glasses manufacturing	27.6	13.9	4.4	383.64	2.1009
Recycle	7.6	4.6	4.4	34.96	0.6512
Clips skin#1	9.858	11.4	4.4	112.39	1.201
Sewing machines	3.8	5.5	4.4	20.9	0.5107
Office#1	8	5.803	4.4	46.425	0.764
Office#2	2.85	3.50	2	9.975	0.785
Office#3	4.50	4.50	2	20.25	1.125

2- Second floor

Region #	Length (m)	Width (m)	High (m)	Area (m^2)	Room Index (RI)
Section #1	25.6	13.9	3	355.84	3.0028
Section #2	8	10.9	3	89.2	1.5731
Section #3	15.88	5.25	3	83.37	1.3151
Section #4	7.88	10.7	3	84.316	1.5126
Section #5	8	10.7	3	85.6	1.5258

3- Third floor

Region #	Length (m)	Width (m)	High (m)	Area (m^2)	Room Index (RI)
Section #1	15.88	15.95	3	253.286	2.652
Section #2	15.88	13.9	3	220.732	2.470
Section #3	17.72	13.9	3	246.308	2.596

Table (A-5) Information tables

1- First floor

Region #	Power (w) For each fitting	Utilization Factor (UF)	Light Loss Factor (LLF)	Flux (Lumen)
Entrance	1*36	0.527	0.6	2300
Plastic glasses manufacturing	1*36	0.75	0.6	2300
Recycle	1*36	0.373	0.6	2300
Clips skin	1.36	0.573	0.6	2300
Sewing machines	1*36	0.309	0.6	2300
Office#1	1*36	0.423	0.8	2300
Office#2	1*36	0.433	0.8	2300
Office#3	1*36	0.550	0.8	2300

2- Second floor

Region #	Power (w) For each fitting	Utilization Factor (UF)	Light Loss Factor (LLF)	Flux (Lumen)
Section #1	1*36	0.8201	0.6	2300
Section #2	1*36	0.6602	0.6	2300
Section #3	1*36	06056	0.6	2300
Section #4	1*36	0.6517	0.6	2300
Section #5	1*36	0.6536	0.6	2300

3- Third floor

Region #	Power (w) For each fitting	Utilization Factor (UF)	Light Loss Factor (LLF)	Flux (Lumen)
Section #1	1*36	0.7852	0.8	2300
Section #2	1*36	0.7670	0.8	2300
Section #3	1*36	0.7796	0.8	2300

Table (A-6) Number of fitting in each space

1- **First floor**

Region #	Power (w) For each fitting	Actual No. of light	Recommended No. of Light	Recommended Flux (fc)	Measured Flux (fc)		
					Min	Max	Ave
Entrance	1*36	2	5.99	15	2.35	2.59	2.43
Plastic glasses manufacturing	1*36	40	39.879	10	9.1	11.60	10.35
Recycle	1*36	3	7.3	10	6.61	6.65	6.63
Clips skin	1.36	11	15.29	10	21.3	25.3	22.77
Sewing machines	1*36	2	7.91	15	7	7.1	7.05
Office#1	1*36	1	0.6138	10	12.60	12.70	12.65
Office#2	1*36	1	3.533	20	3.42	3.61	3.51
Office#3	1*36	6	6.4	30	13.11	13.70	13.40

2- Second floor

Region #	Power (w) For each fitting	Actual No. of light	Recommended No. of Light	Recommended Flux (fc)	Measured Flux (fc)		
					Min.	Max.	Ave.
Section #1	1*36	39	50.76	15	13.3	19.05	15.19
Section #2	1*36	5	10.53	10	5.56	7.31	6.43
Section #3	1*36	7	10.74	10	2.30	6.65	4.44
Section #4	1*36	8	10.1	10	13.40	13.85	13.62
Section #5	1*36	3	10.2	10	2.38	2.66	2.52

3-Thirdfloor

Region #	Power (w) For each fitting	Actual No. of light	Recommended No. of Light	Recommended Flux (fc)	Measured Flux (fc)		
					Min.	Max.	Ave.
Section #1	1*36	16	28.29	20	10.52	26	17.95
Section #2	1*36	18	25.24	30	22.2	22.3	22.25
Section #3	1*36	16	27.71	30	2.44	12.1	7.31

Table(b-1) power losses of motors in the extruder

Electrical Motors	**Current (A)**	**Voltage (V)**	**Power Factor(PF)**	P_{out} **(kW)**	**(kW)**	**L Loss (kW)**
Main Motor	69.16	415	0.9	44.742	63	18.258
Shell Roll Motor (Pressure Motor)	11.3	415	0.9	5.5	7.3	1.8
Pull Roll Motor	4.8	415	0.9	2.2	3.1	0.9
Winder Motor (A and B)	2.13	415	0.9	1.5	2	05
Blower Motor(A)	0.44	415	0.9	0.155	0.29	0.135
Blower Motor(B)	0.42	415	0.9	0.155	0.27	0.115
Blower Motor(C)	0.46	415	0.9	0.155	0.3	0.145
Blower Motor(D)	0.44	415	0.9	0.155	0.29	0.135
Blower Motor(E)	0.45	415	0.9	0.155	0.28	0.125
Crane Motor	2.6	415	0.9	1.02	1.7	0.68
Total Power	**92.2**	**415**	**0.9**	**55.737**	**78.53**	**22.793**

Table (b-1) power losses of motors in thermoforming

Electrical Motors	**Current (I)**	**Voltage (V)**	**Power Factor(PF)**	P_{out}		**Loss**
Un-winder Motor	1.63	415	0.9	0.75	1	0.25
Index Motor	4.3	415	0.9	1.9952	2.8	0.81
Main Motor	1.45	415	0.9	0.68944	0.93	025
Plug Motor	1.87	415	0.9	0.8618	1.2	0.34
Scrap Motor	0.8	415	0.9	0.37	0.52	0.15
Stucker Motor	0.72	415	0.9	0.37	0.5	0.13
Isolator Motor	3	415	0.9	1.5	2	0.5
Total Power	**13.77**	**415**	**0.9**	**6.53644**	**8.95**	**2.4**

Table(b-2) power losses of motors of crusher motors

Electrical Motors	**Current (I)**	**Voltage (V)**	**Power Factor(PF)**	P_{out}	P_{in}	**Loss**
Main Motor	3	415	0.9	1.5	2	0.5
Staking Motor	0.64	415	0.9	0.226	0.3	0.074
Blower Motor	1.5	415	0.9	0.7	1	0.3
Total Power	**5.14**	**415**	**0.9**	**2.426**	**3.3**	**0.874**

Table(b-2) power losses of grinding motors

Electrical Motors	Current (I)	Voltage (V)	Power Factor(PF)	P_{out}	P_{in}	Loss
Grinding Motors(1)	48.7	415	0.9	22.371	31.52	9.15
Grinding Motors(2)	47	415	0.9	22.371	30.5	8.13
Grinding Motors(3)	47.7	415	0.9	22.371	30.9	8.53
Suction Motors(1)	1.5	415	0.9	0.7457	1	0.26
Suction Motors(2)	1.7	415	0.9	0.7457	1.1	0.36
Suction Motors(3)	3	415	0.9	1.4914	2	0.51
Roll pulling Motors	4.8	415	0.9	2.2371	3.1	0.87
Total power	**154.4**	**415**	**0.9**	**72.3329**	**100.12**	**27.8**

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Appendix A

Appendix B

Appendix C