وزارة المياه والري

USAID

WEPIA

Water Efficiency and Public Information for Action

مشــروع الـكـفــاءة المــائـيــة والـتـوعـيــة

AED

Academy for Educational Development

أكاديمية التطوير التربوي (واشنطن)

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Energy Management
&
Conservation Manual

Prepared by EMS

Submitted to:

THE WATER EFFICIENCY AND PUBLIC
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Section I

Introduction

Introduction

Before 1970 the supply and consumption of energy were relatively obscure matters to most people. They were, in fact, functions largely taken for granted. Within less than a decade, however, "energy" has emerged as one of the more provocative words of the times. The shortages and higher prices that arrived with the oil embargo of 1973 - 1974 inspired, among other things a great appreciation of the need for energy conservation.

The rapid economical development, in Jordan combined with the expensive imported fuel prices; led to an increasing recognition and understanding of the need to Energy Management.

Jordan depends almost entirely on imported energy. Our energy consumption (petrol) increased from 1.692 million tons oil in 1980 to 4.673 million tons equivalent in 1998; the cost of which represents 10 - 15 percent of our national products, and a very high percentage of our total product exports. Yet consumers still experience a great lack of awareness of the potential benefits of energy efficiency; there appears to be an inability to define energy related problems and to identify specific areas where savings could be achieved. This is due to lack of expertise in this sector. A study, which was conducted for medium-size industries in Jordan, estimated the potential energy savings to be in the order of 100 million dollars per year.

This energy manual is introduced to you by **Energy Management Services** with the cooperation with **WEPIA**.

The main objective of it is to help asses your energy consumption, plus introducing some energy savings measure, which will help you in reducing your energy bills.

Jordanians have been in the forefront of water conservation for many years. Several projects and actions on the part of Government and citizens alike show that they are world leaders in implementing water conservation behavior. One remaining gap is the implementation and use of water saving devices that make both the supply and consumption of water by the end user, more efficient. It is this gap that **WEPIA** hopes to fill.

What is WEPIA?

WEPIA is a strategic social marketing program of the Academy for Educational Development funder by USAID, in collaboration with the Ministry of Water and Irrigation.

WEPIA is a three-year program with two broad programmatic areas related to water demand management. The first broad area looks at immediate actions towards adopting water efficient technologies, such as water saving devices. The second area addresses the next generation and its attitudes towards water consumption.

What is AED?

The Academy for Educational Development (AED) is a US non-governmental organization with over forty years of development experience in public education and social marketing. AED pioneered efforts in all aspects of development communication, and for the last five years has been a leader in the provision of environmental education. AED's environmental work has taken place in over 23 countries working on such issues as water quality, water conservation, coastal resource management, forest management, urban issues and social issues.

How does WEPIA work?

WEPIA works with a number of non-governmental organizations as its implementing partners. Among these partners are Jordan Environment Society, Royal Society for the Conservation of Nature, Jordan University for Science and Technology, University of Jordan, Center for the Study of the Built Environment, Haya Cultural Center, the Latin Patriarchate Schools and Sharqiyat. Through guided practice **WEPIA** develops the capacity of these partners to deliver water conservation services. Other partner associations represent hotels, hospitals, universities and schools. Policy makers and commercial vendors work with **WEPIA** ensuring that the devices for water efficiency are available. Research agencies and the media also support **WEPIA** for evaluation and promotional purposes.

What is EMS?

Energy Management Services (EMS), was established in 1991 in response to the severe market need of an organization specialized in the management and conservation of Jordan's water and energy resources, and help providing a better environment to the society.

The methodology is to help increase the awareness and needs of environmental services in both the industrial and commercial sectors in particular and the public in general.

EMS, being the first and only private sector organization specialized in this field, adopted a unique approach to introduce this novel concept to the Jordanian market; EMS proposes to their clients a *Performance Consultancy* and *Contracting Agreement*. By which EMS conducts the environmental and energy studies, audits, supply and installation of relevant

Equipment and provides Consultancy services; where **EMS** finances all the stages of the agreement from its own resources, against sharing the results and savings of the project with the client throughout the agreement period, after which the client owns the equipment and enjoys all the savings. This approach provides the incentive to encourage consumers to adopt conservation methods.

The highly experienced engineering team, supported by the most advanced instruments and tools, qualifies the execution of projects in a professional manner resulting in maximum savings to our clients.

Section II

Energy Conservation Program

Topics that will be covered in this session

- The Concept of Energy Management.
- Barriers to Energy Conservation.
- Energy Conservation & the Environment.
- Energy Audit Procedure.
- Measurement and Data Collection.
- Measures Evaluation Procedure.
- Investment & Payback.
- Audit Report.
- Audit Presentation.

Tips

- The cost of conserving energy represents 25% of the cost of generating it.
- Only 65% of the world primary energy consumption is delivered to consumers.
- Use the general questionnaire provided in Appendix I to gain general data about the project.
- Use the Audit forms provided in Appendix J to collect the data required to calculate the energy saving measures.
- Take the Audit form with you to the site, in order to know the data needed for the calculations.
- Don't forget to calculate the Payback period for energy suggested measure.

Energy Conservation Program

- Business objectives
- Energy conservation barriers and incentives
- Energy conservation and environment
- Rapid energy audit
- Success stories

Business Objectives

The "objectives" behind any business are:

- Profits increase,
- Market share expanding,
- And competitiveness enhancement.

For which, one of the methods to increase profits and reduce cost is energy management and energy conservation.

Energy Conservation and Management

- The oil embargo of 1973 - 1974 inspired, the need for energy conservation programs and energy saving technologies.
- Energy efficiency is very cost effective when compared to other supply options (The cost of conserving energy represents 25% of the cost of generating it).
- Only about 65% of the world primary energy consumption is delivered to consumers.
- It is also the cleanest option.
- All of the above plus monetary savings

THE CONCEPT OF ENERGY MANAGEMENT

- Operating cost reduction.
- Equipment optimization.
- Reduced maintenance time.
- Capital cost reduction during design stage.
- Availability of more power to be utilized for higher production levels.
- Enhancement of the environmental image of the facilities.

BARRIERS

- Lack of know-how & technology to evaluate existing situation & proposing the needed economical measures.
- Availability of man power.
- Other business related priorities.
- Guaranteeing the savings.
- Funds availability.

Energy Conservation & Environment

Energy conservation walks hand in hand with the environment protection, since energy conservation will:

- Reduce hot gases emissions
- Reduce water vapor in the atmosphere
- Reduce waste water
- Improve working environment
- Reduce hazardous and hot surfaces
- Saving 100 liter of Diesel will reduce the gases emissions by 273 kg CO_2 equivalent.
- Saving 100 kWh will reduce the gases emissions by 100 kg CO_2 equivalent.

Energy Conservation Program

- Energy Audit.
- Energy Saving Study (Report).
- Implementation.
- Project Management & FU.

Rapid Energy Audit

- Energy Audit means:

Undertaking a comprehensive "Energy conservation Evaluation" of the establishment under study, then come up with energy saving opportunities and measures.

The Goal

- Will be to develop a variety of feasible energy conservation proposals and recommendations aimed at reducing the annual energy consumption and (if possible) increase the efficiency of the establishment without loss of comfort to the occupants/operation.

Energy Saving Measures

Are those proposed steps and procedures to reduce client's energy consumption and cost based on observed opportunities and actual measurements?

AUDIT PROCEDURE

1. Action Plan and Walkthrough
2. Measurements and Data Collection
3. *Monitoring*
4. Analysis and Calculations
5. Investment and Pricing
6. Measures Evaluation
7. Audit Report
8. Presentation

Action Plan

- In Commercial Building the main energy consumption would always be concentrated in auxiliaries that supports the services, such as HVAC systems, boiler, cooling towers, chillers, lighting, water usage, etc...
- Data collected would be on their capacities, working hours, occupancy of the facilities, design criteria and optimization.

WALK-THROUGH

The purpose of the Walk-through survey visit is to familiarize the team with the establishment, its zones, circulation and general environment.

- Upon arrival, your counter-part may brief you on the plan for the day and routing.
- Tour starts from the services departments.
- During the tour note down process details, remarks, observations and questions.
- Fill in the Energy questionnaire

WALK-THROUGH PROCEDURE

Observations and identified opportunities may be in three main areas:

A. Losses in Auxiliaries.
B. Main Energy Consumers.
C. Old Facilities

A. Losses in Auxiliaries such as:

1. UN insulated hot/cold pipes or surfaces
2. Steam leaks
3. Condensate drain to sewer
4. Excessive lighting
5. Lit unoccupied area
6 External lighting
7. Settings (Pressure - Temperature)
8. Hot streams

B. Main Energy Consumers such as:

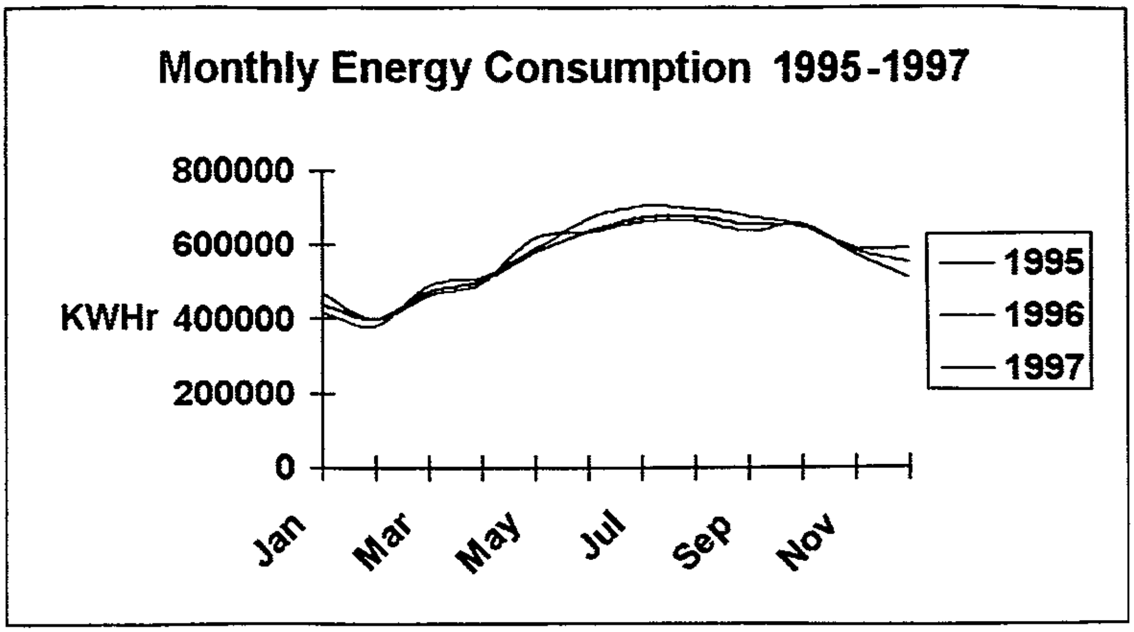
1. Ventilation systems
2. Kitchen
3. Pumps
4. Chillers
5. Mills
6. Laundry
8. Air compressors
9. Lighting

C. Old Facilities also have hidden energy saving potential. Make a note on your check list form

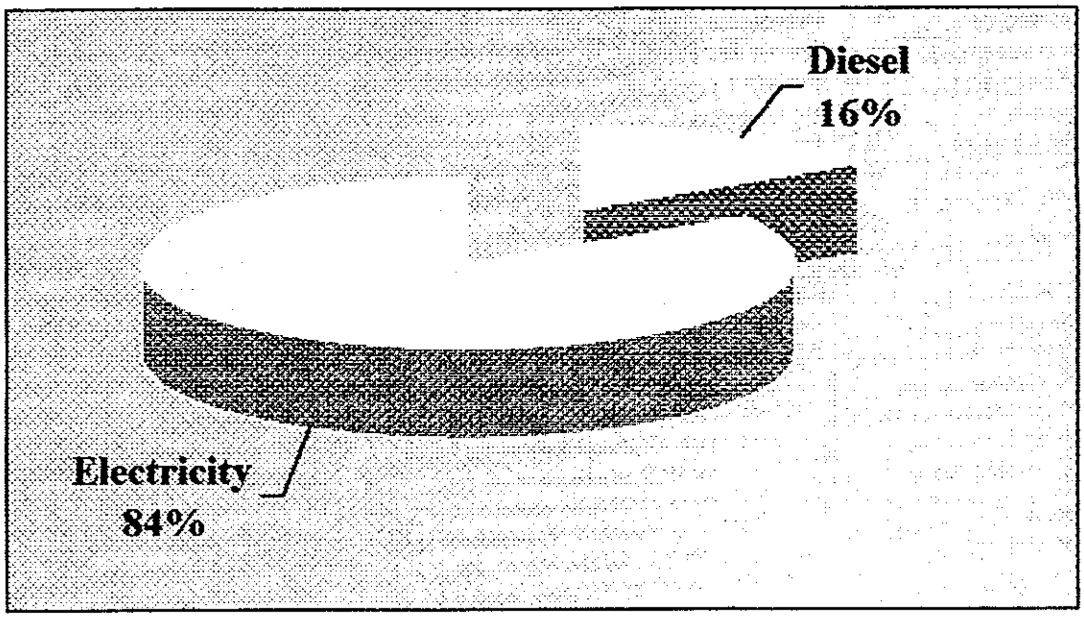
WALK-THROUGH FINDINGS

- Determine main areas with highest potential and hence set a priority list.
- Use your Check List to spot energy measures.
- Determine essential data and measurements needed to confirm savings potentials.
- Set an action plan for preliminary measurement and data collection.

Analysis of Energy Bills



Sectorial Distribution of Energy Consumption (kWh)



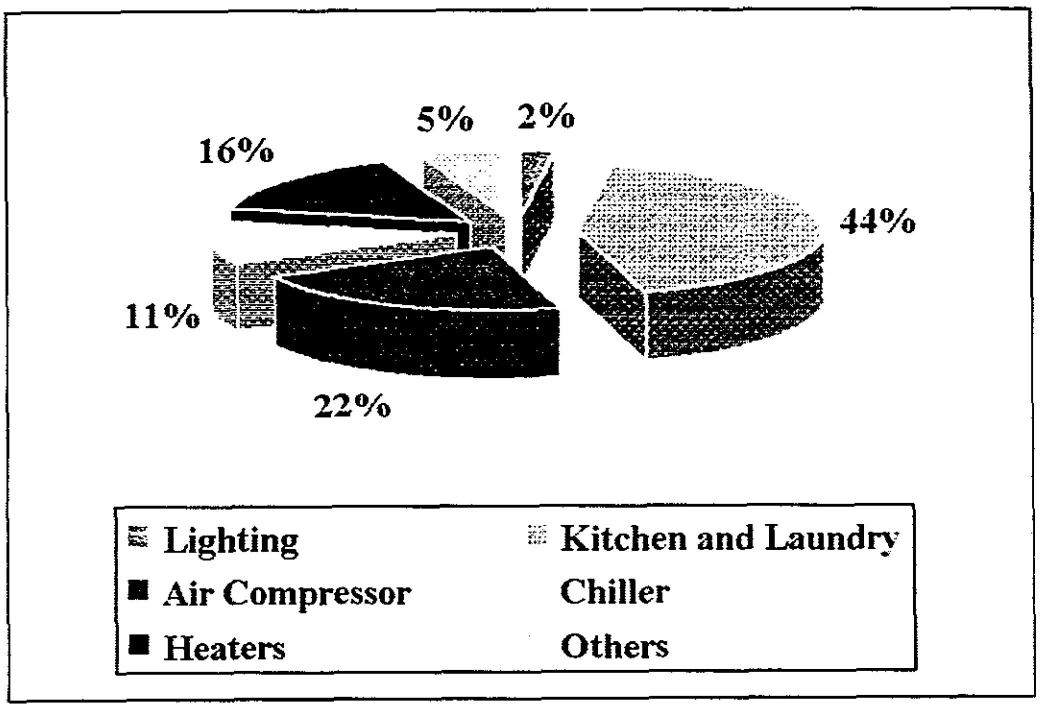
ON-SITE MEASUREMENTS AND DATA COLLECTION

- The purpose of the "On-Site measurement and data collection" is to confirm and quantify the saving opportunities identified during the Walk-through
- The data collection should be as precise as possible and as efficient as possible.

MEASUREMENT AND DATA COLLECTION

- This include measurements to ensure the savings, and searching for new measures.
- This step would require mostly instantaneous measurement, and quantifying measures.
- Proving the savings to client based on:
  - Theoretical method (scientific equations)
  - Actual consumption / production.
  - Random Check.

Energy Bill Sectorial Distribution



Monitoring

- The measures with high potential, deserves to be monitored for a period of time, as deemed necessary, to confirm pattern of behavior and notice any changes associated with out side influencing factors.

- Monitoring should cover all variables that could influence consumption.

ANALYSIS AND CALCULATIONS

- The Propose of this stage is to analyze the findings, complete the calculations and calculate the energy savings.
- Energy Saving will be the difference between the current consumption and the assumed consumption after implementing the measure

Measures Evaluation

- Use the figures produced from your actual measurement and data collected.
- Do NOT introduce non-realistic factors into your calculations and assumptions.
- Do NOT over estimate the savings.
- All measures should be evaluated and approved as follow:

MEASURES EVALUATION PROCEDURE

- Savings and investment.
- Ability to measure and availability of measuring instrument.
- Technology and know how.
- Space.
- Implementation.
- Follow – up.

Investment and Pricing

- Investment is a crucial part of the measure, and is as important as the savings calculated. Make sure that you included all investments related to the measure:
- Initial costs (Equipment, instrumentation, import duties, transportation, accessories, protection, installation, labor, commissioning).
- Running costs (Spare Parts, maintenance, labor, utilities)

Pay-Back Period

- It is the time that should elapse for the operation of measure producing the savings to re-imbrues the investment.
- Pay-back period (years) = Investment/ Savings in one year
- consider feasible measures those with pay-back periods of between 0 - 24 months.

Audit Report

A typical audit report should include the following sections:

1. Introduction.
2. Executive Summary.
3. Establishment General Description.
4. Energy consumption analysis and breakdown.
5. Energy Saving Measures:
    - Summary description.
    - Measurement & Reference Data.
    - Analysis.
    - Recommendations.
    - Savings sample calculation.
6. Energy conservation theory.

Audit Presentation

- Once the audit report is complete and ready to be submitted to the client, set a date and place for submitting the audit report and performing the presentation.

SEQUENCE OF THE PRESENTATION

6. Introduction.
7. Energy Audit Findings & Results.
8. Energy Conservation Proposals.
9. Audit Conclusion.
10. Discussion.
11. Audit Report Submittal.
12. Minutes of Meeting.

Section III

Lighting System

Topics that will be covered in this session

- Lighting Survey.
- Families of Lamps.
- Energy Savings Opportunities.
  1. Turning off excess lighting.
  2. Lamp substitution.
  3. Energy efficient reflectors.
  4. Electronic Ballasts.
  5. Programmable timers.
  6. Time delay timers.
  7. Occupancy Detectors & Photo cell.

Tips

- Lighting consumes about 4% of the world Energy Consumption.
- Lighting Consumption is major in Commercial Sector.
- Always paint the walls with light colors.
- Always study the economical feasibility of any suggested energy saving measure.
- Don't forget to include the labor cost and accessories in the investment.

BACKGROUND

- *Lighting Consumes about 4 % of The World Energy Consumption.*
- *Different Types With Different Performance & Energy C/S's Exist.*
- *Lighting Consumption is Major in Commercial Sector, Less in Industrial Sector*

Building or Entity Analysis

- ***Recommended Procedure:***

1. Conduct a Survey, or:
2. Review Project Plans
   - Less Satisfactory.
   - Do Random Check.

Lighting Survey

It is needed to collect the following information:

- Seeing Tasks & Their Location.
- Type & Quantity of Existing System.
- Present Lighting Levels.
- Lighting Control / Space.
- Reflectance of Walls, Ceiling & Floor.
- Space Geometry (Area Dimensions).
- Operating Schedules.

Please refer to the lighting survey form at the appendix.

Evaluation

1. Evaluation of Individual Spaces.

   Evaluate each space alone, not the whole building.

2. Study Possible Improvements:

   - Consider Different Options.
   - Choose Most Economical & Practical option.

Two Choices to be made in making changes in a Lighting System:

1. **Modification of Existing System.**
   - Simplest Way.
   - Examples:
     - Replacing Lamps.
     - Change Switching Circuits.

2. Replacement with Another System

- Requires Higher Investment.
- Should Be Economically Justified.
- **Example:**

- 1000W Mercury Lamp gives 44700 Lumens.
- Replace it with 400W High Pressure Sodium that gives 45000 Lumens.
- Savings = 605 W Per Fixture.
- Same Light Level is maintained.
- Annual Savings = JD 223
- Investment = JD 267
- P/B Period = 14 Months
- Result: Proposal is justified.

Priorities

The following should be taken into consideration :

- Initial Cost.
- Client Needs & Requirements.
- Applicability.
- Feasibility.
- Timing.

Initial Cost VS. Annual Operating Cost

Initial Costs Include:

- Lamps or Fixtures.
- Wiring.
- Installation.

Annual Costs Include:

- Failure Lamp Replacement.
- Maintenance.
- Electricity (Energy).

Task Lighting Objective

To Provide:

- Task Related Illumination.
- Avoid Unnecessarily High Levels of Uniform Lighting Throughout the Space.

Lighting Levels

The recommended illuminance levels could be obtained from:

1. IES Lighting Handbook (USA).

2. CIBSE Code (UK).

At the design stage consider both:

1. Quantity of Light
2. Quality of Light

Illuminance Modifications

1. Lower Luminaires Closer To Work Surface:

- Use Lower Wattage Lamps.

2. Relocation of Luminaires:

- Remove Unnecessary Luminaires.

Non Illuminance Modifications

Does Not Involve Lamps, Luminaires, or Other System Components.

- Examples:
  - Group Similar Tasks in One Area.
  - Group Workers Having Similar Operating Schedule in One Area.

Reflectance

- Reflectance of Walls, Ceilings, and Floor Affect The Illumination Levels.
- Light Colors Have Higher Reflectance.
- Avoid Excessively Bright Surfaces.
- As a Guide, IES Recommends:
  - For Office-Type Spaces :
  - Ceiling : 80 - 90 %.
  - Walls : 40 - 60 %.
  - Floors : 20 - 40 %.

Space Geometry

Space Dimensions affect the Distribution of Light in The Area.

- Length.
- Width.
- Height.

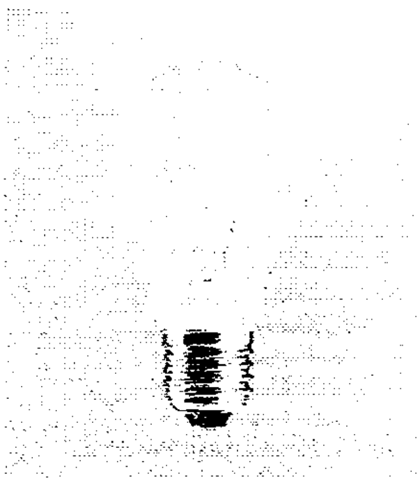
- Open Areas are More Efficient.
- Introduction of Partitions Reduce Illumination.
- Large Rooms Utilize Lighting Energy Better Than Do Small Rooms.
- High Ceiling are Less Efficient.

Families Of Lamps

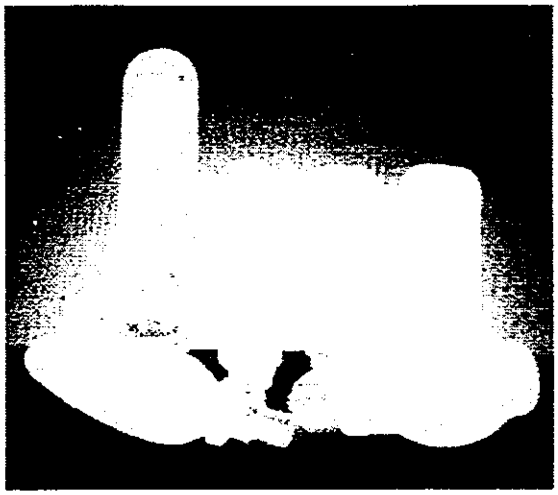
1. Incandescent & Tungsten Halogen.
2. Fluorescent.
3. High Intensity Discharge Lamps.

   A. Mercury Vapor Lamps.
   B. Metal Halide Lamps.
   C. High Pressure Sodium Lamps.
   D. Low Pressure Sodium Lamps.

Incandescent & Tungsten Halogen



Incandescent Lamp



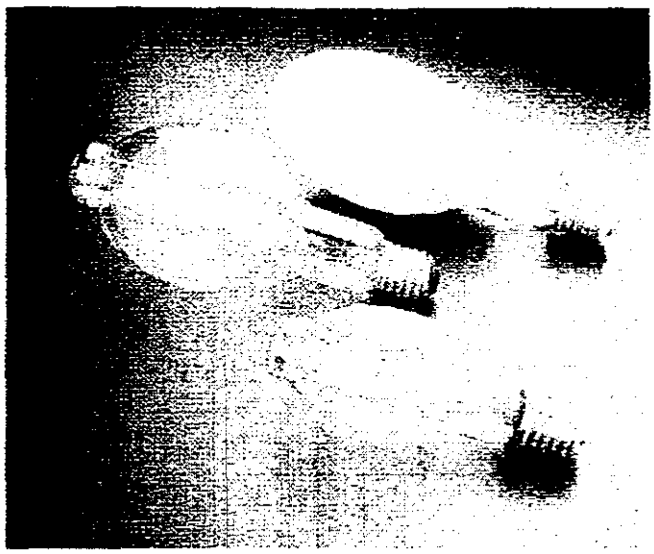
Halogen Lamps

- Produces Light By Electrical Heating of a Wire (Filament) till Radiation.
- Filled with Inert Gas (N, AR).
- The Cap:
  - E: Edison (Screw).
  - B: Bayonet.
- Halogen: Filled with Halogen.
- Rating: 15 -2000 Watt.

Fluorescent Lamps

- Light is Produced By Fluorescent Powders Activated By the Ultraviolet Energy of the Discharge.
- Contains Mercury Vapor at L.P.
- Requires a Ballast & Starter.

HID - Mercury Vapor Lamps



- Produces Light When Electrical Current Passes Through a Small Amount of Mercury Vapor.
- Consists of Two Glass Envelopes.
- Requires a Ballast to Operate.
- Rating: 50 - 1000 Watt.
- Very Similar in Construction to Mercury Lamps.
- Major Difference:
  Contains Various Metal Halide Additives in Addition to Mercury Vapor.
- Rating: 70 - 3500W.

HID - High Pressure Sodium

- Light is Produced When Electrical Current Passes Through a Sodium Vapor.
- Has Two Envelopes:
  - Inner - In Which Light Producing Arc is Struck.
  - Outer - Protective, Clear or Coated.
- Light Color is Golden Yellow.
- Most Efficient of ALL.
- Has a Monochromatic Light Output (Yellow).
- Used Where Color is Not Important.
- Sodium Vapor in Evacuated Envelope Produce The Light.
- Rating: 18 -180 Watt.

How to Define Lamp Type?

- By Shape.
- By Light Color.
- By Starting Time.
- By Model No.

Manufacturer	Incandescent	Halogen	Fluorescent	Blended Mercury
Philips	Standard A	500 T3 Q / CL / P	TL ' D36 W / 25	ML 160 W
Osram	HR IM	64702 Halo LINE	L 36 / 25	HWL

Manufacturer	Mercury	Metal Halide	H.P. Sodium	L.P. Sodium
Philips	HPL	HPI-MHD	SON - SDW	SOX
Osram	HQL	HQI	NAV	SOX

Energy Saving In Lighting System

- **Energy (kWh) = kW x Hours.**

Energy Can Be Saved By:

A. Reducing Electrical Load (Power).
B. Reducing the Operating Time.

Energy Saving Opportunities

Group A: Reducing the Power.

- Turning OFF Excess Lighting.
- Lamp Substitution.
- Energy Efficient Reflectors.
- Electronic Ballasts.

Group B: Reducing the Power.

- Programmable Timers.
- Time Delay Timers.
- Occupancy Detectors & Photocell.

1. <u>Turning OFF Excess Lighting:</u>

- Lighting Levels Standards:
  - CIBSE CODE (UK).
  - IES Lighting Standards (USA).
- Lighting Level is Measured in Lux or Foot Candle Units.
  - 1 FC = 10.76 Lux.

Identifying The Measure:

- Measure in Different Locations of the Area (Record Notes).
- Compare with Standard Value.
- If Measured > Standard then;

  → There is a Possibility to Remove Units or Lamps.

Calculations

Measured Lux = X

Standard Lux = Y

Excess Lamps % = (X-Y) / X *100%.

Excess Lamps = Excess Lamps % * Existing number of lamps.

Saved Elec. Load (kW) = Excess Lamps x (Lamp Watt. + Ballast Watt.)

Saved Elec. Consumption (kWh) = Saved Load (kW) x Operating Hours.

Savings in Energy Cost (JD) =Saved Elec. Cons. (kWh) x Elec. Tariff (JD/kWh).

Electricity Tariff:

- Residential: Slides (0.033, 0.055, 0.063, 0.078 JD/kWh)
- Commercial: Flat 0.063 JD/kWh

Example : Hospital - Laundry Area

Excess Lamps % = [(415 - 300) / 415] x 100%

= 27.7 %.

Excess Lamps (EL) = 27.7 % x 14 = 4 Lamps (After Rounding)

Saved Electrical Load (kW) = No. of Reduced Lamps x (Lamp kW + Ballast kW)

= 4 x (0.036 + 0.010) = 0.184 kW.

Saved Elec. Consumption (kWh) = Saved Elec. Load (Power) x Operating Hours

= 0.184 kW x 8 H/D x 30 D/M x 12 M/Y

= 530 kWh / Year

Savings (JD) = Saved Cons. x Elec. Tariff.

= 530 kWh x 0.063 JD/kWh.

= 33.4 JD/Year.

2. Lamp Substitution

A. One-For-One Lamp Substitution.

B. Family to another Family Substitution.

- Families of Lamps:

  - Low Pressure Sodium.
  - High Pressure Sodium.
  - Metal Halide.
  - Fluorescent.
  - Mercury.
  - Incandescent & Tungsten Halogen.

Highest Efficacy

↓

Highest Efficacy

- Efficacy = Lamp Lumens / Lamp Wattage.

A. One-For-One Lamp Substitution.

- Replace Existing Lamp by a Lower Wattage Lamp.

  - Same Socket.
  - Same Luminaire.
  - Provide Required Illumination.
  - Achieve Required Color C/S's.

Example: Replace Inc. 60W Lamp by Energy Efficient Compact Fluorescent 15W.

- Inc. 60W : 730 Lumens, E27 Socket
  220 V, No Ballast.

- C. FL. 15W : 900 Lumens, E27 Socket
  220 V, Built in Ballast.

- 75 % Energy Saving + 23 % Higher Illumination.

Example: Replace FL. 40W Lamp by FL. 36W.

- Similar or Higher Lumens.

- Save 10 % of Energy Consumption.

- Replace Old Fluorescent Lamps by New More Efficient Ones.

B. Family to another Family Substitution.

- Replace Existing Lamps by another Type which has:

  1. Higher Efficacy
  2. Required or Acceptable C/S's.

- Need to Replace the Whole Unit,

Or ..

- Only Replace the Lamp & Control Gear.

Examples:

- Replace Incandescent Lamps By Fluorescent Lamps Fixtures.
- Replace Tungsten Halogen Fixtures By H. P. Sodium or Metal Halide Units.
- Replace Mercury Units By H. P. Sodium or Metal Halide Units.

Measurements Required

1. Lux Measurements.
   - Luxmeter
2. Electrical Load Measurements
   - Digital Multi Meter Or..
   - Power Demand Analyzer.
3. Operating Hours.

Accurate data can be taken from the lamp or manufacturer catalogues. Operating hours can be taken from area users

Calculations

- Similar to Those of Turning OFF Excess Lighting Measure
- Calculate:

  1. Existing System Consumption & Cost
  2. Proposed System Consumption & Cost
  3. Savings = Difference

Example: Outdoor Front Wall Lighting

Existing Lamp Type	: Inc. 100W.
No. of Existing Lamps	: 16.
Lighting Operating Time	: 12 Hours/Day.
Proposed Lamps Type	: C. FL. 20W.

• Inc. 100W	: 1380 Lumens.
• C. FL. 20W	: 1200 Lumens.

Existing Situation:

Lighting Load	= No. of Lamps x (Lamp kW x Ballast kW)
	= 16 x 0.100 = 1.6 kW
Elec. Consumption	= Lighting Load x Operating Hours = 1.6 kW x 12 H/D x 365 D/Y = 7008.0 kWh/Year
Energy Cost	= Elec. Cons. x Electrical Tariff = 7008 kWh x 0.063 JD/kWh = 441.5 JD/Year

Proposed Situation :

Lighting Load	= No. of Lamps x (Lamp kW x Ballast kW) = 16 x 0.020 = 0.32 kW
Elec. Consumption	= Lighting Load x Operating Hours = 0.32 kW x 12 H/D x 365 D/Y = 1401.6 kWh/Year
Energy Cost	= Elec. Cons. x Electrical Tariff = 1401.6 kWh x 0.063 JD/kWh = 88.3 JD/Year
Savings	= 441.5 – 88.3
	= 353.2 JD/Year

3. Efficient Reflectors

- Lighting Design Equation

$$N = \frac{E * A}{FL*UL*MF}$$

$$N = \frac{k}{UL}$$

Where,

E	:	Required Lux.
FL	:	Lamp Lumens.
A	:	Room Area (m2)
UF	:	Utilization Factor.
MF	:	Maintenance Factor.

UF Depends On:

- Luminaire (Reflector).
- Room Colors (Walls, Ceiling)
- Room Index (Length, Width, Height)

$$\text{Room Index} = \frac{L \times W}{(L + W) \times H}$$

Fluorescent Lighting:

- Sometimes No Reflector Exist then;
  - 50 % of Light is Wasted Upward.
- Normal Reflector Exist then;
  - Part of Light is Absorbed.
  - Part of Light is Wasted Inside the Luminaire.

Depending on Wall Reflectance & Room Index:

- If No Reflector Exist then: UF: 0.22 - 0.87.
- If Normal Reflector Exist then: UF: 0.39 - 0.89.
- Using Efficient Reflectors: **UF: 0.80 ~ Approx. 1 Can Be Reached.**
- From Lighting Design Equation:

$$N = \frac{k}{UL}$$

N: Required Number of lighting units to achieve certain Lux.

Data Required

In Addition to All Data Collected During Lighting Survey;

- Details about Existing Lighting Fixture.
- Type & Rating.
- Dimensions.
- Manufacturer.

Therefore, Installing energy efficient reflectors will improve the utilization factor (approximately doubled) , and we can remove half at the lamps from fluorescent units without affecting the illumination level.

4. Electronic Ballasts

- Fluorescent Lighting Need a Ballast to Operate.
- Conventional Ballasts are Used.
- Conv. Ballast, Core & Coil, Iron Cored, Magnetic Ballast are Several Names for the Same Devices.

Disadvantages of Conventional Ballasts

- High Power Loss (10 - 20 %).
- Limited Frequency: Reduces Lamp Efficiency.
- Lower Lamp Lumens Due to Ballast Resistance.
- Need a Starter.
- Heat Sources.
- Affected by Low Temperature.
- Relatively, Heavy Weight:
  - Difficult to Handle.
  - Difficult to Install.
  - Higher Shipping Costs.

Electronic Ballast:

- Converts 50 Hz Electrical Supply to 25 - 40 kHz, Hence Resulting in Better Performance & C/S's.
- Energy Saving + Better Performance.

Advantages of Electronic Ballasts

- Much Lower Ballast Losses: Only 1 Watt.
  - FL. 2 x 36W Consumes:
  - With Conventional Ballast : 92 W.
  - With Electronic Ballast : 72 W.
  - Savings % : 22 %.
- Much Smoother Light Output.
- Higher Average Light Output.
- Absence of Audible Noise
- Lower Heat Generation. Reduced Cooling Costs.
- Longer Life (16 - 20 Years)
- Dimming Possibility

- Reduced Weight.
- Longer Lamp Life.
- No Flickering.
- Instant Starting.
- Functioning at Low Temperature (- 10°C).
- No Starter is Required.
- High PF (0.95-1) with no need for capacitors.

Calculations

Savings Can Be Estimated Using:

1. Average % of Savings: 20 - 25 % of Total Unit Consumption.
2. Manufacturer Data (Catalogues).
3. Measurements.

Need of Lighting Control

Every One Turns On Lighting When He Needs That, But Few People Care to Turn Lighting OFF When They Do Not Need It.

5. Control Lighting Using Time Delay Timers (TDT)

Install TDT to:

- Turn On Lighting When Needed.
- Turn OFF Lighting Otherwise.

- TDT is a Timed Switch:
  - When Switch is Turned ON.
  - TDT will Turn it OFF After a Pre-Set Time Delay (Minutes).
- This Time Delay can Be Adjusted According to Work Requirements.
- Each TDT Has Limited Connected Load (kW, Ampere,..).
- Lighting Load to Be Controlled Should Be Within Timer Ratings Or Electromagnetic Contactors Should Be Used to Switch ON/OFF The Load.

Lighting System

Identifying The Measure

Areas which are Frequently Unoccupied, and Needed Only For Short Periods of Time While Lighting is Operational Regardless of That, Then TDT Can Be Used to Control Lighting Operation.

Example Cases

- Storing Areas
- Air Compressors Rooms
- Generally, Automatic Machines Rooms
- Lockers Areas
- Staircases

Calculations

- Similar Approach:
  - Calculate Existing Electrical Consumption.
  - Calculate New Electrical Consumption.
  - Savings = Difference.

- Only. Operating Hours Will Change

6. Programmable Timers

Potential Areas:

- Areas with considerable number of lighting units (minimum 4 units).
- Areas with windows.
- Areas that are rarely occupied.
- Areas where occupation is for short period for several times.
- Usually closed areas.

Types of Programmable Timers:

1st. Category:

- Electromechanical Timers.
- Electronic Timers.
- Chargeable & Not Chargeable.

2nd Category:

- Daily, Weekly, Monthly, Annually.
- Each Timer Has Limited Connected Load (kW, Ampere).
- Lighting Load to Be Controlled Should Be Within Timer Ratings Or Electromagnetic Contactors Should Be Used to Switch On/OFF The Load.

Identifying The Measure

- Areas Where the Occupation is Continuous or Frequent, But On Pre- Determined Times and Duration, While Lighting is Operational Regardless of That, Then Timers Can Be Used to Control Lighting Operation.

- Areas Where Type of Work May Change During Day Time are Potential Areas For Using Timers to Control Lighting Operation, Part of the Lighting May be Turned OFF, For Example Cleaning Times.

Example Cases

- Offices.
- Production Areas (Break Times).
- Outdoor Decorative Lighting.
- Illuminated Signs.
- Classrooms.

7. Occupancy Detectors

Different Names For Same Control:

- Occupancy Detectors or Sensors.
- Motion Detectors.
- Presence or Absence Detectors.

- Occupancy Sensors: Electronic Switch Sensitive to Motion.

  - Switch ON : Detecting a Moving Body.
  - Switch OFF: No Motion.

- Principle of Operation:

  - Passive Infra Red Detectors.
  - Sonic (Sound) Detectors.

- PIR: Detects Invisible Heat Radiation Emitted by Moving Bodies, such as People or Animals.

- Each Detector Has Limited Connected Load (kW, Ampere).

- Lighting Load to Be Controlled Should Be Within Detector Relay Ratings Or Electromagnetic Contactors Should Be Used to Switch On/OFF The Load

Identifying The Measure

- Areas Where the Occupation is Occasional or Related to a Certain Work That May Not Always Required, While Lighting is always Operational Regardless of That, Then Occupancy Detectors Can Be Used to Control Lighting Operation

- Visual Observations Will Help in Identifying the Measure.

- Asking Proper Questions Will Also Help.

- People Usually Do Not Feel That They Leave Their Offices That Much.

Example Cases

- Offices Where Occupants Have a Site Activities.

- General Areas That May Be Occupied By Different People.

- Automatic Machines Rooms.

- Storing Areas.

- Meeting Rooms.

- Auditorium.

Occupancy Sensors Specifications

- Mounting:
  - Wall Mounted.
  - Ceiling Mounted.
- Detection Zone:
  - Wall : Forward, Sides, Angle.
  - Ceiling : Diameter, Height.
- Rated Max. Permissible Load:
  - Measured in Ampere, kW, kVA.
- Switch OFF Delay:
  - Adjustable Time Setting .
- Built in Photocell:
  - Adjustable Light Level Setting.

Calculations

- Similar Approach:
  1. Existing Electrical Consumption.
  2. New Electrical Consumption.
  3. Savings = Difference.
- Only Operating Hours Will Change.

Estimating New Operating Hours

1. Can Be Estimated by Determining:

   A- Max. No. of Times the Area May Be Used.
   B- Max. Time Occupied / Time of Use.

   New Lighting Operating Time = A x B.

2. Or as a Percentage of Existing Operating Time (25%, 50%, 75%)

Lighting Controls

- In General: Use any control signal that can minimize the lighting operating hours to reduce lighting energy consumption.
- Same calculations and principles apply for all.

Example: Hospital: X-Ray Room

Summary Description:

This room is needed for short periods, several times a day while lighting is always operational.

It is suggested to control lighting using motion detectors

Computation Details:

1. **Computation parameters**

Existing No. of Lighting Fixtures	: 6
Existing Lighting Type	: FL. 4x18W
Existing Operating Hours/Day	: 24
Existing Working Days/Month	: 30
Estimated New Oper. Hours/Day	: 50% (12 H/D)

2. **Annual Energy Saving**

A. Existing situation:

Lighting load = No. of fixtures * fixture kW

Lamp kW = 0.018 kW
Ballast kW = 0.010 kW / 2 Lamps

Fixture kW = Lamps kW + Ballasts kW
= 4 * 0.018 + 2 * 0.010
= 0.092 kW

Lighting Load = 6 x 0.092

= 0.552 kW

Electrical consumption = Lighting load * Working hours/year
= 0.552 kW *24 Hrs/day*30 Days/month*12 M/Y
= 4769.3 kWh/Yr

Lighting consumption cost = Electrical consumption * electrical tariff
= 4769.3 kWh/Yr *0.063 JD / kWh
= 300.5 JD/Yr .

B. Suggested Situation:

No change on the existing lighting load will take place only the operating hours will be reduced from 24 hours to 12 hours daily.

New Electrical Consumption	= Lighting load * operating hours /year. = 0.552 kW*12 hr/day*30day/month*12 month/yr = 2384.6 kWh/Yr.
New lighting consumption cost	= New consumption * electrical tariff = 2384.6 kWh/Yr * 0.063 JD/kWh = 150.2 JD/Yr

3. <u>Energy Savings:</u>

Saving in electrical consumption	= Existing consumption - New consumption = 4769.3 – 2384.6 = 2384.7 kWh /Year

4. <u>Annual Monetary Savings:</u>

Savings in Energy Cost	= Existing lighting cost - New lighting cost = 300.5 – 150.2 = 150.3 JD/Year
Savings	= 150 JD / Year
Investment	= 125 JD
P/B Period	= Investment x 12 / Annual Savings = 10 Months

Implementation Cost Feasibility

- What we need?
- Initially:
  1. New Equipment.
  2. Wiring & Accessories.
  3. Installation (Labor).
- Long Run:
  1. Energy
  2. Maintenance
  3. Complete Replace (End of Lifetime)

1. Equipment Cost: See the suppliers list in the appendix.

2. Wiring & Accessories:

- Check site and place of installation.
- Draw wiring and control diagram or get help from contractors.
- Try to implement it internally or get external contractors.
- Wiring and accessories Cost Range: JD 5 – 50 / unit.
- Installation Cost Range : JD 15 – 50 / Unit.

5. **Investment details:**

- Equipment:
  - Occupancy Detector : JD 75.
- Wiring & Accessories:
  - Wiring & PVC Pipes : JD 25.
- Installation:
  - Electrical Technician : JD 25.

Total Initial Implementation Cost : JD 125.

6. **Payback Period**

- Simple Payback Period = Initial Investment / Annual Savings (Years)
  = 12 * investment / Annual Savings (Months)
- Complex Payback Period
  - For large Investments.
  - Related to Interest Rate & Savings Variations.

Maintenance

- Lighting Lamp has certain lifetime.
- Compare lifetimes before replacing any lamps.
- Electronic Ballasts Lifetime is Greater than Magnetic Ballasts and Also Increase Lamps Life Time.
- Reflectors life time is very long (>15 Years).
- Consider Control Measures if Payback Period is less than Three Years Since Equipment May Fail.
- Look at the Annual Savings and P/B and Decide.

Section IV

Air Conditioning System

Topics that will be covered in this session

- Air Conditioning Equipment.
- Distribution Systems.
- Reducing Cost of Generating Cooling:
  1. Raise chilled water temperature.
  2. Reduce condenser water temperature.
  3. Reduce scale or fouling.
  4. Reducing auxiliary power consumption.
  5. Heat Recovery System.
  6. Absorption chilling.
  7. Thermal Storage.
- Reducing the amount of cooling:
  1. Optimize temperature and relative humidity.
  2. Use correct amount of outside air.
  3. Use temperature reset.

Tips

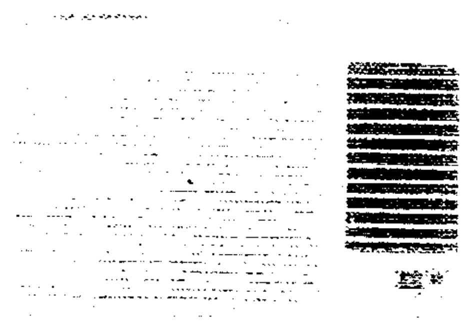
- Reducing infiltration will result in energy savings.
- Put the set point of the AC not lower than 22-24 °C only.
- Always clean the filters and condensers.
- Efficient lighting system will reduce cooling load.
- Reduce solar heat gain through windows (Solar films).

BACKGROUND

A / C EQUIPMENT

1) Window or through the wall

- Normally used for air conditioning.
- Can be provided with electric resistance heaters for heating.
- They are usually of the " Fan coil " type.
- Equipped with separate fan motors driving the condenser and the evaporative fans.
- Equipped with built in thermostat.

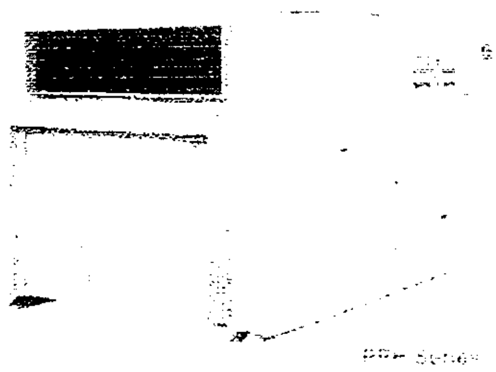


2) Split Units

- There is no chilled water system since the system operates with direct expansion.
- Manufactures claim first cost savings of 20% and power savings up to 25% due to the elimination of the chiller and water pump.
- Most room air conditioners and split units are now given an Energy Efficiency Ratio (EER), which enables you to determine the relative efficiency of different units in terms of BTU/Watt-hr.
- Newer and more efficient units will have an EER of (10) or above.

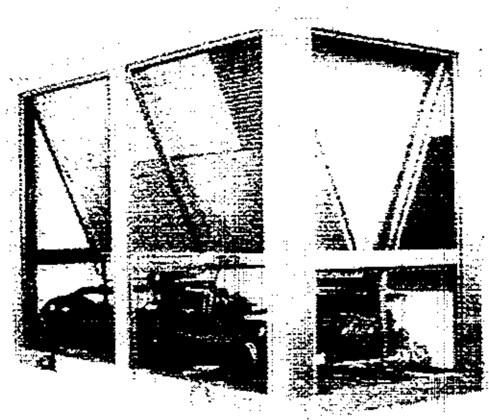
3) Roof Top Unit

- Self-contained air conditioning systems designed for mounting on the exposed roof of a commercial or industrial building.
- They are most frequently of the reciprocating type and air-cooled with all components contained in a weatherproof enclosure.



4) Electric Driven Compressors

- Can be of the reciprocating, centrifugal or screw types.
- The reciprocating compressor consists of pistons in from 1 - 12 cylinder acting as pumps to increase the pressure of the refrigerant from the low side to the high side of the system.
- Centrifugal units are basically fans or blowers, building refrigerant pressure by forcing the gas through a funnel shaped opening at high speed.
- Screw Compressors are mainly two screws building the refrigerant pressure as the male and female high displacement rotors rotate and mesh with each other.
- Centrifugal compressors are water cooled, more quite, requires less maintenance not generally used below 50 tons capacity.



5) Absorption Chillers

- Operate on either steam or hot water above 250 °F with two components, the generator and the absorber, performing the same basic function as a compressor .
- The chilling effect is obtained through the interaction of two connected, closed tanks with Lithium Bromide.

COEFFIICIENT OF PERFORMANCE

- This term is used to measure the efficiency of different types of chillers.

$$C.O.P = \frac{\text{Heat Moved (Refrigeration Effect)}}{\text{Energy Required}}$$

- As a rule of thumb the following C.O.P can be used as a guide for various types of units:

  1) Absorption Chiller : 0.50.
  2) Electric Drive Compression : (2.40 - 5).

- C.O.P will vary significantly based upon a number of factors:

  1) The type of refrigerant.
  2) Motor efficiencies.
  3) Pump efficiencies
  4) Air cooled chillers, , generally have a lower C.O.P. than water cooled units.

SELECTION GUIDE

The following is a rough guide for selection:

- up to 80 tons (280 kW) - Reciprocating.
- 80 - 120 tons (280-420 kW) Reciprocating or Centrifugal.
- 120 tons to 200 tons (420 - 700 kW) - Screw, Reciprocating or Centrifugal.
- 200 to 800 tons (700 - 2800 kW) - Screw or Centrifugal.
- Above 800 tons (2800 kW) – Centrifugal.

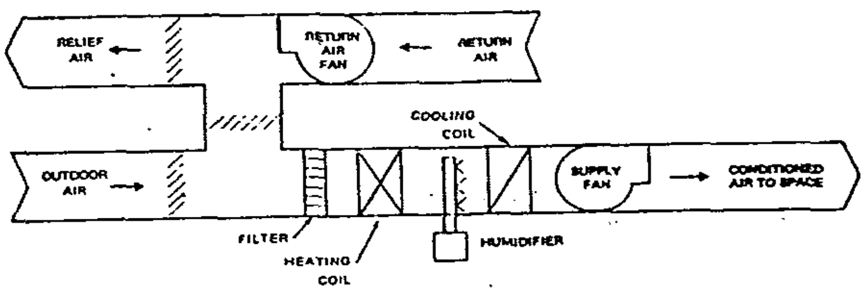
COOLING TOWERS

- A cooling tower is a device that cools water directly by evaporation.
- It operates on the principle of adiabatic heat exchange (no heat is added to or subtracted from the system).
- Cooling is accomplished by spraying water into a tower with trays to allow for gradual passage of the hot water from top to bottom.
- Air is introduced at the bottom by fans, exhausting at the top.
- Although parabolic - or natural draft - cooling towers are available which use no mechanical devices for introducing cooling air to the tower.
- In cooling tower operations, it is assumed that for every pound of water evaporated there are 1000 BTU of heat removed. (about 550 Kcal/kg).
- The rate of evaporation is affected by the wet bulb air temperature and the cooled water temperature.
- The difference between the two is known as the approach temperature.
- Towers are most commonly sized for a 10 F degree approach.

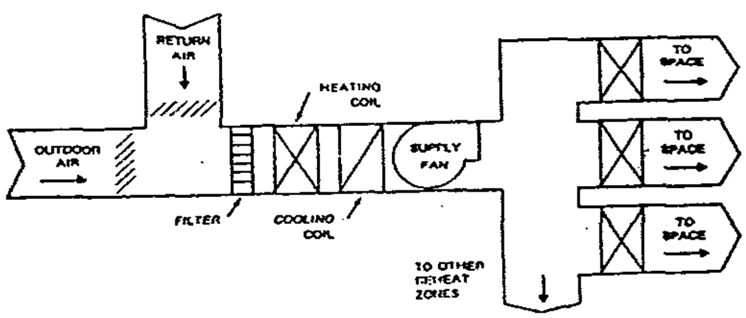
DISTRIBUTION SYSTEMS

The distribution systems of HVAC networks is classified according to the type of network and to the number of pipes used to supply cold and hot water to the different zones, and as follows:

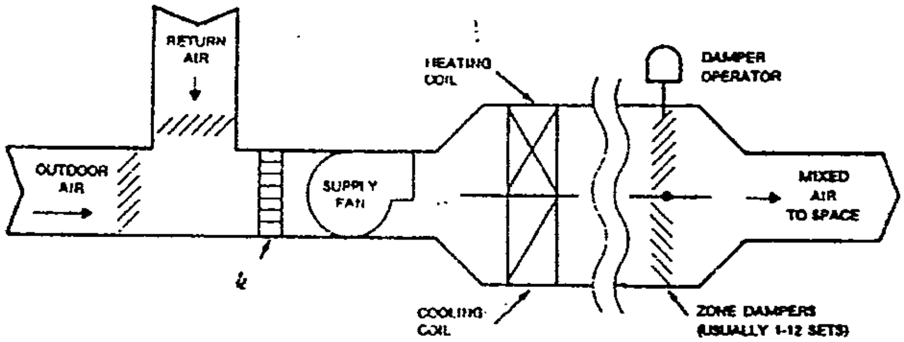
1) **Single Zone Systems:** These are the most basic types of system. They consist of mixing conditioning, and fan section.



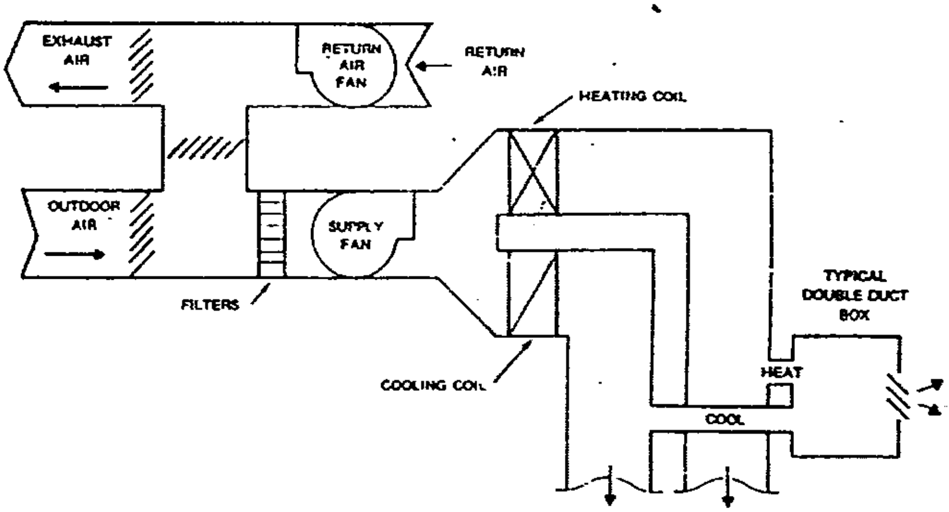
2) **Terminal Reheat Systems :** Fixed cold temperature air is supplied to the reheat system in the terminal units as required by thermostats located in each conditioned space.



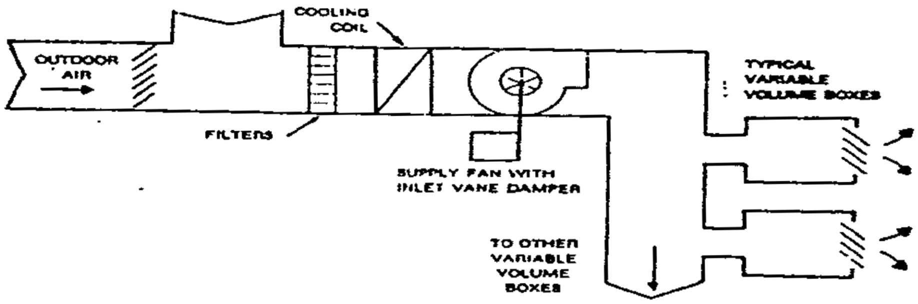
3) **Multi Zone Systems:** These condition all air at the central system and mix heated and cooled air to satisfy the various zone loads as sensed by zone thermostats.



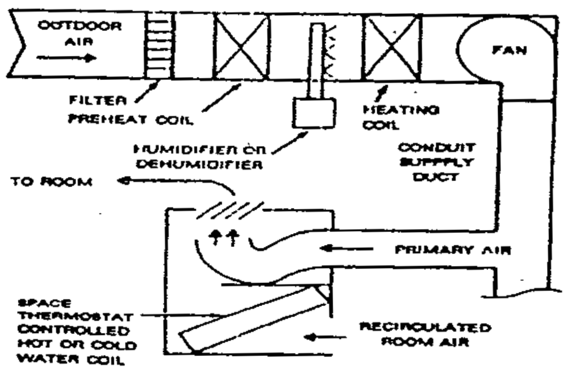
4) **Dual Duct Systems:** Air is ducted to the spaces amd mixed in terminals boxes .



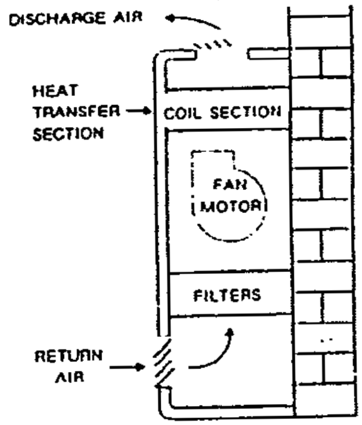
5) **Variable Air Volume Systems:** This system delivers a varying amount of air as required by the conditioned zone. Terminal sections are usually single duct variable volume boxes with or without reheat controls.



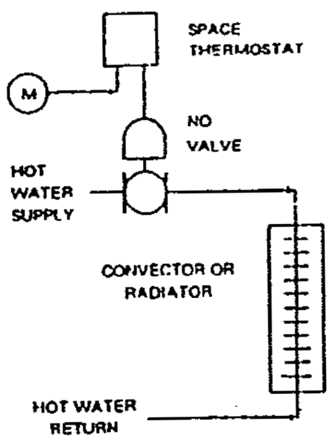
6) **Induction system:** Conditioned primary air is supplied to the unit where it passes through nozzles or jets and draws room air through the induction unit coil..



7) **Fan Coil System:** A simple cabinet with heating and/or cooling coil, filter, fan and motor. It generally uses 100% return air to condition the space.

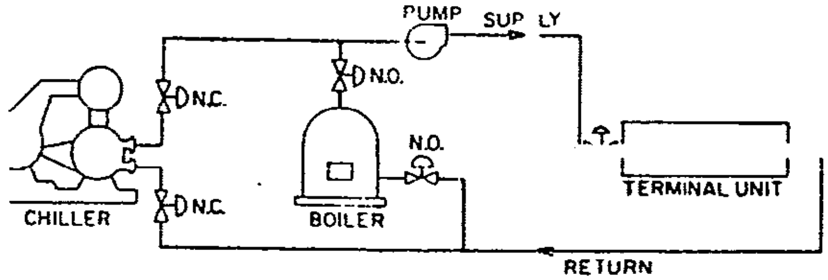


8) **Perimeter Radiator:** They are normally used around the perimeter of a building and under windows to compensate for heat loss through the walls.

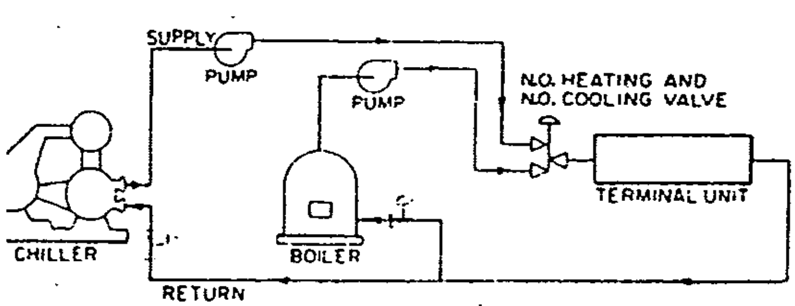


Air Conditioning System

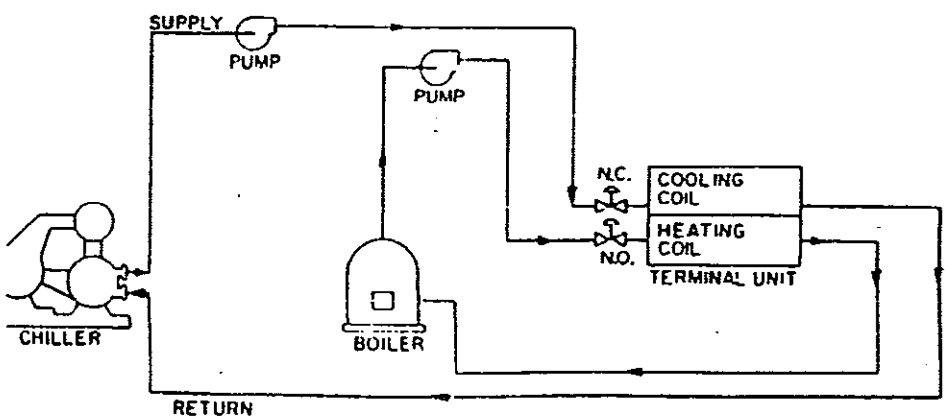
9) **Two Pipe System:** This system is used to transmit hot or chilled water through the same piping for heating and cooling.



10) **Three Pipe System:** In this system there is one pipe for chilled water, one for hot water, and the third serves as a common return.

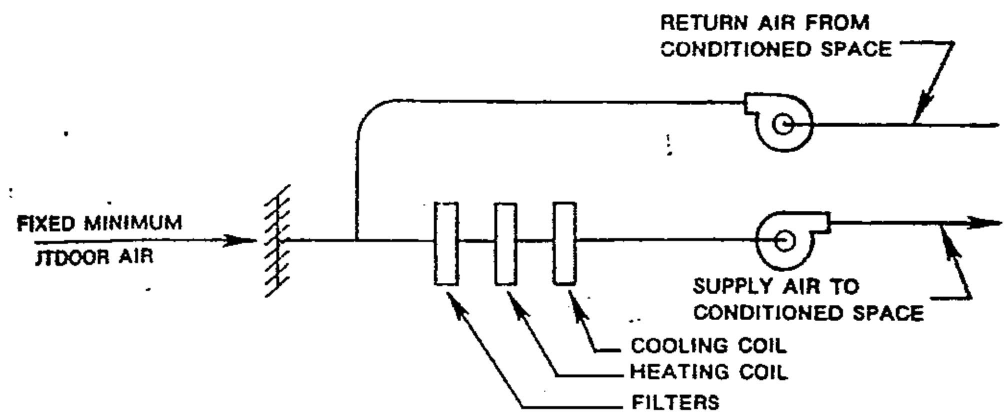


11) **Four Pipe System :** One pipe is used for hot water, another for cold water and two pipes for their return.

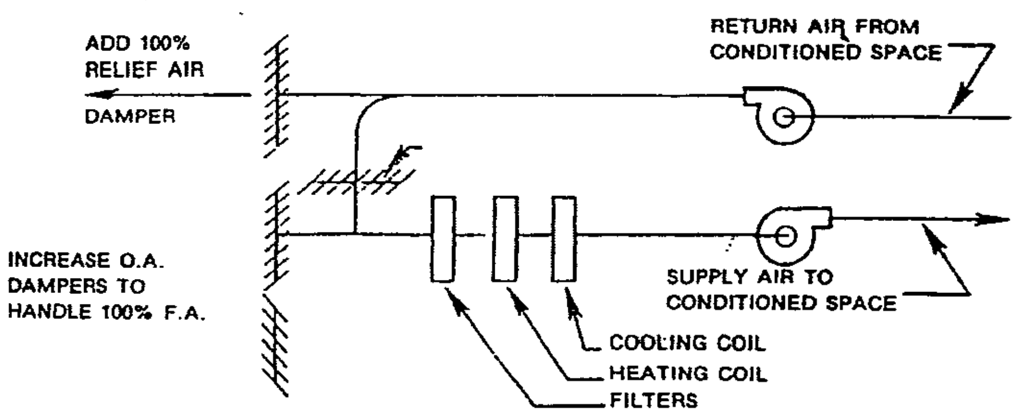


12) **Economy Cycles:** They are used to allow you to take advantage of the maximum possible use of outdoor air when that temperature is lower than the normally circulated inside air in the cooling cycle.

Typical A.C. System Without Economy Cycle



Typical A.C. System with economy cycle



Energy Saving In HVAC System

METHODS TO REDUCE ELECTRICITY COSTS FOR HVAC

- Savings can be divided into two general areas:

A) Reducing the cost of generating heating and cooling.
B) Reducing the amount of heating and cooling required.

A. <u>REDUCING COSTS OF GENERATING COOLING.</u>

The basic principle to be applied in reducing the cost of refrigeration is:

1) Operate the temperature of the conditioned space as high as possible.
2) Lower the temperature in the heat rejection process to minimum.

POTENTIAL NO. 1: Raise Chilled Water Temperature.

- The energy input required for any liquid chiller increases as the temperature lift between the evaporator and the condenser increases.
- Raising the chilled water temperature will cause a corresponding increase in the evaporator temperature and thus decrease the required temperature lift.
- The Ch.W.T leaving the chillers usually remains constant or even decreases as the cooling load decreases.
- Since the cooling load is less than the designed for about 95 % of the time and since the design Ch.W.T is chosen to satisfy Max. demand, reduced demand can be met with water that is not quite so cool.
- The following table is used to find out the percentage of savings from increasing the chilled water temperature.

Chilled Water Temperature Increase, °F

Machine	1	2	3	4	5	6	8	10
Absorption	0.8%	1.6%	2.4%	3.2%	4%	4.9%	6.5%	8.1%
Centrifugal	1.6%	3.2%	4.8%	6.4%	8%	9.6%	12.8%	16%

Air Conditioning System

Example:

An office building has two 150 Ton chillers, electricity tariff is 0.063 JD/kWh, cooling season is 10 hrs/day, 25 day/month, 5 month/year, average loading 50%.

- What are the JD per year attained from increasing chilled water temp. by 3 °F?

1. From chiller catalogue "Petra" at 95 °F ambient.
2. At 45 °F ⇨ kW/TR = 1.009 (for comp only).
3. At 48 °F ⇨ kW/TR = 0.982 (for comp. Only).
4. Saving =2*150*50%*(1.009-0.982)*10*25*5.

   = 5062.5 kWh

   = 5062.5*0.063

   = 318.94 JD/yr

POTENTIAL NO. 2: Reduce Condenser Water Temperature.

- The effect of reducing condenser water temp. is very similar to that of raising the Ch.W.T , namely reducing the temp. lift that must be supplied by the Compressor.
- Some water cooled systems have cooling tower bypass valves that maintain the temp. of the cooling water entering the condenser while outside temp. drop.

Condensor Temperature Reduction, °F

Machine	1	2	3	4	5	6	8	10
Absorption	0.5%	1.1%	1.6%	2.1%	2.6%	3.2%	4.2	5.3%
Centrifugal	1.1%	2.2%	3.3%	4.4%	5.5%	3.6%	8.8%	11%

POTENTIAL NO. 3: Reducing Scale or Fouling

- The heat transfer surfaces in chillers tend to collect various mineral and sludge deposits from the water that is circulated through them.
- Any build-up insulates the tubes in the heat exchanger causing a decrease in heat exchanger efficiency.
- Thus, requiring a large temp. difference between the water and the refrigerant.
- If fouling occurs in the evaporator tubes, the effect is equivalent to lowering the Ch.W.T in clean tubes.
- In the condenser, fouling is equivalent to raising the condenser water temp.in clean tubes.

POTENTIAL NO. 4: Reducing Auxiliary Power Consumption

- The total energy cost of producing chilled water is not limited to the cost operating the chiller itself.
- Condenser or cooling tower fans, condenser water circulating pumps, and chilled water circulating pumps must also be included.
- In fact, in centrifugal chilling plants, the auxiliary equipment often consumes 25 % or more .

POTENTIAL 5: Heat Recovery System

- Exhaust air temperature from any air-conditioned space always less than the ambient fresh air temperature.
- By Installing heat wheel between the relatively low temp exhaust air and the relatively high temp. fresh air will reduce the cooling load of this fresh air.

POTENTIAL NO. 6: Use Absorption Chilling to Shave Peak

- In installations where the electricity demand curve is dominated by the demand for chilled water, absorption chillers can be used to reduce the overall electricity demand.
- Although absorption chilling is rarely competitive on an annual basis, use of absorption chilling for short periods of time during peak load can reduce the total energy bill.

POTENTIAL NO. 7: Thermal Storage

- The storage of ice for later use is an increasingly attractive option.
- Because of utility demand charges, it is more economical to provide the cooling source during non air-conditioning periods and tap it when air conditioning is needed, especially peak period.

B. REDUCING THE AMOUNT OF COOLING OR HEATING REQUIRED.

POTENTIAL NO. 1: Optimize Temp. and Relative Humidity

- There is a "comfort zone which is acceptable to the residents of that zone and/or to the process taking place in the zone.
- ASHRAE Standard 55-88, 1981, describes the comfort zone for people-occupied spaces for cooling and heating (Refer to the appendix).
- For example, in the summer operating at a zone humidity level of 30% R.H when 65 % would suffice is obviously much more energy expensive.
- Electrical costs can be reduced by 25 % by simply optimizing zone conditions.
- Set room sensor cooling temp. to 23 °C (74 °F) or higher where possible.

	Recommended Inside Design Conditions Summer			
	Deluxe		Commercial	
	D.B °F	RH %	D.B °F	RH %
Apt, hotel, office, school, hosp	74-76	45-50	77-79	45-50
Shops, barber, supermarket	76-78	45-50	78-80	45-50
Auditorium, resturant	76-78	50-55	78-80	50-60

POTENTIAL NO. 2: Use Correct Amount Of Outside Air

- Ventilation requirements (inside activities) will dedicate the minimum amount of makeup air .
- In certain cases it is more economical to use more than this minimum level.
- If cooling is required and the outside air temperature and humidity is less than the return air temperature and humidity, it is cheaper to use 100 percent outside air.
- There are two automatic control methods for accomplishing this:

1. Economy Cycle

The temp of the outside air is taken and then used to determine the optimum split without reference to the difference in Relative Humidity (latent heat load) between the two streams.

2. Enthalpy Control

Both the temp and Relative Humidity of the outside air is measured to optimize the return air/makeup split.

Example:

Suppose we have average 78 °F return air at 50% R.H and average 92 °F outside air at 42% R.H. The system flows 10000 CFM of air. In the example we will consider a single zone system in a cooling mode.
System operation: 10 hr/day, 25 day/month, 5months/yr

Effect of Percent Outside Air on Cooling Coil Load

% Outside Air	Room Sensible Load (Ton)	Room Latent Load (Ton)	Room Total Load (Ton)	Cooling Coil Load (Ton)
35	21.1	4.4	25.5	35.6
20	21.1	4.4	25.5	31.1

Sensuble Heat $= CFM_{sa} * 1.08 * (T_{rm} - T_{sa})$

Latent Heat $= CFM_{sa} * 0.68 * (W_{rm} - W_{sa})$

Total Heat $= CFM_{sa} * 4.45 * (h_{rm} - h_{sa})$

- The reduction in cooling coil load is from 35.6 tons to 31.1 tons, a decrease of 12.6 percent.

Reduced Load = 35.6-31.1

= 5.5 TR

= (5.5 TR*12000 BTU/TR)/3412 BTU/kWh

= 19.34 kWh (Cooling)

C.O.P = 3

Power Consumed = 19.34/3

= 6.45 kWh (Electricity)

Power Cost = 6.45*0.063 JD/kWh

= 0.406 JD/hr

= 0.406*10*25*5

= 507.5 JD/yr.

POTENTIAL NO. 3: Use Temperature Reset

- In many reheat systems the chilled water coil is operated at a fixed leaving temperature.
- Many times the temp. for air leaving the chilled water coil is chosen to be lower than any air required at the various zones.
- Therefore, the reheat coils must all operate. The overall affect is to cool the air and then reheat it back to the same state or higher temp as required.
- If this temperature is too low, more heat will be required.
- Temperature reset refers to automatically changing the temperature leaving the cooling coil for a reheat system and the mixed air temperature for the other systems so that a minimum of heat is required.

Example

In hospital, a 9000 CFM multi-zone AHU, mixed air temp 81 °F and 48% RH cooled down to 55 °F.
Zone # 1 : 3000 CFM at 65 °F
Zone # 2 : 3000 CFM at 80 °F
Zone # 3 : 3000 CFM at 95 °F

Air Temp. Leaving Chill Water Coil °F	Chill Water Coil, Load BTU/Hr	Reheat Coil Load For Zone 1 BTU/Hr	Reheat Coil Load for Zone 2 BTU/Hr	Reheat Coil Load for Zone 3 BTU/Hr	Total Reheat Load BTU/Hr
55	379000	33000	82500	132000	247500
65 *	180000	0	49500	99000	148500

By using temp reset (65 °F instead of 55 °F) :

- The cooling requirements are lowered by 199000 BTU/hr (52 %) .
- The heating requirements are lowered by 99000 BTU/hr (40 %).

Based on a cost of JD 4.1 / 1000000 BTU for heat , and electrical cost of 0.063 JD/kWh and machine C.O.P of 3.

Savings in Reheat = 99000 BTU/hr * JD 4.1 /1000000 BTU
= 0.406 JD/hr.

Savings in Cooling = (199000 BTU/hr * 0.063 JD/kWh) / {(3412 BTU /kW-hr * 3)}
= 1.225 JD/hr.

Total Saving = 0.406+1.225

= 1.631 JD/hr

Section V

Heating System

Topics that will be covered in this session

- Heating System Types.
- Energy Saving in Boiler Plant.
- Energy Saving in Space Heating System.
- Reducing envelope losses.
- Temperature Control.
- Energy saving using Water Saving Devices.

Tips

- Schedule a regular maintenance for the boiler; the reduction in boiler efficiency will cause energy losses.
- Always check the insulation of pipes & fittings.
- Check thermostats are set correctly.
- Turn off heating in un-used rooms.
- Install foils behind radiators.
- Try not to use electric heaters.
- Maintain windows rubber seals to reduce infiltration.

Energy Management In Heating Systems

Introduction

- Air Conditioning is the simultaneous control of temperature humidity, air movement and the quality of air in a space.
- Although many of the savings to be derived from HVAC systems will be achieved by modifications, in the existing control system.
- A basic understanding of the HVAC system is essential in any effort to reduce energy used.

Heating System Types:

1) Hot water heating systems :

- Operated by oil, gas or electricity.
- Temperature of the water normally below (100 °C).
- Operating pressure normally atmospheric pressure.
- Electric hot water boilers or heaters are the most expensive in operation, although its efficiency is very high (about 100%).
- Steam and water are both used for domestic hot water and air heating distribution systems.

2) Infrared heaters:

- Operate on gas, oil or electricity.
- Transmit heat energy directly to the occupants or building contents without appreciably heating the surrounding air.
- Infrared heaters particularly useful in high bay buildings, semi open or outdoor areas.

3) Portable Unit Heaters:

- Operate with oil, gas or electricity.
- Mostly used for spot heating areas,
- They are available without and with blowers.
- The former are easier to maintain, but blowers are required where large heating areas require a greater distribution.

4) Heat Pumps:

- Designed to extract heat from outdoor air
- Transmit it to the inside for heating,
- Then, reverse themselves to remove heat from the inside when in cooling mode.
- They are more efficient for heating than electric resistance heaters when the outside temperature are 4 °C or higher.
- Below that temperature a supplementary resistance heater is needed.

Energy Saving Measures

1) Boiler Plant

Energy savings could be achieved by improving the operating efficiency by:

A. Regular maintenance.
B. Improve thermal insulation of boilers, pipes and fittings "valves".
C. Isolate inoperative boilers.
D. Replace old inefficient boilers.

2) Space heating systems

Energy savings could be obtained by avoiding overheating, this could be achieved by:

A. Check thermostats are set correctly
B. Turn off heating in unused rooms.
C. Install weather compensating controls.
D. Install more accurate thermostats and thermostatic radiator valves.
E. Install zone controls for areas of extended use.
F. Fit time controls to eliminate out of hours heating.
G. Install foil behind radiators.
H. Install shelf above radiators.
I. Maintain windows rubber seals to reduce infiltration.

3) Reduce envelope losses

A. Thermal insulation will reduce wall and roof losses by 70-80%, the pay-back period around 5 years.
B. Cavity wall will reduce wall losses by 50-55%.
C. Double glaze will reduce losses from windows by 40-45%, the pay-back period 4 -5 years if windows area represent about 20% of the outside wall area.

Example 1:

Measure: Temperature Control.

Operating Temp.	23 °C
Average Ambient temp	5 °C
Operating Hours	10 hrs/day
Operating Days	25 day/month
Operating Months	4 month/yr
Fuel Cost	1000 JD/yr

1) Calculate the fuel savings when inside temp. is reduced to 20 °C and the operating hours decreased to 9 hrs/day:

Current degree hours = Yearly Operating Hours * (Operating Temp.- Ambient Temp)
= 10*25*4*(23-5)
= 18000 Degree.Hrs.

Heating System

Proposed degree hours = Yearly Operating Hours * (Operating Temp.- Ambient Temp)

= 9*25*4*(20-5)

= 13500 D. Hrs.

Savings = [(Current D. Hrs-Proposed D. Hrs) / Current D. Hrs]*Current Fuel cost.

Savings = [(18000-13500)/18000]*1000

Savings = 250 JD/yr

= 25%.

2) Calculate the investment required:

Room Thermostat	75 JD
Programmable Timer	60 JD
Wiring and Labor	50 JD
Total Investment Cost	185 JD

Pay-back = Investment / Savings

Pay-back = 185/250

= 0.74 year

= 9 months

Suppliers:

SAM Engineering.
MOHA Est.

Example 2
Water and Energy savings by using Water Saving Devices:

The following table describes the consumption of water for one person:

	Shower	Basin	Toilet
Daily Use / Person	5 Min	3 Min	3 times
Water Quantity / Day /Person	50 Liters	15 Liters	27 Liters
Water Quantity / Year /Person	18.25 M^3	5.48 M^3	9.86 M^3

Annual Water QTY = 18.25+5.48+9.86
= 33.6 m^3 / person

Min Water saving = 35%.

Water Saving QTY = 35%*33.6
= 11.75 m^3/yr

Cost Of Water = 1.0 JD/m^3

Monetary Savings = 11.75*1.0

= 11.75 JD/yr/Person

Assume 75% of the water used by shower and 30% of the water used in wash basin are hot water at 45 °C.

Average water temp 25 °C
Boiler efficiency 80%
Fuel used Diesel

- Hot water QTY = 18.25*75%+5.48*30%
= 15.3 m^3/yr/person.
- Hot water saving = 35%
= 5.36 m3/yr/person.
- Heat required to heat this water quantity from 25°C to 45°C = m Cp (T_h-T_c)

Where;

m : Water quantity in liters.
Cp : Heat content, for water = 1 kCal/kg.K.
(T_h-T_c) : Temperature difference.

Heat Required = 5.36*1000*1*(45-25)

Heat QTY = 107200 Kcal/yr/person

$$\text{Diesel QTY} = \frac{\text{Heat QTY}}{\text{C.V * diesel density * Efficiency}}$$

$$= \frac{107200}{10200 \text{ kcal/kg} * 0.835\text{kg/Lit} * 80\%}$$

= 15.73 liter/yr/person

Diesel cost = 0.113 JD/liter

Heating System

Savings	= 15.73 * 0.11
	= 1.75 JD/yr/person

Total Savings	= Water Savings + Fuel Savings
Total saving	= 11.75 + 1.75
	= 13.5 JD/year/person

Investment Required:

Wash basin aerator	4.0 JD/piece.
Shower head	4.5 JD/piece.
Displacement bags	3.5 JD/piece.
Special key	3.0 JD/piece.

Total Investment 15 JD.

Pay-back	= Investment / Savings
Pay-back	= 15 / 13.5.
	= 1.11 years.
	= 13 Months.

Suppliers:
Al Rawnak hardware stores.

Section VI

Electric Motors System

Topics that will be covered in this session

- Types of motors.
- Motor losses.
- Motor characteristics.
- Measurements of Motor Performance.
- Energy Saving Measures:
  1. Automatic Control of Motor Operation.
  2. Matching Motor to load.
  3. High Efficiency Motors.
  4. Variable Speed Drives.

Tips

- Induction motors represent 90% of existing motors.
- Total losses in motors are about 10%-20%.
- Put a maintenance schedule for all the motors.
- Rewinding of the motor will affect its performance.
- Don't forget to include any accessories or electric panel and wiring required in the investment.

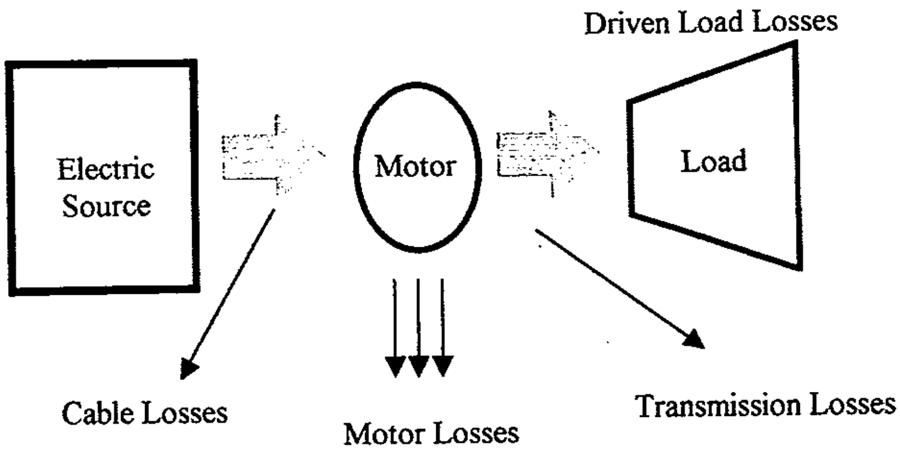
Motors Background

Types of Motors:

1. Squirrel Cage Induction Motors: About 90 % of Existing Motors.
2. Synchronous Motors.
3. Slip-Ring Motors.
4. DC Motors.

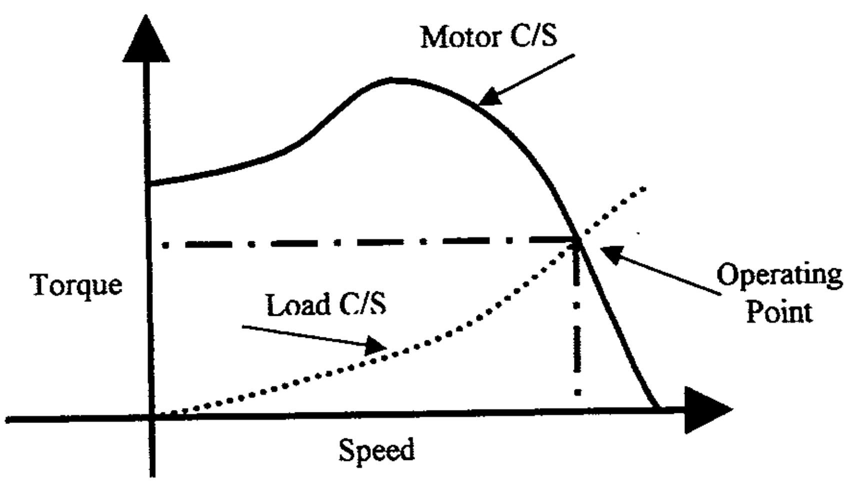
Motor Performance:

Typical Motor Setup:



- **Output Power = Torque x Speed / 9550**
  - Power : in kW
  - Torque : in N.M
  - Speed : in RPM

- **Torque / Speed C/S's:**
  - System C/S Curve:
  - Motor C/S Curve:



Input Power:

- Single Phase = V x I x P.F.
- Three Phase = $\sqrt{3}$ x V x I x P.F.

Input Power = Output Power + Losses

Motor Efficiency = P out / P in

Motor Losses

A) Magnetic (Core) Losses:

1. Hysteresis Losses : Energy required to magnetize the core material.
2. Eddy Current Losses: Due to current passing through the core material.

- Voltage Related
- Constant Irrespective of Motor Load
- Fixed Losses 15 - 20 % of Total Losses.

B) Copper Losses (I^2R Losses):

- I^2R Losses in Rotor & Stator.
- Proportional to the Load Current.
- Stator Losses: 40 - 45 % of Total Loss.
- Rotor Losses: 20 - 25 % of Total Loss.

C) Friction (Mechanical Losses): Function of the motor speed.

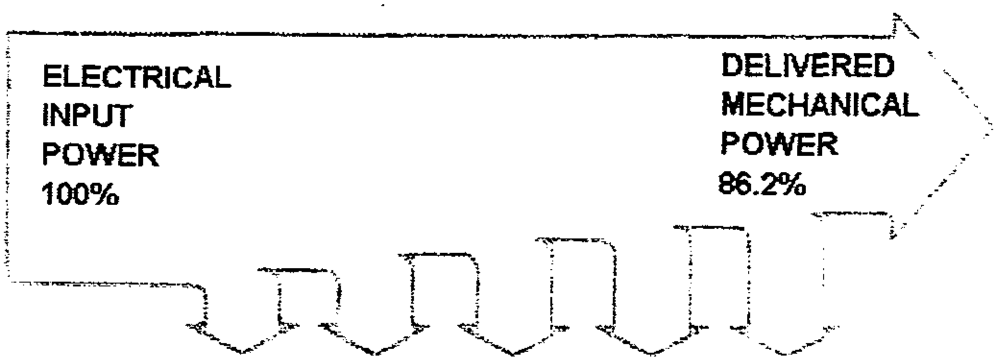
- Windage Losses.
- Bearing Losses.
- Brush Friction Losses.
- Fixed Losses: 5 - 10 % of Total Losses.

D) Stray Losses:

- Result of Leakage Flux Induced by the Load Currents.
- Difficult to be Measured or Calculated.
- Generally: Proportional to (I rotor).
- 10 - 15 % of Total Motor Losses.

Example: An example illustrating different kinds of motor losses.

5 HP, 4 POLE, 3 PHASE MOTOR TYPICAL ENERGY FLOW

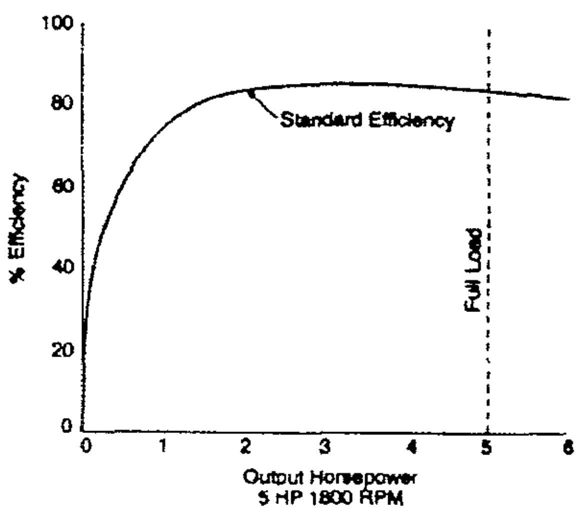


		STATOR RES. LOSS	ROTOR RES. LOSS	CORE LOSS	FRICTION & WINDAGE LOSS	STRAY LOAD LOSS	TOTAL
AVERAGE STANDARD MOTOR	PERCENT OF LOSSES	40%	25%	20%	5%	10%	100%
	PERCENT OF INPUT	6.1%	3.6%	3.0%	0.7%	1.4%	14.8%

Motor Characteristics:

Manufacturers Usually Supply Motor C/S's as Curves or Tables.

- Motor Efficiency (Vs) % Loading



Measurements of Motor Performance

- Input Power:
  - Can Be Measured Using Digital P.F Meter or Power Analyzer.
- Motor Efficiency:
  - We Need to Determine Motor Loading.
  - There is Two Approaches to Determine Motor Loading then Efficiency.

Determine Motor Efficiency

A. <u>Input Power Method:</u>

1. Input Power Measurement.

2. Manufacturer:
   - Efficiency vs. Output Power.

3. Draw Efficiency vs. Input Power.
   - By Dividing P.out / Efficiency.

4. Using New Curve Determine Efficiency.

B. <u>Speed Measurement Method:</u>

1. Using a Tachometer: Measure Motor Speed (RPM).
2. Using Speed vs Motor Load % Curve: Determine the Loading of the Motor.
3. Using Efficiency vs Motor Loading %: Determine Motor Efficiency.

Note: Frequently, Manufacturer Data are Not Available

- Use General Curves Available or Make Approximations.

$$\% \text{ Load} = \frac{\text{No load rpm} - \text{actual rpm}}{\text{No load rpm} - \text{full load rpm}} \times 100$$

Where,
No load rpm = Sync. Speed = 120*f / P.
Full load rpm = Name Plate rpm.

P out = % Loading * P rated
Eff. = P out / P in

Factors Affecting Motor Performance

1. Maintenance.
2. Rewinding.
3. Power Supply Quality.
   - Voltage Variations : ±6 %
   - Frequency Variations : ±3 %
4. Age.

Electric Motors System

Energy Saving Measure

Motors - Check List

Before starting with the energy saving measures, the following data should be obtained, in order to determine the suitable motor for any measure. Most of the data required could be obtained from the name plate of the motor, or could be found in the catalogues:

- Motor Nameplate Details (V, A, PF, kW, RPM, Frame..).
- Motor Type (AC, DC, ..).
- Motor Application (Pump, Fan, Conveyer, etc...).
- Motor Running Duration.
- Motor Control (Manual, Automatic and how).
- Existing Starter (DOL/ Star Delta).
- Age of the Motor.
- Motor Rewinding.
- Motor Actual Measurements (V, Amp, PF).
- Power Factor Correction.
- Motor Running Temperature.

Main Energy saving measures:

In this section we will explain the following energy saving measures:

1. Automatic Control Of Motor Operation.
2. Matching Motor to Load or Replacing Oversized Motors.
3. Install High Efficiency Motors.
4. Control Motor Speed (Variable Frequency Drive).

1. Automatic Control Of Motor Operation:

Sometimes motors are left operational when there is no need for that, so it is suggested to control these motors and turning it off when there is no need for it.

- **Examples:**
    - Air Compressors.
    - Exhaust Fans.
    - Air Handling Units.
    - Ventilation Units.

Turning off those motors will save a lot of Energy, while no or low investment is required, this could be done by:

A. Programmable Timers.
B. Temperature Controllers.
C. Level Switches.
D. Pressure Controllers.

Savings Calculations:

- Calculate Existing Motor Consumption:

Annual Savings in kWh = Motor kW x (H_1-H_2)

Where:

- H_1 : Existing Motor Operating Hours.
- H_2 : New Proposed Motor Operating Hours.
- Motor kW from measurements or 70% of Rated kW.

Annual Savings in JD = Savings (kWh) x Tariff (JD/kWh)

2. Matching Motor to Load:

Motors are usually oversized for the following reasons:

- Safety Factors.
- Over Estimated Loads.
- Wrong Calculations.
- Voltage Drop.

Identifying the Measure

To determine if the motor is oversized or not , some measurements should be taken:

1. Electrical Measurements:
- Power (kW).
- Power Factor.
2. Speed Measurements (RPM).

Using the previous mentioned equation, calculate the Loading Ratio:

$$\% \text{ Load} = \frac{\text{No load rpm - actual rpm}}{\text{No load rpm - full load rpm}} \times 100$$

If Motor Loading Ratio < 50 %, then

- Efficiency Will be very Low.

⇨ Calculate for Replacing it.

Calculations

A. Existing Motor Load & Consumption.

B. Proposed Motor Load & Consumption.

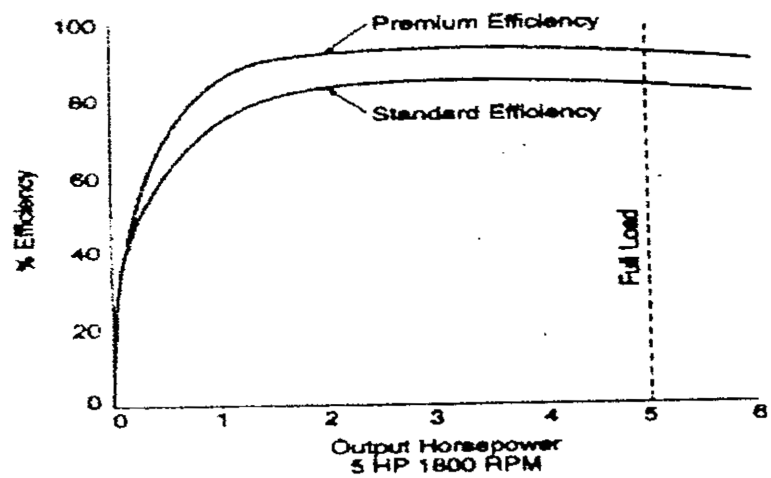
C. Savings = Difference.

3. High Efficiency Motors:

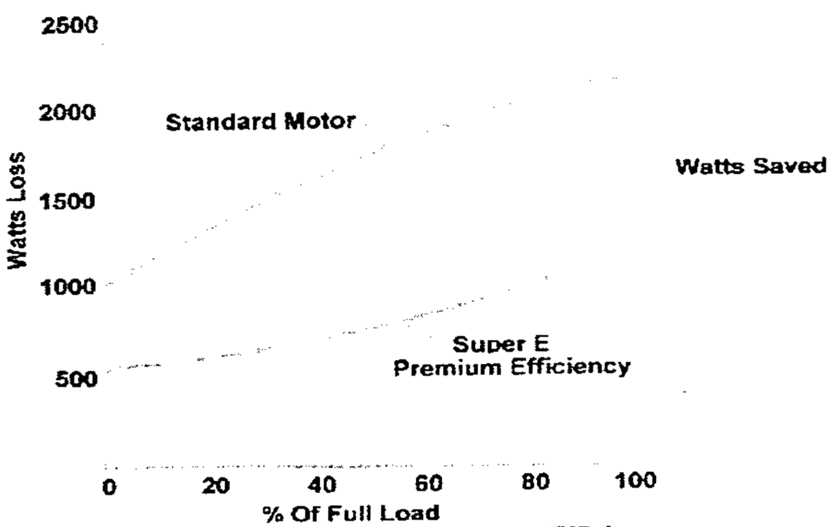
Main characteristics of High Efficiency Motors:

- 3 -5 % More Efficient than standard motors.
- Better Efficiency C/S's.
- Similar or Higher Power Factor.
- Lower Temperature and Noise.
- Less Affected by Supply Fluctuations.

More Efficient: The following figure shows the difference in efficiency between the Standard motor and the high efficiency one.



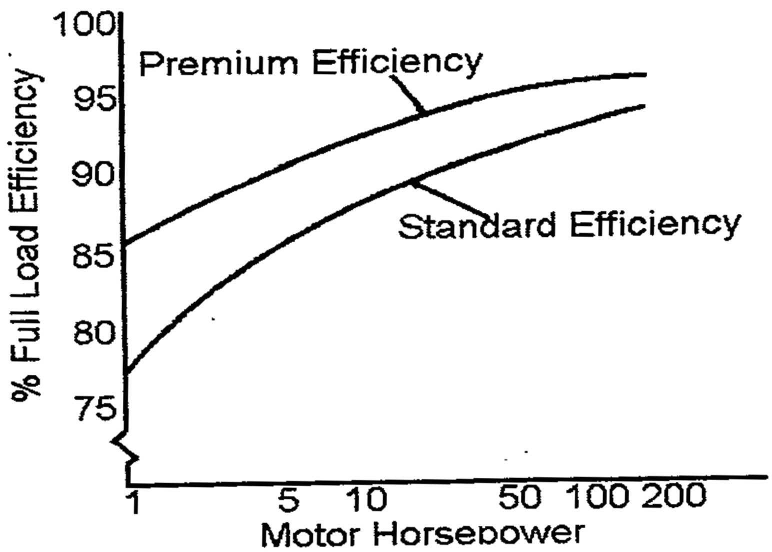
Motor Losses: The following figure shows that the high efficiency motor has less losses than the standard motor.



Watts Loss Standard Vs. Premium Efficiency
25HP, 1800 RPM, TEFC Motor

Electric Motors System

Efficiency (vs.) Horsepower: This figures shows that as the Horse power increases the Efficiency of the standard motor and the high Efficiency Motor become close to each other.



Efficiency Vs. Motor HP
General Trend

Energy Saving

$$\% \text{ Of Savings} = 1 - \frac{\text{Existing Motor Efficiency}}{\text{Proposed Motor Efficiency}}$$

Example:

Existing Motor Efficiency = 88%.
Proposed Motor Efficiency = 93%.

% of Savings = 1- (0.88 / 0.93)

= 5.4 %

Electric Motors System

Example:

Case Description:

An electrical motor is found to be operating **4992** hours per year. Electrical measurement showed that the power input to the motor was **25** kW, while the nameplate showed that the rated values were :

(kW = 22.5, Vr = 400, Ir = 45A, P.Fr = 0.85)

Savings Calculations:

$$\text{Load Factor} = \frac{\text{Actual Power Input}}{\text{Rated Power Input}}$$

= 25/(1.732*400*45*0.85)

= 25/26.5

Load Factor = 0.94

Motor Efficiency = Pout / Pin
= 0.94 x 22.5 / 25

= 84.6%

Which means high efficiency value and this motor cannot be replaced with smaller normal efficiency motor. However, replacing this motor with a 22.5 kW high efficiency motor with 92% efficiency then some savings can be achieved.

$$\% \text{ Of Savings} = 1 - \frac{\text{Existing Motor Efficiency}}{\text{Proposed Motor Efficiency}}$$

= 1 - (0.846 / 0.92)

= 8.0 % of Existing Input Power.

= 8.0 % * 25

Savings = 2 kW

Annual saving in energy cost = 2 kW * 4992 hr/yr * 0.063 JD/kWh

= 629 JD / year

New Motor Cost = 1250 JD

P/B Period = 1250 / 629

= 2.0 Years

New Motor Specifications

- Sufficient Size for Existing Max. Load.
- Same or Suitable Frame to fit in place of old motor.
- Same Speed.
- Same Voltage System.
- Same or Suitable C/S's.
- Same or Better Specifications.

4. Variable Speed Drives :

Introduction

- Variable Speed Drives (VSD) Control the Speed of the Motor to Match the Variable Load.
- Power Consumptionα (Speed)^3.
- Small Reduction in Speed Will Cause Significant Reduction in Power Consumption.
- Very Big Potential But Carefully.

Examples: The following shows the percentage of savings that could be achieved when Reducing the speed of the motor.

Speed Reduction %	Power Savings %
5 %	14.3 %
10 %	27.1 %
20 %	48.8 %
30 %	57.8 %
50 %	87.5 %

Features of AC Variable Frequency Drives

Standard Protection Features:

- Over / Under Voltage.
- Soft Start/Stop.
- Phase-Phase/Earth Shorts on Output.
- Overload Protection.
- Motor Phase Failure.
- Acceleration & Deceleration.
- Electronic Reversing.
- Computer Control Option.

Typical Applications

1. Variable Torque:

- Compressors, Fans, Centrifugal Pumps.
- $T = k \times n^2$
- $P = k \times n^3$

2. Constant Torque:
- Conveyors, Agitators, Crushers.
- $P = k \times n$

Where , n: Motor Speed.
k: Constant.

Requirements for VSD Control

- High Level of Variable Load: Operating at Partial Loads for Long Times.
- Long Annual Operating Hours.
- Possibility of Speed Variation.

Example Cases

- Pumping Applications.
- Air Handling Units.
- Under Loaded Compressors with Low Duty Cycles.
- Fans & Ventilation Systems.

Non Suitable Applications

- Fully Loaded or Highly Loaded Motors.
- Motors that can not Tolerate RPM Decreases.
- Motors Subjected to Frequent Start/Stop Operations (e.g. Cranes).
- Motors that Handle Heavy Loads at Starting Times.
- Synchronous Motors.
- DC Motors.
- Underwater Motors.

VFD Control

VFD can control motor speed and load in three ways:

1. Manual: from the VFD Control Panel.
2. Remote: from external control signal (temp, level, ..).
3. Time Schedule.

Calculations

1. **Calculate Existing Motor Consumption.**
   - Motor kW x Annual Operating Hours.
2. **Determine Average New Speed: % (X)**
   - Savings % = $1 - (X)^3$

3. Use Safety Factor 0.8 – 0.95 depending on the accuracy of your calculations:

- VFD efficiency: 95 – 98%
- Accuracy of measurements or estimation
- *Speed reduction estimation*

Example: Using Variable Frequency Drive on Heating Ventilation Fan.

1. <u>Computation Parameters:</u>

- Motor Measured Load = 11.19 kW
- Existing Operating Time = 24 Hrs/Day
- Operating Days/Month = 30.4
- Operating Months / Year = 12
- Estimated Percentage Of Savings = 53 %

The Fan was operating 24 hours at full speed. It is suggested to reduce the speed at certain periods according to the following time schedule.

Time	Hours	Speed %	Saved kW	New kW	KWh
7:00 - 14:30	7.5	90%	3.032	8.16	61.2
14:30 – 15:30	1	60%	8.773	2.42	2.4
15:30 – 19:00	3.5	80%	5.461	5.73	20.1
19:00- 20:00	1	50%	9.791	1.40	1.4
20:00 – 23:00	3	80%	5.461	5.73	17.2
23:00 – 12:00	1	50%	9.791	1.40	1.4
12:00 – 4:00	4	70%	7.352	3.84	15.4
4:00 – 7:00	3	60%	8.773	2.42	7.3
Total	24				126.2

Existing Consumption = 268.6 kWh/Day.

Average % of Savings = 53.0%.

2. Annual Energy Savings

Existing Electrical Consumption = Electrical Load(kW)*Operating Hours/Year

= 11.19 kW * 24 Hr /Day * 30.42 D/M* 12 M/Y

= 98035 kWh/Year

Existing Energy Cost = Electrical Consumption * Electrical Tariff

= 98035 kWh * 0.063 JD / kWh

= 6176 JD / Year

Saving In Electrical Consumption = Estimated Saving % * Existing Electrical Cons.

= 53% * 98035 kWh

= 51959 kWh

3. Annual Monetary Savings

Savings In Energy Cost = Savings In Electrical Consumption * Electrical Tariff

= 51959 kWh* 0.063 JD /kWh

Annual Savings **= 3273 JD / Year**

4. Investment Details

Equipment:

VFD 15 kW	: JD 1500
Time Control Unit	: JD 300
Electrical Panel and Protection	: JD 500
Wiring & Accessories	: JD 100
Installation	: JD 100
Total	**: JD 2500**

P/B Period **= 9 Months**

Section VII

Combustion System

Topics that will be covered in this session

- Calibration.
- Flue gas Analysis.
- Stack temperature.
- Smoke Measurements.
- Draft Measurements.
- Stack losses.
- Reducing Excess air.
- Heat Losses due to burner cycling.
- Cleanliness.
- Effect of Boiler Calibration on fuel Consumption.

Tips

- Monitor the chimney, the flue gases should be colorless.
- Stack losses can range from 7% to 30%.
- Soot should be removed manually.
- Scale should be removed chemically.
- The burner should not start more than 2-3 times per hour.
- Replace (ON- OFF) burners to modulating ones.
- Don't forget to include labor cost in the investment.

Energy Management In Combustion

Petroleum Products Tariff & Specifications.

Fuel Type	Specific Weight Kg/liter	Lower C.V Kcal/Kg	Tariff JD
Kerosene	0.79	10350	0.110 /Liter
Diesel Oil #2	0.835	10200	0.110 /Liter
Heavy Oil #6	0.968	9680	72.5 /Ton
LPG	-	10960	0.192/Kg

1- CALIBRATION:

- Combustion is the chemical reaction of oxygen with a substance to produce heat.

- Fuels usually contain Carbon, Hydrogen and sometimes traces of Sulfur.
- Coals are mostly Carbon , while liquid and gaseous fuels are Hydrocarbons.
- C_nH_m+Air (O2 + N2 +Other Gases) $\longrightarrow$ $CO_2+CO+O_2+SO_2+SO_3+$**NOx+Heat**
- Fuel consumption is affected directly by combustion efficiency.
- Combustion efficiency depends on:

  1- Exhaust gas temperature.
  2- O_2 % in flue gases.
  3- CO_2 % in flue gases.
  4- CO % in flue gases.

2- FLUE GAS ANALYSIS:

- The product of any combustion process is heat and exhaust flue gases.
- Flue Gas Analysis is used to indicate the air-to-fuel ratio and the degree of completeness of combustion.
- Percent of O_2 & CO_2 are indicators of the amount of excess combustion air.
- Percent of CO and CO_2 are indicators of the completeness of combustion.
- Good mixing = perfect combustion when flue gas analysis shows minimum CO or O_2, and a maximum value for CO_2.
- For greatest efficiency, the fuel-and-air mixture should be adjusted until the maximum CO_2 level is obtained.

- The following table lists the ultimate CO_2 readings for the varying amounts of excess air in the combustion of common fuels.

Effect of Excess Air on CO 2 in Combustion Products

Natural Gas	12	10.7	9.8	8.3	7.2	6.3	5.7	4.5	3.7
Propane	14	12.6	11.5	9.8	8.5	7.5	6.7	5.3	4.4
Butane	14.3	12.9	11.7	10	8.6	7.6	6.8	5.4	4.5
Distillate Oil	15.2	13.8	12.6	10.7	9.3	8.2	7.4	5.9	4.9
Residual Oil	15.6	14.1	12.9	11	9.6	8.5	7.6	6.1	5
Bituminous Coal	18.4	16.7	15.3	13	11.4	10.1	9	7.2	6
Anthracite Coal	19.8	18	16.5	14.1	12.4	11	10	7.9	6.9

3- STACK TEMPERATURE:

- Net stack temp = Flue gas temp - Ambient temp.
- Stack temp should be kept as low as possible without causing cold end corrosion which caused by formation of sulfuric acid H_2SO_4 due to:
- $SO_2 + \frac{1}{2} O_2 \longrightarrow SO_3$.
- $SO_3 + H_2O$ vapor $\longrightarrow H_2SO_4$.
- High stack temperature (400 °C or above) indicate one of the following conditions:
  1- Excessive draft (Poor draft regulation).
  2- Dirty heating surfaces.
  3- Poor design of heat exchange surfaces.
  4- Undersized furnace.
  5- Over-firing.

- If the stack temperature exceeds the steam, water, thermal oil or the sitting temperature of any heating boiler or furnace by 65 °C at full load then fuel savings potential is indicated.
- Stack temp. should be kept above:

Natural gas	>	120 °C.
Oil # 2	>	135 °C.
Oil # 6	>	150 °C.
Coal	>	165 °C.

4- SMOKE MEASUREMENTS:

- The smoke in the stack can be used to estimate the cleanliness of combustion.
- Smoky combustion can indicate:
  - Improper air delivery.
  - Insufficient draft.
  - Improper fuel viscosity.
  - Oil pump malfunction.
  - Defective or incorrect fuel nozzles.
  - Improper fuel to air ratio.
  - Excessive air leaks.
- Practically, when combustion conditions are adjusted, maximum CO_2 should be controlled at a point that does not cause excessive smoke.

5- 1.4 DRAFT MEASUREMENTS:

- Draft: The rate at which combustion gases passes through the boiler.
- Excessive draft will increase stack temp. and reduce CO2 percentage.
- Inadequate draft results in insufficient air and smoky operation.
- Perfect draft, the flame bushes out to nearly fill the firebox.
- Draft readings are usually taken in the firebox and in the stack.
- Low draft in the firebox can result in leakage of smoke and other combustion products into the surrounding area.
- Stack draft must be high enough to prevent positive pressure in the combustion chamber.

6- STACK LOSSES:

- Main source of heat losses is through stack.
- Additional heat lost by radiation from furnace walls and by blow-down.
- A stack loss is the heat required to raise the flue gas from room temp. to stack temp. measured after last heat transfer surface.
- Stack losses can range from 7% to 30%.
- The latent heat of the water vapor in the stack is also considered a loss.
- Latent heat is the heat that would be available if all the water vapor in the flue gas were condensed into liquid water.
- The amount of water vapor corresponds to the hydrogen content of the fuel. Loss is about 13% for natural gas, 8% for oil, and 6% for coal.
- Stack losses can be reduced by decreasing either the temp. or the volume of the flue gas or both.
- Flue gas temp. is reduced by improving heat transfer or by reducing the amount of excess combustion air.
- A certain amount of excess air is necessary to complete combustion within the confines of the combustion chamber.
- Only enough air to prevent incomplete combustion or flame impingement on the tubes should be provided.
- The more efficient the burners are from the point of view of mixing, the smaller this necessary quantity of excess air will be.
- Excess air is usually added as combustion air to the furnace.
- Another source is through leaks in the casing or through out-of-service burners.

Section VIII

Steam System

Topics that will be covered in this session

- Basic Principles.
- Steam tables.
- Steam System Components.
- Energy Saving in Steam.
  1. Optimize blow down.
  2. Reduce Boiler pressure Settings.
- Steam Network.
- Steam Utilization.
- Condensate Recovery.
- Steam Traps.
- Overall System efficiency.

Tips

- Per 10 °C of temperature raising of feed water, Fuel savings of 1.5% could be achieved.
- Per 10 °C of temperature raising of Combustion air, fuel savings of 0.5% could be achieved.
- Per 20 °C drop of the gases temperature, fuel savings of 1.25% could be achieved.
- Per 2% of blow down rate reduction, fuel savings of 0.32% could be achieved.
- Check and maintain all steam traps.
- Recover and reuse condensate where possible.

Energy Management In Steam System

Basic Principles

- Steam is simply water in vapor state.
- Heat is added to reach the boiling point (Sensible Heat).
- More heat is added to convert water to vapor (latent heat).
- The steam is saturated.
- If more heat is added, the steam is called Superheated.
- The steam is conveyed from the boiler to the end user where heat transfer takes place.
- The latent heat is given up the, steam condenses at the boiling point to liquid.
- The resulting condensate still contains the energy added to bring water to boiling point.
- This condensate must be reused.

Steam Tables

- Provide the characteristics of steam under different conditions:

  1. Temperature.
  2. Pressure.
  3. Enthalpy of water (sensible heat).
  4. Enthalpy of evaporation (latent heat).
  5. Enthalpy of steam (total heat).
  6. Specific volume of steam.

Steam	Steam	Specific Enthalpy			Steam
Pressure	Temperature	Water (hf)	Evaporation (hfg)	Steam (hg)	Specific volume
Bar	'C	KJ/KG	KJ/KG	KJ/KG	m^3/KG
0.5	81.3	340.5	2305.4	2645.9	3.24
0	100.0	419.0	2257.0	2676.0	1.67
1	120.4	505.6	2201.1	2706.7	0.88
3	143.8	605.3	2133.4	2738.7	0.46
5	158.9	670.9	2086.0	2756.9	0.32
7	170.5	721.4	2047.7	2769.1	0.24
9	180.0	763.0	2015.1	2778.1	0.19
10	184.1	781.6	2000.1	2781.7	0.18

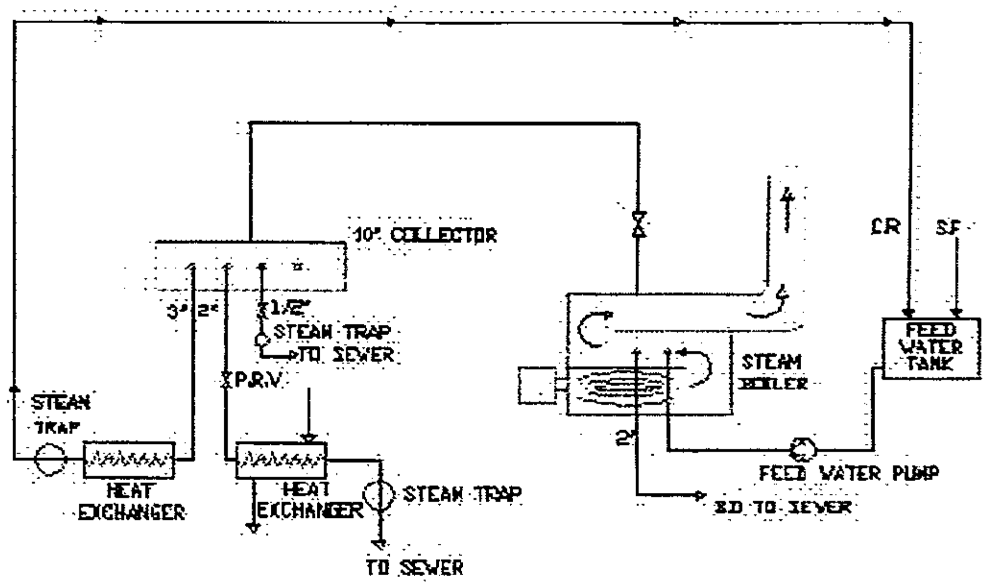
- As the pressure in the steam boiler rises, the boiling point of water (and hence the steam temperature) also rises, increasing the usefulness of steam as a heating medium.

- The amount of heat required to raise water to the boiling point (sensible heat) and to convert it to steam (latent heat) changes.

- Since the latent heat is usually regarded as the "useful energy" in the steam, high-pressure steam contains less useful energy but at a higher temperature.

Steam System Main Components:

1. Steam Generator (Boiler).
2. Steam network (pipes, valves, steam traps).
3. Condensate return (tanks, pumps).
4. Steam consuming equipment's (steam users).



Efficiency

- The overall system efficiency relates the useful work obtained by the user to the fuel burned in the boiler.
- Overall efficiency is the multiplication of the above individual main component efficiencies.
- Small improvement in the efficiency of each element can result in significant improvement in the overall system efficiency.

1) Energy Saving in Steam Boiler:

A. Combustion Efficiency.

It has been discussed in the previous section.

B. Blow Down.

- The process of steam generation results in the concentration of dissolved and suspended solids in the boiler water.
- Above a certain level of concentration, these solids encourage foaming, causing carry-over of water with the steam.
- Because they can be laid down as a scale inside the boiler, they can cause local overheating which could lead to tube failure.
- It is therefore necessary to control the level of concentration of the solids and this is done by the process of "blowing down".
- Certain volume of water is drawn off - and is automatically replaced by feed water.
- Thus maintaining the optimum level of total dissolved solids (TDS) in the water inside the boiler.

Blow Down Percentage = S1/(S2-S1)*100%

S1 :TDS level of feed water - PPM

S2 :Desired TDS level in boiler – PPM.

- Per 2 % reduction of B.D rate, (0.3 %) of fuel will be saved.

- Also substantial savings in the cost of water, water treatment and chemicals used.

C. Reduce Boiler Pressure

- When the pressure in the steam boiler increases:
- The boiling point of water increases.
- The amount of heat required to raise water to the boiling point (sensible heat) increases.
- The useful energy in the steam (latent heat) is decreased.
- High-pressure steam contain less useful energy at higher temperature.
- It is a common practice in most industries to use higher steam pressure than required. Hence, fuel consumption is higher than normal rates.
- When the boiler working pressure is reduced to match the desired limits:
- Heat input and other losses will be reduced,
- The final fuel consumption is minimized under the same operating conditions.
- It is easy to reduce the operating pressure of a system in order to adjust it to meet the specific needs.
- The right steam pressure for a particular task is the lowest acceptable.

Steam System

Example Case : Reduce Steam Boiler Pressure Settings

Boiler working pressure	P_1 : 9 bar
Total steam enthalpy	Q_1 : 2778 KJ/kg
Conversion factor	f : 4.186 KJ/kcal
Boiler output	m : 2500 kg/hr
Max pressure required	P_2 : 7 bar

- Pressure drop in steam pipes should be taken into consideration before suggesting new operating pressure assuming this pressure drop is one bar, then, it is proposed to reduce the boiler pressure by One bar.

- Boiler reduced pressure P3 : 8 bar
- Total steam enthalpy (8 bar) Q2: 2774 KJ/kg (From Steam Tables).

- Energy Saving = Heat required at 9 bar - Heat required at 8 bar

- Heat required at 9 bar $= (Q_1 * m) / f$

$$= \frac{2778 * 2500}{4.186}$$

$= 1659102$ kcal/hr

- Heat required at 8 bar $= (Q_2 * m) / f$

- Heat required at 8 bar $= \frac{2774 * 2500}{4.186}$

$= 1656713$ kcal/hr

- Energy Saving $= 1659102 - 1656713$
  $= 2389$ kcal/hr

- Fuel Saving $= \frac{\text{Energy Savings}}{C.V * d * E}$

- Fuel Saving = 0.354 lit/hr

- Annual Fuel Saving = Fuel Saving * boiler Operation Hours
  = 0.354 * 7200
  = 2549 lit/yr.

- Annual monetary saving = Annual fuel saving * fuel cost
  = 2549*.110
  = 280 JD/yr.

Steam System

2) Steam Network Distribution

- The efficient steam generation is not the end.
- Steam must be available at the required time in the right quantity, pressure and condition.

A-Pipe Sizing

- Distribution losses can be minimized by installing properly sized pipes.
- Pipe sizing should be done according to volumetric flow rate.
- Over sized means high capital cost and higher radiation losses.
- Under sized means large pressure drop.

B- General Lay-out

- Proper provisions must be made for proper draining of the condensate.
- Well insulated 100 mm pipe steam pipe at 7 bar, 30 m length, can condense 10 kg of steam per hour.
- Although it represent less than 1% of the carrying capacity, but it is 10 liters of water that should be removed.

C- Insulation

- Steam and condensate pipes, valves and flanges should be insulated to reduce losses.
- Insulation can often be applied easily and quickly without interrupting an operation or process.
- The effect of insulation in reducing heat losses may be estimated using various equations for heat transfer.
- Each bare flange is equivalent to 0.3 m of bare pipe.
- Each bare valve is equivalent to 1.5 m of the bare pipe.
- All hot flat surfaces of steam consumed equipment, cylinders, and H.W.F.T should be insulated.

Example: Calculating Savings From Insulation

Pipe Heat Losses Without and With 1" Insulation W / m Surface Temperature C						
	50		100		150	
1/2"	32	6	100	17	200	28
1"	45	7	140	22	300	36
11/2"	60	9	200	26	400	44
2"	75	12	240	24	500	54
3"	100	15	340	40	700	72
4"	130	17	400	50	850	90
6"	170	24	600	70	1200	120

Steam System

Pipe diameter 11/2"
Pipe length 100 m
Surface temp. 100 °C
Operating hours 7200 hr/Yr.
Bare pipe Loss 200 W/m
Insulation loss 26 W/m
Fuel used Diesel

Heat Loss = 100*(200-26)*0.86*7200
= 107740800 Kcal/yr.

Fuel Loss = 107740800 / (10200*.835*.793)
= 15952 Lit/yr

Savings = 15952*0.110

= 1754.7 JD/yr.

Investment required

Insulation material 150 JD
Labor Cost 50 JD
Total Investment **200** JD

Pay-back = (Investment / Savings)
= 200/1754.7
= 0.11 year.

Suppliers:
Rock-Wool Industrial Co.

3) Steam Utilization

- After having efficient steam generation and efficient steam distribution systems, it is equally important to have an efficient steam utilization system by:

  1) Maintaining the required temp. and press.
  2) Periodic de-scaling of H.E surfaces.
  3) Proper and efficient steam trapping.
  4) Preventing steam leaks.

Reducing Steam Leaks

- Steam leaks affects directly the fuel consumption cost, the water cost and the water treatment costs.
- Any steam leaky joint should be fixed immediately.
- The following table allows rough estimates of the steam leak losses, thus allowing the losses to be quantified in monetary terms.

STEAM LEAK RATE THROUGH HOLES (kg/hr)

Orifice	Steam Pressure (Kpa)				
Dia (mm)	105	170	345	520	690
0.80	0.39	0.52	0.81	1.17	1.50
1.60	1.55	2.09	3.36	4.68	6.00
2.40	3.50	4.68	7.59	7.00	13.50
3.20	6.23	8.32	13.55	18.77	24.00
4.00	9.68	12.95	21.14	29.32	37.50
4.80	13.95	18.68	30.45	42.27	54.09

- 1 mm hole diameter passing steam at 7 bar from steam pipe or any fitting or from steam trap will cause loss of 2 kg of steam per hour.

If the system operates 7200 hrs/Yr, then the energy loss will be 120 JD/Yr.

4) Condensate

- Condensate is hot distilled water.
- Returning it to the boiler feed tank will save considerable amount of fuel.
- It will also save water, the cost of water treatment, and heat wasted in excessive blow-down.
- Steam traps are used to drain the water from the piping network and after the steam utilization.

Steam System

Steam Traps

- Steam traps are the key to optimum steam and condensate system operation.
- Main functions:

  1- Removing condensate.
  2- Removing air and other gases.
  3- Preventing steam loss.

- There are three basic types of steam traps:

  1- Thermostatic (Temp. Difference).
  2- Thermodynamic (Change of the state).
  3- Mechanical (Density Difference).

- Collecting condensate means taking the discharge from one or more steam traps into a piping system, which carry it to the boiler feed-water tank.
- It is important to note that the piping does not interfere with the proper operation of the steam traps.

<u>**Example Case:**</u> **Condensate Recovery**

Condensate temp.	T_1 : 95 °C
Make-up water temp.	T_2 : 25 °C
Condensate flow rate	M : 250 Lit/hr
Boiler operation	H : 7200 hr/yr.
Specific heat	S : 1 kcal/kg °C
Fuel used	Diesel
Fuel cost	C : 0.110 JD / Lit

Heat losses $= M * H * S * (T_1 - T_2)$
$= 250 * 1 * (95 - 25) * 7200$
$= 126{,}000{,}000$ kcal / yr.

$$\textbf{Fuel Cost} = \frac{\text{Heat losses} * \text{Fuel cost}}{C.V. * d * E}$$

C.V.	Calorific Value	= 10200 kcal/kg
d	Diesel Density	= 0.835 kg/lit
E	Boiler Efficiency	= 79.3 %

$$\text{Fuel Cost (saving)} = \frac{126000000 * 0.11}{10200 * 0.835 * 0.793}$$

Fuel Cost (saving) = 2052 JD/Yr.

Steam System

Water Treatment Cost Savings

= M * H * Water Treatment Unit Cost
= 0.250 * 7200 * 0.2 JD / m^3
= 360 JD / Yr.

Water Saving = M * H * Unit Cost
= 0.250 * 7200 * 1 = 1800 JD / yr.

Total Savings = Fuel Savings + Water Savings +Water Treatment Cost Saving

= 2052+360+1800

= **4212 JD / Yr.**

Investment required

Steam traps 5 units	600 JD
Pipes and fittings	850 JD
Labor cost	250 JD
Total Investment	**1700 JD**

Simple Pay-back = Investment / Savings

= 1700 / 4212

= 0.4 years

Suppliers

SAM (Spirax Sarco)
EDT (TLV)

Steam Cost

What is the cost of 1 ton of steam at 7 bar without and with condensate recovery?

From Steam Tables @ 7bar:

Latent Heat = 2047.7 kJ/Kg
Sensible Heat = 721.4 kJ/Kg
Total Heat = 2769.1 kJ/Kg
S.H = 26 %
L.H = 74 %

A. With Condensate recovery:

Required Heat = (2047.7 *1000) / (4.186)
= 489178 Kcal

Fuel Quantity = 489178 / (10200*.835*.793)
= 72.4 Liter

Fuel Cost = 72.4 * 0.11
= 7.964 JD

Steam System

B. Without Condensate Recovery

Fuel Cost = 10.774 JD

In case of H.F.O: The cost will be 4.6 JD with recovery and 6.2 JD without recovery.

Overall System Efficiency

1) Boiler Efficiency

Stack Losses	20%
Shell losses	3%
B.D Losses	3%
Net Boiler Efficiency	**74%**

2) Distribution

Insulation	6%
Net Distribution Eff.	**94%**

3) Utilization Efficiency

H. Exchanger losses	3%
Leak	2%
Net Utilization Eff.	**95%**

4) Condensate Losses

Assume 50 % recovery	13%
Condensate Efficiency	**87%**

Overall system eff. **= 0.74* 0.94*0.95*0.87**

= 57.5%

The 57.5% is Low efficiency and could be increased easily, lets see what will happens to the system efficiency if the sub-system efficiencies increased as shown below:

1) Boiler Efficiency:	NEW	OLD
Stack Losses	15%	20%
Shell losses	2%	3%
B.D Losses	2%	3%
Net Boiler Efficiency	**81%**	**74%**

Steam System

2) Distribution		
Insulation	4%	6%
Net Distribution Eff.	**96%**	**94%**
3) Utilization Efficiency		
H. Exchanger losses	2%	3%
Leak	1%	2%
Net Utilization Eff.	**97%**	**95%**
4) Condensate Losses		
Assume 80 % recovery	5%	13%
Condensate Efficiency	**95%**	**87%**

Overall system eff. **= 0.81* 0.96*0.97*0.95**
= 71.6 %

Fuel Savings = {1 - (old Eff / new eff)}*100%
= {1 - (0.575 / 0.716)*100%
= 19.7 %

We can see that we could achieve a 19.7% fuel savings, if we could improve and reduce the losses in the whole system to an acceptable range that could be reached by implementing low cost energy conservation measures.

Steam System

Energy Conservation Measures

- Boiler Calibration.
- Boiler cleaning
- Improve Boiler Shell Insulation
- Control and Reduce Boiler B.D According to Manufacturer Recommendations.
- Heat Recovery from B.D, Chimney and any waste heat source.
- Reduce Boiler Pressure where possible.
- Use Fuel Additives and fuel conditioners.
- Insulate all steam and condensate pipes, flanges and valves and all flat hot surfaces.
- Control the pressure and temp according to the process requirements.
- Clean the heat exchange surfaces.
- Recover and reuse all condensate where possible.
- Prevent burner recycling
- Recover the flash steam.
  - Check and Maintain all steam traps periodically.
  - Use cheap energy sources.

Rule of Thumb

- Per 10 °C of temp raising of feed water 1.5% Fuel saving.
- Per 10 °C of temp raising of comb. air 0.5% Fuel saving.
- Per 20 °C drop in flue gas temp1.25% Fuel saving.
- Per 2% of blow down rate reduction. 0.32 % Fuel saving (F.W.T 70 °C)

Appendix A

Lighting Characteristics

Introduction:

Energy conservation is a wide comprehensive concept. It includes both energy savings and logical use of energy. It represents the following aspects:

1. Optimal economical use of Energy Sources.
2. Improvement of equipment and machines efficiency, operating conditions and maintenance.
3. Development of modern methods for design implementation an installation.

Lighting consumes about 4% of total energy consumed in the world, and this percentage varies between countries according to the size of the industrial sector and building systems in these countries.

Many energy conservation studies and researches concentrate on industrial lighting systems in attempt to reduce its energy consumption. In fact, since 1950, mercury lamps efficiency had been improved by 65% fluorescent by 80% and sodium lamps by 115%. At the same time many researches are still working on developing new types of lamps with very high efficiency and minimum energy consumption.

(Figure A.1) shows the improvement of efficiencies of different types of lamps.

Nowadays the wrong concept (the brighter the better), which was common for a long period of time, has been disappeared. Therefore new methods of lighting systems design were developed in parallel with concentration on investigating new manufacturing technology of lamps. Particularly increasing illuminance of these lamps.

Lighting is a major source of energy consumption in your building. But unfortunately some of that consumption is wasted. If you don't include lighting as part of your plan, you will be missing some excellent conservation opportunities.

Even though many modern office buildings utilise windows for architectural aesthetics, we seldom see natural light used in task lighting. Lights have to be on during all occupied hours. Unfortunately, they often remain on after working hours even though only a few people occupy the building.

In the past twenty years, lighting design standards have changed and our buildings reflect the trend toward increased lighting levels. At present, average annual electrical usage amounts to from 22,000 to 35,000 Btu's per square foot per year. (These figures are based on 2.5 to 4 watts per square foot, occupied 10 hours a day, 5 days per week). This represents 40 - 70% of the targeted 55,000 Btu's/year/ft^2 recommended for new construction. That's worth looking at!

Determining the need for an Energy Management Program

Early standards to restrict lighting dealt only with buildings and were confined to limiting power as an evaluation point for compliance. They did not address energy. None were design procedure, but rather established power budgets or limits that the designer should not exceed in designing the lighting system, or in making modifications to an existing facility. Power reduction, however, is only one part of the conservation story.

Energy = power * time

A savings in energy can be achieved by reducing either power (connected load in watts or kilowatts) or by reducing time (hour use in kilowatt-hours). Energy reduction options include modifying or replacing the lighting system with a more efficient one, using replacement components that use fewer watts, or modifying the operating characteristics of the building to reduce kilowatt hours. If both power and time are reduced, the energy saving potential is further increased.

Although the opportunities for reducing energy in an existing structure are more limited than those in new system planning, from both a structural and financial (return on investment) aspect, energy savings must be an important concern to the existing building owner. As more energy-efficient space is made available in commercial building, competition for tenants, together with the results of growing fuel costs, should be an effective incentive to modify lighting systems.

Before energy can be conserved, it must be identified, by evaluating the lighting systems presently installed and how they are used.

Building Analysis

The recommended procedure for analyzing a lighting system is to conduct a survey of the building to determine what is in place. An alternative method is to review the building project plans, if available. This is a less satisfactory way of establishing a basis for an energy-saving program because deviations from design specifications may have been made over the years, creating a discrepancy between plans and the actual system as maintained. If the building survey is done from drawing, a random check should be made of lamps and fixture in certain areas of the building to find out what substitutions if any, have been made.

In addition to surveying the connected power and usage of the lighting system, it may be advantageous to note other factors that affect the decision to make changes to avoid making another survey at a later date.

Seeing tasks and their locations should be identified and the present lighting level measured and recorded. There may be an opportunity to reduce power, for example, in an existing space that is uniformly lighted to a level higher than the tasks required, by modifying the system so that it relates to task lighting requirements, with less illumination in the surrounding non-task areas.

Other items to be noted during a survey of a facility include how the lighting installation in each space is controlled (locally switched, panel board), reflectances of the room surfaces (ceiling, walls, floor), and space geometry (ceiling height, room length and width) many existing buildings power and energy savings may also be achieved by an evaluation and subsequent modification of the maintenance program and operating procedures. Improving a lighting maintenance program, or instituting one where none exists, may allow some reductions in power because the system will operate closer to its initial design efficiency and perhaps fewer watts will be required to deliver the light level specified.

Following a survey of the building, an evaluation should be made of individual spaces and the lighting system analyzed for improvements. The results form the basis for an energy management program to modify the system for savings in energy and money.

Modification of Existing Systems

Before undertaking any changes in the lighting, it should be recognized that the installation is a system - a set of related components and elements, as interrelated to one another as lighting is to other systems in the building. Although savings can be achieved by making power reductions in components, such as removing two out of four lamps in one luminaires or disconnecting a percentage of luminaires in one area, these measures should only be taken after a careful analysis of the entire system has been made to determine the effects of random curtailment.

There are two choices to be made in making changes in the system; a modification of the existing system or a replacement of one system with another. Modifying, or retrofitting, is the simplest way of achieving energy savings. Included are items such as replacing one light source with another of a higher efficacy. Substitutions of this nature may be made within one family of lamps or by changing from one family of sources to another, if compatible with the luminaires. For example, by using parabolic aluminised reflector (PAR), reflector (R), or elliptical reflector (ER) incandescent lamps in place of standard A types, equal light (measured in lux) may be provided with a 50% power reduction. In the fluorescent family of sources, reduced wattage lamps will make possible a 14 to 20% reduction in power consumed by standard types.

Replacement of Existing System
System replacement involves replacing one system with another and usually requires a higher investment than retrofitting. Energy savings, however, are achieved as a result of the lower annual operating costs of the new, more efficient system and contribute to the determination of payback. For example, by replacing a 1000-W mercury vapour system with a 400-W high-pressure sodium installation, a power savings of 605 W per fixture (including ballast losses) can be achieved, while maintaining the light output at the same level (44,700 lumens for mercury, versus 45,000 for high pressure sodium).

Priorities
Some modifications may be accomplished easily and at little or no cost, while others may involve extensive retrofit or system replacement, with higher capital expenditures to be considered. Not all suggestions are applicable to all building types, and the owner must establish his or her own priorities of selection and timing feasibility.

Initial Cost vs. Annual Operating Cost
Initial costs include lamps, fixtures, wiring, and installation. Annual costs include lamp replacement, maintenance, and electricity. Although a system is purchased only once, its operating costs are an ongoing expense. It is this expense program.

Annual cost savings can be estimated by calculating the annual operating costs of the proposed modified system. Data needed for an economic analysis include the cost of the new lamps and fixtures, installation charges, cost of replacing lamps, life of the old and new lamps.

Other energy savings to evaluate are demand charges. A demand charge is the peak kilowatt value during the billing period. If the lighting load is reduced, the peak demand may also be reduced and therefore the demand charge.

Illumination Requirements
To ensure that space is utilized as efficiently as possible when designing for new occupancy or when evaluating the present space layout, it is important to become familiar with the principal function of the facility, the types of tasks to be performed, the space allocated or necessary for each and the proportion of workspace to circulation. Lighting should be planned, redesigned, or modified to relate to the task performance needs.

Task Lighting Requirements
The emphasis here is on the identification of the tasks performed in any area of the building so that the location of the lighting equipment, the orientation of the tasks, an the illumination requirements in quantity and quality may be co-ordinated. The objective should be to provide task related illumination while avoiding unnecessarily high levels of uniform lighting throughout the space. Symmetrical, uniform lighting layouts may be acceptable when worker density is high; otherwise, areas surrounding the tasks will be over-lighted.

It is essential to know the precise location of the tasks especially those that may require special treatment, so that the appropriate level may be provided at the task with lower levels in the surround. If changes in space use occur or are anticipated, flexibility of relocating luminaires should be planned. The location and angle of the work planed should also be determined, so that the recommended illuminance level is achieved in the plane of the task. Examples of this are adjustable drafting tables an vertical displays of merchandise or library stacks. Any measurements of existing or modified lighting levels should be made in that plane and not simply on the horizontal.

Lighting levels
Recommended illuminance levels are those established by the Illuminating Engineering Society of North America and contained in the IES Lighting Handbook, 1981 and also in CIBSE The Chartered Institution of Building Services Engineers / London. These are minimum, maintained values on the task. The value for each task is selected from a range of illuminances, depending on the age of the worker, the need for speed and accuracy in performing the task, and the task background reflectance.

In the building survey present lighting levels should be measured. If the present maintained level for a task is higher than the level contained in the IES or CIBSE range for that activity, the system should be modified to reduce the quantity of light on the task and at the same time reduce the connected power and energy used. A simple retrofit method to reduce the level is to replace the existing light sources with lower-wattage lamps. Another solution is to control individual luminaires or groups with separate switch controls, so that selected units can be independently turned on or off or dimmed as needed to vary the illuminance in the area.

Quantity of illumination is only one aspect of task performance, and it should be noted that the quantity of the light delivered on the task plane is equally important. Any modifications in the system should consider both aspects, since the quality of the lighting may be adversely affected at the same time as quantity is reduced. On the other hand, quality may be improved with changes if visual comfort is improved through a reduction in glare.

(Table A.1) Examples of activities/interiors appropriate for each standard service illuminance

Standard Service Illuminance (lx)	Characteristics of activity/interior	Representative activities/interiors
50	Interiors visited rarely with visual tasks confined to movement and casual seeing without perception of detail	Cable tunnels, indoor storage tanks, walkways.
100	Interiors visited occasionally with visual tasks confined to movement and casual seeing calling for only limited perception of detail	Corridors, changing room, bulk stores
150	Interiors visited occasionally with visual tasks requiring some perception of details or involving some risk to people, plant or product.	Loading bays, medical stores, switch rooms
200	Continuously occupied interiors, visual tasks not requiring any perception or details	Monitoring automatic processes in manufacture, casting concrete, turbine halls
300	Continuously occupied interiors, visual tasks moderately easy, i.e. large details > 10 min arc and/or high contrast	Packing goods, rough core making in foundries, rough sawing.
500	Visual tasks moderately difficult, i.e. details to be seen are of moderate size (5 - 10 min arc) and may be of low contract. Also colour judgment may be required.	General offices, ceramic decoration, meat inspection.
750	Visual tasks difficult, i.e. details to be seen are small (3 - 5 min arc) and of low contrast, also good colour judgments may be required.	Drawing offices, ceramic decoration, and meat inspection.
1000	Visual tasks very difficult, i.e. details to be seen are very small (2 - 3 min arc) and can be of very low contrast. Also accurate colour judgment may be required.	Electronic component assembly, gauge and tool rooms, retouching paint work.
1500	Visual tasks extremely difficult, i.e. details to be seen extremely small (1-2 min arc) and of low contrast. Visual aids may be of advantage.	Inspection of graphic reproduction, hand tailoring, fine die sinking.
2000	Visual tasks exceptionally difficult, i.e. details to be seen exceptionally small (<1 min arc) with very low contrasts. Visual aids will be advantage.	Assembly of minute mechanisms, finished fabric inspection.

System Modifications
Without replacing one system with another, it may be possible to modify the present lighting to improve the illuminance in the space: a compromise between the two approaches of retrofit and system redesign.

In high-ceiling areas, or if lighting levels on the task are inadequate and it is possible to do so, lower the luminaires closer to the work surface to increase the quantity of light. By lowering the luminaires it may also become practical to reduce wattage by relamping with lower wattage lamps of a higher efficacy and still maintain the recommended illuminance level on the task, provided that the light distributed from lowered fixtures is still available.

If space utilisation has been changed since the building was occupied initially and without an accompanying change in the lighting system, there may be a need for removal of some luminaires, or their relocation. These may be permanently disconnected or used elsewhere in the facility. For example, if a large area has been subdivided with partitions, the luminaire location may no longer be appropriate for the present space layout. In extreme cases, luminaires have been left in place bisected by the addition of a stack of filing cabinets or other floor-to-ceiling divider. Their removal improves not only the energy efficiency of the lighting in the space, but also its design esthetics.

Non-illumination Modifications
Not all changes that increase the efficiency of the lighting system necessarily involve the lamps, luminaires, ballasts, or other system components. Some have to do with changing workstations and the materials used by the workers.

It may be advantageous, for example, to group tasks that have the same lighting requirements into one area, or to relocate workstations, which are scattered in poorly utilised space. If consolidation can be achieved, lighting may be reduced or turned off in some area of the building.

Such a relocation of tasks may also improve the quality of the lighting because of improvements in visual comfort. When reorienting workers in a space, make sure that the luminaire and worker relationship does not result in any direct or reflected glare (veiling reflections) that will obscure the details of the task to be performed.

If only a few workers are occupying a building at certain periods or after hours, it lessens energy requirements to group their functions in one area or floor of the building. An examination of individual tasks may produce some ideas for quantity and quality improvement. For example, a worker using printed materials with high contrast will require a lower illuminance level than a worker using materials of a poor contrast, such as illegible, fourth generation photocopies. Changing the colour of the paper used for some writing tasks may be a simple and effective way to produce a better contrast for the employee and thereby improve performance, both in speed and accuracy with a reduction in the quantity of light necessary for the task.

Lighting for Non-task Areas
If an overall general lighting system is changed to a system of task lighting with a lower level in the surround, it may be desirable to use some of the power saved as supplementary lighting for interest and balance in the space: for example, on painting, murals, for plants or on walls, or to define the boundary of the space. Pleasantness of the environment and human factors of enjoyment and well-being should not be completely sacrificed to energy efficiency.

In areas without visual tasks, review the present level of illumination and type of system in use for possible reduction or modification, provided that any type of system in use for possible reduction or modification, provided that any changes are consistent with safety and esthetics for the application.

Reflectances
Major surface reflectance's should be high, that is, light colours should be used whenever possible, but excessively bright surfaces are to be avoided because they cause discomfort or help to create a "sterile" environment. As a guide, the Illuminating Engineering Society recommends the following reflectance's for office-type spaces: ceiling 80 to 90%, walls 40 to 60%, and floors 20 to 40%. Ceiling reflectance values have little impact on direct lighting systems, but luminance ratios between luminaires and the ceiling should be considered when selecting ceiling materials and finishes. Indirect lighting systems do require a higher ceiling reflectance than direct distribution luminaires to ensure the maximum quantity of light being reflected back into the room.

The selection of furnishings in residential, commercial, and institutional buildings will affect the lighting quantity. For example, in both office and school applications, desktops should be chosen carefully to minimize extreme luminance ratios between the task and its plane.

Space Geometry
The geometry of the space length, width, and ceiling height - affects the distribution of light in an area. Open areas are more efficient, while the introduction of partitions will reduce illumination. Large rooms utilize lighting energy better than do small areas of the same ceiling height. High ceilings are less efficient than lower ones, because of the increase in distance of the light source from the work plane.

System Elements
Whatever light source type, luminaire, or ballast is selected, it should be remembered that system efficiency is the criterion, not the separate efficiencies of components.

Light Sources

Characteristics of Families of Lamps
The following is a brief review of the basic categories of light sources, which will give some guidance on how to select an appropriate lamp for a given application.

The families of lamps are incandescent, fluorescent, high-intensity discharge - mercury, metal halide, and high-pressure sodium - low -pressure sodium. Each source has its own operating characteristics of efficacy (efficiency), life, colour (chromatically and colour rendition), and ballast requirements. - Table (J.2) Light Source Characteristics.

Incandescent
Although they are the least efficiency of the light sources and have a shorter life than any other types, incandescent lamps have many advantages over other types. Initial and replacement costs are low. Small in physical size, these point sources are easily controlled and can be dimmed. No. ballast is required. The colour quality produced is the base by which many people judge the colour rendition of other sources.

Fluorescent
Advantages of fluorescent lamps include higher efficacy and longer life than incandescent. A choice of chromaticity (colour temperature) and colour rendition can be obtained, depending on the phosphor mix of the lamp chosen.

High-Intensity Discharge (HID)
Mercury, metal halide, and high-pressure sodium make up this category of lamps. Operating characteristics of HID sources are similar of those of fluorescent, and ballasts are required.

Self-ballasted mercury lamps are more efficient than incandescent but less efficient than standard mercury types. Efficiency is improved again in metal halide, as is colour rendition by the addition of metal additives.

High-pressure sodium is the most efficient of the three HID source types and has excellent lumen maintenance over life.

Low-Pressure Sodium
These lamps have the highest efficacy of all sources and have been used extensively in Europe.

Efficacy
The efficacy of a light source is the ability to convert power (watts) into light (lumens), expressed as lumens per watt. for example, a 100-W incandescent lamp rated at 1710 lumens has an efficacy of 17.1 lumens/W. The higher the wattage, the more efficient the lamp, that is, the higher the efficacy. As shown in table 9, incandescent lamps have the lowest efficacy range and high-pressure sodium the highest of the white light sources.

Life
Rated average life is the life obtained on the average from large representative groups of lamps in laboratory tests under controlled conditions. It is based on survival of at least 50% of the lamps and allows for individual lamps or groups of lamps to vary considerably from the average.

Application Suitability
Despite disadvantages of efficacy and life of incandescent lamps, their colour rendition and the characteristics described earlier make them suitable for a variety of applications in residences, museums, and merchandising spaces and for specific high lighting effects in other commercial applications. An application is suitable in terms of the quantity and quality of light delivered to the task if the source produces the best solution for the client's needs.

Fluorescent lighting accounts for a large portion of commercial and institutional applications. In higher wattages its efficacy is better than mercury vapour and equal to, or better than, some metal halide lamps. Its immediate starting capability and low cost compared to some HID installations make it still competitive for energy and operating costs.

In the HID family, mercury lamps are recommended where a higher-efficacy source than incandescent is required, while still providing good colour rendition and uniformity to make people, buildings, and surroundings acceptable. Metal halide is more efficient in luments per watt and is used in indoor and outdoor applications where good colour rendition is necessary.

High-pressure sodium (HPS) has been widely accepted for exterior lighting for street and highway installations, for building floodlighting and parking-lot lighting, and for indoor installations in industrial facilities.

Note that HID sources require a warm-up period before full output is achieved, although there is usable light almost immediately at a low intensity.

Low-pressure sodium is confined to exterior applications, or for indoors spaces, such as warehouses, where colour rendition is of no concern.

One-for-One Lamp Substitution
One of the easiest and least costly methods of reducing connected power energy is to replace lamps in an installation with other of a lower wattage, provided that the substitute type is compatible with the system, with the desired light source colour, and with colour rendering needs.

Such substitutions may result in equal or less light (lower efficacy) or higher light output using fewer watts.

Lamp Substitution with Luminaire Modifications
If low-wattage incandescent lamps are being used, consider the possibility of using fewer, more efficient lamps of a higher wattage. Source wattage, however, must not exceed luminaire rating, and a careful evaluation should be made of the possible change in light distribution in the space if some fixtures are no longer used.

A change in light source type can increase the quantity of light at a lower wattage. If this occurs, power may be further reduced by removing or disconnecting luminaires, provided that task lighting quantity and quality requirements are met. Again, an evaluation should be made of the distribution pattern of light contrasts of task and surround. Removal of lamps from fixtures - for example, one fluorescent lamps from a two-lamp system - or the use of "dummy" fluorescent lamps, should be examined in terms of the effect on power factor in the system.

Selection of Higher Efficacy Lamps for a New System
Changing from one family of lamps to another of higher efficacy can produce greater savings than a single lamp substitution of interchangeable types, even considering the cost of the improvement in the energy savings analysis.

To evaluate replacement of one system with another, include the following items:

1. Determine the lighting level required for the leak or area and check the maintained lumen rating of the lamp presently used. Consider whether the present level meets the needs, or if an increase or decrease is desirable.

2. Is colour rendition a concern for the space and its occupants? Or is colour of minor consideration compared to efficacy or life?
3. Select a light source that has the highest efficacy consistent with colour rendition, life (maintenance schedule and costs), and application suitability.
4. Make a rough estimate of the number of lamps required based on the lument rating of the proposed system.
5. Select the appropriate luminaire for the source and application.
6. Determine the number of fixtures required, their cost, and the installation cost.

This six-point outline is a simple data accumulation guide for a preliminary estimate of determining the value of installing a new system.

Luminaries
The ability of the luminaire to deliver light is based on "controls" within the housing. which determine how the lumens from the lamp will be emitted into the space. The controls may reflect transmit, or refract light. Examples include: reflectors within the luminaire, such as parabolic elliptical; diffusers that transmit light: and lenses that refract the rays, changing the direction or angle of the light. All materials also absorb some of the energy from the source.

The term coefficient of utilization (CU) or Utilization Factor (UF) describes the ratio of the lumens received on the work plane from a luminaire, to the lumens emitted by the luminaries lamps alone and describes how well a luminaire distributes it slight. The CU of a luminaire considers its efficiency, candlepower distribution, geometry of the space. the mounting height above the work plane, and surface reflectance's. CU values are found in the IES Lighting Handbook and in CIBSE Code and in manufacturer's literature. Before using the CU tables the following should be know; effective ceiling an floor cavity reflectance's, wall reflectance's, and room cavity ratio (RCR).

Ballasts
Ballasts are current-limiting devices necessary for the operation of discharge sources. Fluorescent and HID lamps have a negative resistance - current is allowed to rise an would do so indefinitely, destroying the lamp, if a limiting device, a ballast, were not used. Ballasts also provide sufficient starting voltage to strike the arc if the supply voltage is inadequate.

Some general comments to keep in mind regarding HID ballasts may help in the decision process about system modifications. Mercury lamps will operate from ballasts for metal halide sources, but the converse is generally not true. For energy purposes, therefore, most existing mercury systems cannot be "upgraded" in efficacy to metal halide installations without ballast changes.

To improve the efficiency of the circuit a power factor correcting capacitor built into the ballast will draw leading current to compensate for the lagging current in the remainder of the circuit. High-power-factor ballast are recommended to prevent a possible power-factor penalty billing from the utility. Power factors of 0.9 and higher usually have no penalty.

Note: If lamps are removed from luminaires to save energy, it is advisable to disconnect ballasts at the same time since they will continue to consume current even with lamps removed. Consumption will be approximately in the range 6 to 14W. Ballasts can be removed and stored for later use.

Day lighting
If day lighting can be effectively used, it should be considered either to replace some of the electric lighting, which can then be turned off for certain hours of the day, or as a supplementary source, so that the electric lighting in the immediate area can be reduced by switching or dimming.

Contribution to Electric Lighting System

If possible, windows and window placement (fenestration) should be designed to provide maximum penetration of daylight without glare. Daylight from more than one point in the room (preferably, from two sides of the room) will give better uniformity than from one. It is recommended that the height of the windows equal at least 50% of the depth of the room and that total glass area equal 25% of the floor area.

From a lighting standpoint, it is also necessary to consider the orientation of workers in the space versus the day lighting distribution to minimize any discomfort and disability glare.

As with an electric lighting system, there are light loss factors associated with day lighting. Losses occur with fenestration design - mullions, joints; with the type of transmission material - sheet glass, glass block, double glaze, reflective coating; and with the use of daylight controls and their reflection or absorption quality - shades, louvers, exterior overhangs, exterior plantings. Poor maintenance of the fenestration also causes losses of penetration by dirt collection on the glazing material.

Control of Daylight and/or Electric Lighting

Photocells in the system can be used to sense variations in light level in the space, and when used with switch/dimmer controls allow day lighting to substitute or supplement the electric lighting system. It is important that these controls be selected with manufacturers' data for a given situation. Improper design may cause too frequent variations in the system, resulting in distractions.

Lighting System Controls

Even with efficient lamps and luminaires etc., energy used for lighting can be wasted in several different ways. Careful monitoring studies show that, in general, people will usually turn lighting on only when they use it, but cannot be relied upon to turn it off when daylight would provide adequate condition or when rooms are to be unoccupied. Exhortation can be helpful in the short term, but the ideal solution is to provide manual switch on and some form the control for switching off. a further source of unnecessary use results from the common practice of controlling large areas of lighting with small numbers of switches, or by confusing switch layouts, such that individual requirements can only be met by turning on many luminaires. Controls are a very effective way of reducing lighting costs, but before incurring significant capital costs it is suggested that the occupancy pattern and occupancy behaviour should be studied. This will enable the most cost effective system of control to be installed.

Manual controls

Switching arrangements should at least permit individual rows of luminaires parallel to window walls to be controlled separately. Controls (both mechanical and electronic) are available to permit individual luminaires in a large installation to be switched by the occupants most affected. Switches should be as near as possible to the luminaires which they control. One simple method, which has been used effectively, is the pull cord operating ceiling switches adjacent to each luminaire. Electronic controls (ultrasonic or infra-red) can be placed on or near the occupants' desks to give them control of one or more luminaire. A master control of this type avoids any necessity for wiring to switches on walls, but does require specific control units to be fitted to luminaires. Sensing devices are generally not suitable in factories, the best applications being sport halls, office cleaning and other places where occupancy can be intermittent.

Automatic controls

a. Photoelectric controls: Photoelectric control of lighting can ensure that the lighting will be turned off when the daylight alone provides the required illuminance. For example, a photoelectric sensor could respond to the exterior illuminance and be set to operate at that exterior illuminance which provides the design illuminance at the work place.

Gradual "top-up" (or dimming) control is preferable to simple on-off switching. Occupants do not dislike it and it saves more energy than switch control. It is possible to control the light output of fluorescent lamps to provide sufficient illuminance to top-up daylight when it fails to reach the design level of the artificial lighting by itself. Such a system will use less energy than one, which switches the lighting on fully for the whole time that the daylight is below the design illuminance.

With fairly deep interiors having two or more rows of lights running parallel with the window wall (or walls), it may be advantageous to use a separate controller for each row. If the control is of the on-off type, only the row nearest the window should be operated in this way to ensure user acceptability, although careful design with multi-lamp luminaries may be acceptable. Potential energy savings can be large (up to 50 percent of uncontrolled use has been claimed) but evaluation of particular installations is required to determine their cost effectiveness. In general, top-up or dimming control is more expensive than on off, but it save more energy and is more unobtrusive.

b. Time controls: If the occupation of a building effectively ceases at a fixed hour every working day, it may be worth installing a time switch so that most of the lighting is switched off soon after this time. Arrangements may need to be made, however, for security lighting and individuals working late to override part of the switching with subsequent automatic switching off and override cycles to avoid accidental leaving on. The building cleaning routine may also need special arrangements.

c. Mixed control system: Switch control can produce considerable energy saving. A time control system, for example, which switches all selected lights off at a fixed period in the day, but with personal local override (switch on), can have a payback of one and a half to two years. If this is fitted at the time of refurbishment, payback can be one year or less. This general principle is well suited to multi-occupant spaces such as group offices, but with care can be applied in schools, factories and warehouses etc. Commercial systems exist which enable this principle to be followed and can also offer the further option of photoelectric switching - with occupant override- to promote greater savings. The use of remote switching (e.g. by infra-red transmitters, or ultrasonic), to fulfill the localized override facility is also possible.

Operating Schedules
An analysis of operating hours in the building may reveal the necessity of educating workers to control the lighting. Usage patterns should be identified during the building survey and modifications based on those results. Definitions of the nature and duration of occupancy for each space help to determine the lighting requirements consistent with safety and security.

Evaluation of Building Space Use

Analyze the usage in the building and inform an encourage employees to participate in operating the facility efficiently. Lights should be turned off when they are not needed: incandescent - whenever the space is not in use; fluorescent - if the space will not be used for 5 minutes or longer; HID - if the space will not be used for 30 minutes or longer.

Lighting the building for occupied periods only, with a reduced level for unoccupied and cleaning hours, may require the addition of manual or programmable controls in an existing building.

Modification of Hours of Operation
The possibilities are numerous for changing the hours of operation and depend on an understanding of the present usage patterns. Changes should be evaluated from the standpoint of their effect on the users of the building, as well as the savings to be achieved.

At a start, consider the following ideas for implementation. There will obviously be other peculiar to a particular operation. Reschedule cleaning and adjust schedules to minimize the lighting used, by concentrating cleaning in fewer spaces at the same time and by turning off lights in unoccupied area. Lights may also be turned off during lunch periods except in circulation spaces.

On the exterior, parking might be restricted to specific lots, so that lighting is reduced to

lighting might be operated for fewer hours each night.

Psychology of Changeover

It has become evident, however, from the experience of people who have attempted lighting system changes, that in addition to the factual material and the specific recommendation, there is also a philosophy of implementation methods that must be heeded.

The Human Aspect

Regardless of the method selected for achieving power and energy savings - complete system replacement or modification of an existing system - it is important to consider the human aspect of energy conservation. Buildings and building systems should be designed with people in mind, for the occupants' performance, comfort, convenience, safety, and an enjoyment of the surroundings. An energy management program for lighting should not be achieved at the expense of employee satisfaction.

To ensure favorable reaction and support from employees for energy savings, they must be involved in the program.

SUMMARY

Each building, each space within a facility has its own characteristics and should be carefully surveyed before an energy program for lighting is developed, and any system modifications analyzed for their impact on the operation of the entire building. Power and energy savings in any one space may appear to make little or no contribution to the overall goal for the building, but when evaluated in context with the savings achieved in all areas, the accumulated benefits for the operation may be significant.

Energy consumption and availability, productivity, economic growth, jobs, and our standard of living are all linked together. Energy management provides a way for commerce and industry to stay productive. A management program for lighting offers not only the means to achieve energy savings, but can result in improved lighting systems that benefit employees and their working environment.

Appendix B

Air Conditioning Theory

HEATING, VENTILATION AND AIR-CONDITIONING (HVAC) SYSTEMS

INTRODUCTION

Air Conditioning is the simultaneous control of temperature humidity, air movement and the quality of air in a space.

This section will introduce you to various types of Heating Ventilation. and Air Conditioning Systems and acquaint you with numerous options available for heating. cooling and distribution, although many of the savings to be derived from HVAC systems will be achieved by modifications, in the existing control system. a basic understanding of the HVAC system is essential in any effort to reduce energy used.

HEATING SYSTEMS

Hot water heating systems can be operated by oil, gas or electricity in much the same manner as steam generating boilers. The basic difference between the two systems is in the temperature of the water-below 212 °F and operating pressure normally at the atmospheric pressure.

Electric hot water boilers operate in the same manners as electric steam boilers with the exception that boiler pressure is maintained at atmospheric pressure and the water temperature is reduced below the boiling point. Efficiencies are very high approaching 100%.

Steam and water are both used for domestic hot water and air heating distribution systems. These distributions systems are described later.

Infrared heaters operate on gas, oil or electricity and transmit heat energy directly to the occupants or building contents without appreciably heating the surrounding air. They are particularly useful in high bay buildings, semi open or outdoor areas.

Unit Heaters are mostly used for spot heating areas, they are available in propeller types or with blowers. The former are easier to maintain, but blowers are required where large heating areas require a greater distribution then is normally possible with propellers type.

Heat Pumps are system designed in such a manner that they can extract heat from outdoor air and transmit it to the inside for heating, then reverse themselves to remove heat from the inside when in cooling mode. They are generally more efficient for heating than electric resistance heaters when the outside temperature are40F ,or higher Below that temperature a supplementary resistance heater is generally utilized.

AIR-CONDITIONING EQUIPMENT

Window or through the wall units are normally used for air conditioning only, however, many are provided with electric resistance heaters for heating as well. They are usually of the Fan coil, type and are generally equipped with separate fan motors driving the condenser, and evaporative fans. Most room air conditioners are now given an Energy Efficiency Ratio (EER) which enables you to determine the relative efficiency of different units in terms of BTU/Watt-hr. Newer and more efficient units will have an EER of ten or above. For capacities 18000 BTU/hr or above, electrical requirements are 230 Volts.

As an example of the effect of EER on electrical consumption, there are two well-known air conditioners on the market, each rated at 18000 BTU capacities. Unit one has an EER of 9.7 and uses 1856 Watt each hour. Unit two has an EER of 8.8 and uses 2045 Watts each hour or 10% more electricity for the same cooling capacity.

Electric Driven Compressors can be of the reciprocating or centrifugal types. The reciprocating compressor consists of pistons in from 1 - 12 cylinder acting as pumps to increase the pressure of the refrigerant from the low side to the high side of the system. Centrifugal units are basically fans or blowers, building refrigerant pressure by forcing the gas through a funnel shaped opening at high speed. Centrifugal compressors are not generally used below 50 tons capacity where reciprocating units dominate the market. They are acceptable for capacities between 50 - 100 tons and particularly suited for the 100 -2000 tons range. They are generally more quite, require less maintenance, and have less vibration than a comparable reciprocating unit, but are not suitable for use for air condensers and must be water-cooled.

Absorption Chillers operate on steam or hot water above 250, F with two components, the generator and the absorber,
Performing the same basic function as a compressor. The chilling effect is obtained through the interaction of two connected, closed tanks with Lithium Bromide, a salt solution in one and water in the another. The salt solution in the absorber soaks up some of the water in the evaporator, thus cooling the remaining water by evaporation. This refrigeration effect is utilized by putting a coil in the evaporator tank. Since the salt solution is continuously absorbing water vapor, part of it is pumped to a generator to maintain the proper salt concentration. Steam is used in the generator to boil off the excess water vapor. A water-cooled condenser is used to recapture the waste heat from the generator, returning to the evaporator.

Roof Top unit are self contained air conditioning systems designed for mounting on the exposed roof of a commercial or industrial building. They are most frequently of the reciprocating type and air-cooled with all components contained in a weatherproof enclosure.

Screw Type Compressors are also available form many suppliers. They function somewhat differently than the other compressor type system so are included as a separate categories.
With this type of compressors there is no chilled water system since the system operates with direct expansion. Manufactures claim first cost savings of 20% and power savings up to 25% due to the elimination of the chiller and water pump.

The Major disadvantage of this type of system is in the limitations imposed by the need to use the refrigerant itself as a cooling medium with refrigerant run outs of 200 feet being the maximum currently possible. They are available in capacities ranging from 50 to 460 tons.

COEFFICIENT OF PERFORMANCE

This term is used to measure the efficiency of different types of chillers. It is calculated as follows:

$$C.O.P = \frac{\text{Heat Moved (or refrigeration Effect)}}{\text{Energy Required}}$$

Although each chiller will have its own rating assigned to it by the manufacturers. as a rule of thumb the following coefficients of performance can be used as a guide for various types of units:

Absorption Chiller	-	0.50
Electric Drive Compression	-	(2.40 - 5)

We should point out here that the C.O.P will vary significantly based upon a number of factors. Air cooled chillers, for example, will generally have a lower C.O.P. than water-cooled units. The type of refrigerant, motor efficiencies and pump efficiencies will have a significant effect. In each case the manufacturer should be contacted for specific data relating to that system being evaluated (Figure 1) illustrates some of these effects.

Effect of Chilled Water and Condensing Water Temperatures

on

Coefficient of Performance

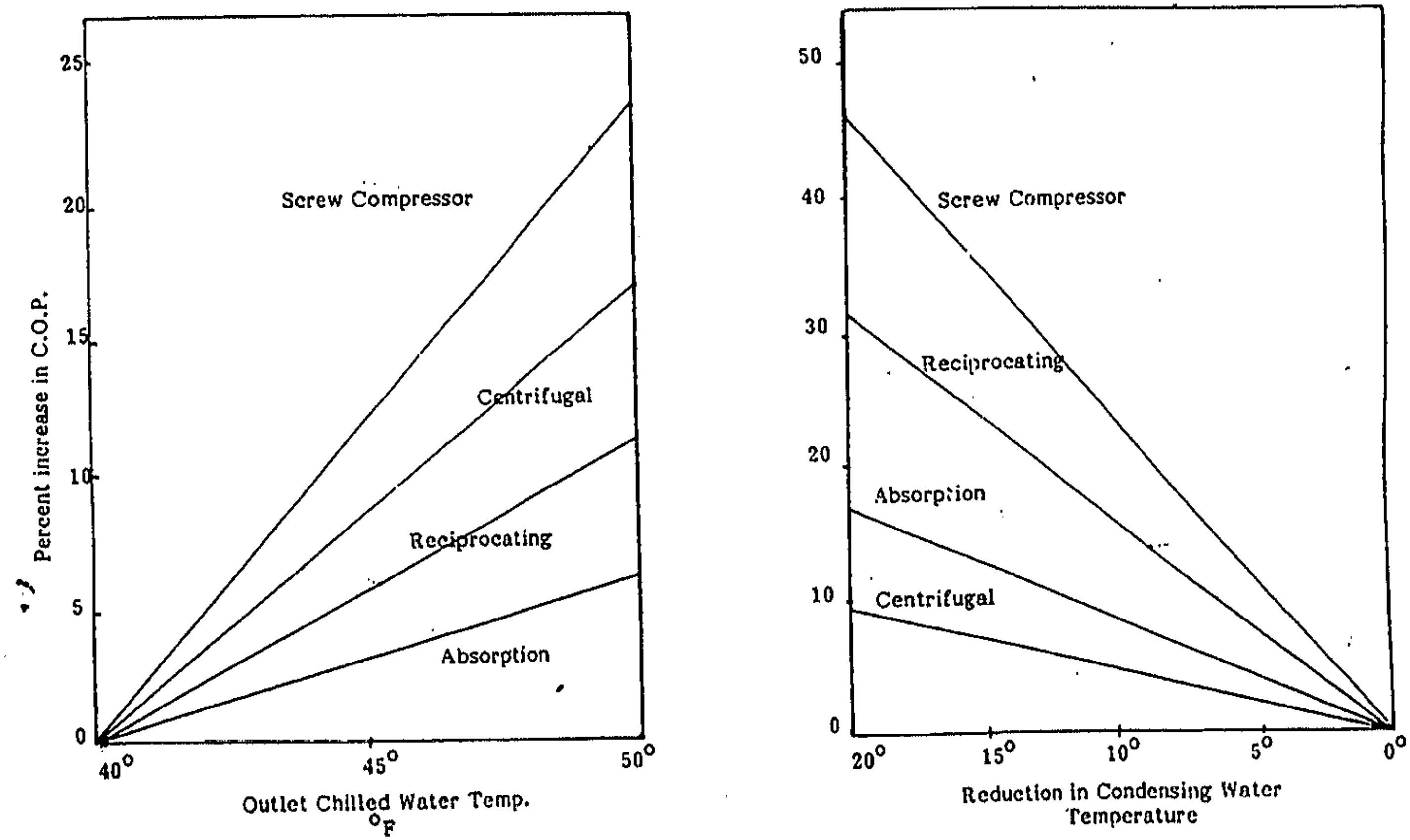


Figure (1)

Appendix C

Insulation Theory

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Heating is the process that maintains a given space at a temperature above that of the ambient temperature. This involves the use of furnaces or boilers to supply the produced heat of combustion to a suitable medium, usually air or water, which transfers the heat to a specified space or process. Heat transfer is the transient flow of thermal energy from one system to another due to temperature difference between the two systems. There are three modes for heat transfer:

1. Convection Heat Transfer: In convection heat transfer, heat is transferred from one system to another by means of moving fluid such as air or water.
Heat loss due to natural convection can be calculated using the following formula:

$Q = a\,(t - b)^{4/3}$

a: coefficient relating to orientation of the surface of natural convection
t: surface temperature (°C)
b: ambient temperature (°C)

2. Conduction Heat Transfer: In conduction mode of heat transfer the systems are in physical contact and heat is transferred from one molecule to the adjacent one. Thus the high agitation of the hotter molecule is transferred to the cooler molecule.

3. Radiation Heat Transfer: In contrast to heat transfer by conduction and by convection, which require a medium for their existence, heat transfer by radiation takes place in complete vacuum. It is an electromagnetic radiation, which is of the same nature as solar radiation.
Heat loss due to radiation can be calculated using the following formula:

$$Q = 4.88 \times e\left[\left(\frac{t+273}{100}\right)^4 - \left(\frac{b+273}{100}\right)^4\right]$$

t: surface temperature (°C)
b: ambient temperature (°C)
e: emissivity of the surface

Since in a process plant there is heat flow from one place to another and since, the temperature of the surrounding usually below the process temperature, at least one mode of heat transfer from the process to surrounding will exist, causing a considerable amount of energy to be lost. To prevent this from happening, a thermal insulation is used to insulate the hot surfaces from the surrounding.
Heat loss after insulation can be calculated using the following formula:

$$Q = \frac{t - a}{\left[\left(\frac{s}{k}\right) + \left(\frac{1}{8.51}\right)\right]}$$

t: surface temperature (°C)
a: ambient temperature (°C)
s: insulation thickness (m)
k: insulation thermal conductivity (w/m. °C)

Reasons for Insulation

Safety

Even if energy were free it would still be necessary to apply thermal insulation for reasons of safety. Safety for operatives means that where there is a possibility of coming into contact with hot (or possibly very cold) surfaces, protection should be given to prevent possible injury or shock. Apart from the safety of operatives, there could be the possibility of fire risk where combustible materials are in the proximity of hot surfaces. If we include "comfort" in the term safety we must also consider the case of operatives working at control panels etc. on high temperature plant.

All the above considerations point to the criterion for the thermal insulation for safety purposes to be surface temperature and not the rate of heat loss.

Most cases for thermal insulation are made on the basis of economics but clearly in these circumstances the cost of energy does not enter our calculations. What does, of course, is the relative costs of different types of thermal insulation to produce the required surface temperature within whatever physical limits apply.

The type of surface can play a role in deciding what surface temperatures should be used in the case of operatives' safety the following are the recommended limits:

Non-metallic surfaces within reach of operators without need of ladders, etc. 65 °C maximum
Metallic surfaces as above; 55 °C maximum
Metallic and non-metallic surfaces accessible by ladders, etc; 50 °C maximum
Similarly there is a recommended limit for extremely cold surfaces minus; 10 °C minimum

Where the above limited are not likely to be met by insulated or non-insulated surfaces, protection should be provided for the operators in the form of an effective guard - say an open mesh screen with mesh size such that no accidental contract can be made with the protected surface.

Process Requirements

The delivery of steam, hot water, hot gases or cold liquids and gases from a central source to the point of use in an acceptable condition and at an acceptable temperature must be a requirement of all process plant. Again, in this case the level of insulation required to provide this result is not decided upon the economic grounds of energy loss.

There are, of course, many different processes requiring different temperatures and conditions, and calculations must be carried out for each specific case. There are, however, some common principles, which should be borne in mind. The heat loss from, say one meter of pipe, will depend upon the temperatures of the gas or liquid being conveyed and the air around it. The level of insulation will obviously influence this heat loss per meter but at whatever level we fix the heat loss per meter, by insulation it will be constant as long as the internal temperature is maintained. However, if the rate of flow is reduced and no supplementary heating is provided the temperature drop at the delivery point will be in almost inverse proportion to the flow rate. For example, halving the flow rate will nearly double the temperature drop between source and point of delivery. Similarly the heat loss as a proportion of the flow will double, i.e. a 10% heat loss will increase to nearly 20%.

Where flows are considerably reduced due to the low loads at particular times, it is clear that much lower delivery temperatures than normal will be found. There may be some mitigating effect due to lower heat loss following from lower mean fluid or gas temperatures but not if the delivery temperature must be maintained by providing a higher initial temperature that will increase the losses.

The assessment of acceptable levels of insulation can be broken down into two parts. The first is the assessment of the heat loss from the external surface and the second is the effect that the heat loss will have on the temperature and condition of the gas or liquid in the system.

It must be remembered that the total losses from a system will include those due to valves and flanges as well as heat loss through supports, etc. Depending on the degree of insulation on these items they could contribute up to 20% of the total heat loss of the system. Consideration should therefore be given to these losses.

There may be cases when the temperature must be kept high to avoid condensation so as to prevent corrosion or non-desirable emissions. One example of this is with oil-fired boiler plant. From the point of boiler plant efficiency exit temperatures from the boiler will be as low as possible so that every bit of energy is extracted from the fuel. The flue will therefore need to be insulated in such a way that the flue gases are kept above acid dew point given a relatively low temperature to start with. Problems can arise particularly on light loads when flue gas velocities and temperatures are both naturally low. On some large plants the insulation of the flue can be some 10-20% of the total insulation cost of the complete station.

Cost Saving

The economic benefits to users of insulation will vary according to each particular case and the method of financial appraisal. Financial benefits for new schemes can include not only the actual fuel (energy) savings but also the reduction in the heat generator capacity as well as boiler house size and ancillary equipment (or refrigeration capacity as the case may be). There will also be the reduction in distribution capital costs, the reduction of on going distribution costs such as pumping and condensation losses amongst others. In the case of existing installations the scope for peripheral savings may not be as great but the use of more insulation may save the cost of installing additional plant when loads are increased as well as the obvious savings on generation.

Optimum sizing of distribution mains is an exercise in itself bearing in mind the parameters, which have to be taken into account, i.e. generating pressure of steam or hot water, pipe sizing for the load and, of course, the effect of different levels of insulation on both. The exercise can be further complicated by possible tax allowances on new plant and the particular method of financial appraisal.

One of the simplest methods of financial appraisal is the "Pay-back" system where costs are compared with savings and the result is expressed in terms of, for example "two year pay-back" that is where the savings repay the capital costs in two years. Normally for payback calculations, the cost of capital in terms of interest paid or foregone is not brought into the calculation nor is the expected life of the process or insulation, taxation, maintenance, etc. All these variables can, of course, be taken into account but usually a more sophisticated method of appraisal would then be used.

For many projects the aim is to achieve the "lowest cost in use". This means that over a given period of time different capital investments and running costs can be compared with one another and that which gives the lowest total cost over the given period is deemed the economic choice.

Process Plant will almost certainly be insulated to give a payback of less than two years. The payback period actually increases with insulation thickness - such incremental thickness having an increased time of payback. The final increment should pay for itself well within the life of the plant or that of the insulation whichever might be deemed the shorter.

The cost of installing the insulation and the cost of the finishing materials should also be considered. This is particularly relevant when comparing high performance insulation with more conventional materials. If a 50mm diameter pipe is insulated with 25mm of high performance insulation instead of the 75mm of conventional insulation, which would normally be used, then the surface area is reduced by a factor of 3. If the surface cladding is stainless steel then the cost saving would go a long way towards paying for the higher cost of the high performance insulation.

Figure (D-1): shows the heat gain from uninsulated chilled water pipes at 45° F.
Figure (D-2): shows the heat loss from uninsulated hot water pipes up to 180° F
Figure (D-3): shows the heat losses from uninsulated hot water pipes up to 350° F
Figure (D-4): represents the heat losses or gain from bare and insulated ducts.

Appendix D

Electric Motors Theory

Introduction

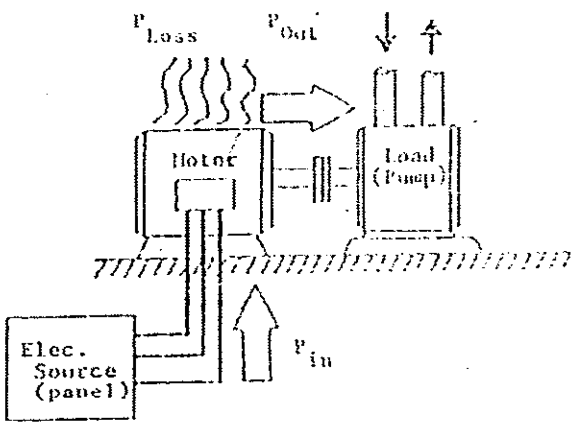
Electrical use in 1990 in the United States was approximately 1.54 * 10^{12} kW-hrs. Electric motors consumed approximately 66% of this energy or about 1 * 10^{12} kW-hrs. Saving 10% of this amount for electricity at $.05/kW-hr would result in five billion dollars saved annually.

Motor Performance

There are many different types of electric motors. Basically motors can be divided by the type current supplied to the motor AC or DC. In AC motors a further subdivision is made between induction and synchronous motors. In the induction motor the synchronous speed is set by the rotary speed of the magnetic field. Slip (operation at less than synchronous speed) occurs in the induction motor. In a synchronous motor the rotor is "synchronized" with the rotating magnetic field so that it can be regarded as a constant speed motor except under extreme load.

The following figure shows a typical motor load set-up. One point to observe is that all of the losses in a motor result in this energy being transferred as heat to the surroundings.

$P_{in} = P_{out} + P_{Loss}$



The output power of a motor is determined by motor torque, T_m, and motor speed usually measured in RPM (revolutions per minute). Both the motor and the load have a characteristic curve as shown in Figure (C.M-2). Notice that the speed and torque developed by the motor are determined by the point where these two curves intersect. The output of the motor is given by:

$$\text{Output horsepower} = \frac{\text{Torque } \ell\text{ft} - \text{lbf x RPM}}{5252}$$

The efficiency of a motor is defined as

$$\eta = \frac{\text{output power}}{\text{input power}}$$

Consider the following example:

A 100 HP motor operates at full load with an efficiency of 92 percent.
Find the losses and input.

$$P_{out} = 100\ (.746\ \text{kW/hp}) = 74.6\ \text{kW}$$

$$P_{in} = \frac{P_{out}}{\eta} = \frac{74.6}{.92} = 81.1\ \text{kw}$$

$$P_{loss} = P_{in} - P_{out} = 6.5\ \text{kW}$$

It is extremely important to realize that efficiency and power factor vary with load. The largest potential savings with electric motors is to match motor to load as will be explained subsequently.

As this figure shows there is a tremendous variation of efficiency (and power factor) with load. It is shown in the example below that the biggest potential savings for a motor is to match motor to load so that operation is accomplished in the high efficiency range of the motor.

<u>EXAMPLE</u> : Suppose we have a 7.5 hp load to be driven by either a 10 hp (Eff. = 90.2%) or a 50 hp (Eff. = 94.1%) motor. Which is a better choice?

Suppose at 7.5 hp the operating pf's are 0.80 and 0.40 for the 10 and 50 hp motors. The 10 hp is at its maximum efficiency point (90.2%). For the 50 hp motor at full load:

$$P_{in} = \frac{50 * (0.746)}{0.941} = 39.64\ \text{kw}$$

$$\text{losses} = 2.34\ \text{kW}$$

Suppose half of these losses (2.34/2) = 1.17 kW) are fixed losses, and the other half vary with the square of current. Estimate the current as

$$7.5/50 * (1/0.4) * I_{rated} = 0.375\ I_{rated}$$

$$\text{variable losses} = 0.375^2\ (1.17) = 0.164\ \text{kW}$$

$$\text{or total losses} = 1.17 + 0.16 = 1.33\ \text{kW}$$

$$\text{The efficiency of the 50 HP motor is then} = \frac{7.5\ (.746)}{7.5\ (.746) + 1.33} = 80.8\%$$

Hence, the 10 HP motor would be 9.4 percent points more efficient. The power savings for the 10 HP motor versus the 50 HP motor would be

$$(1 - \frac{\text{50 HP efficiency}}{\text{10 HP efficiency}})\ 100 = (1 - \frac{80.8}{90.2})\ 100$$

$$= 10.4\%$$

Appendix E

Combustion Theory

Flue Gas Analysis is used to indicate the air-to-fuel ratio and the degree of completeness of combustion. The gas components usually measured are CO_2, CO and O_2. The percentages of CO and CO_2 can be used as indicators of the completeness of combustion. Percent O_2 and CO_2 are indicators of the amount of excess combustion air.

With good mixing, perfect combustion is attained when flue gas analysis shows no CO or O_2, and a maximum value for CO_2. The theoretical maximum CO_2 in dry flue gas is termed ultimate CO_2. For greatest efficiency, the fuel-and-air mixture should be adjusted until the maximum CO_2 level is obtained. Table (E.1) lists the ultimate CO_2 readings for the varying amounts of excess air in the combustion of common fuels. A low CO_2 or high O_2 reading indicates the presence of too much excess air.

Stack Temperature Measurement

Net stack temperature is obtained by subtracting the ambient temperature from the flue gas temperature. A high net stack temperature indicates that the heat is being wasted to the atmosphere. Good practice dictates that stack temperature should be kept as low as possible without causing cold-end corrosion.

Cold-end corrosion is generally caused by the formation of sulphuric acid (H_2SO_4) when SO_3 from the combustion of the fuel comes in contact with water vapour. Sulphur in fuel usually burns to SO_2. In the presence of large amounts of excess air, some of this will be converted to SO_3 which combines with the water vapour to form sulphuric acid. If the temperature of the air heater, air ducts, and stack falls below the acid dew point, the sulphuric acid will condense on the metal surfaces.

Overly high stack temperature, 400° C (750° F) or above, may indicate one of the following conditions:

- Excessive draft
- Dirty heating surfaces
- Poor design of heat exchange surfaces
- Undersized furnace
- Incorrect or defective combustion chamber
- Over firing of boiler or furnace
- Poor draft regulation.

Smoke Measurement

The amount of smoke in the stack gas can be used to estimate the cleanliness of combustion. Smoky combustion can indicate one or more of the following conditions:

- Improper air delivery
- Insufficient draft
- Improper fuel viscosity
- Oil pump malfunction
- Defective or incorrect fuel nozzle
- Improper fuel-to-air ratio
- Excessive air leaks
- Improper preheat.

When combustion conditions are adjusted, maximum CO_2 should be controlled at a point that does not cause excessive smoke.

Simple smoke measurements can be made using a variety of different methods. The standards will vary somewhat, according to the equipment used, and instructions accompanying each should be followed. First-hand experience also plays an important part in deciding maximum smoke permitted.

Draft Measurements

Draft determines the rate at which combustion gas passes through the furnace or boiler. Excessive draft can produce an increase in the stack temperature and will reduce the percentage of CO_2 in the flue gas.

Inadequate draft can result in insufficient combustion air and smoky operation. At perfect draft, the flame bushes out to nearly fill the firebox, giving maximum time for clear burn-out.

Draft readings are usually taken in the firebox and in the stack. Low draft in the firebox can result in leakage of smoke and other combustion products into the surrounding area. Stack draft must be high enough to prevent positive pressure in the combustion chamber.

Stack Losses

The above tests aid in determining the source and cause of heat losses. It will be found that the main source of heat loss is through the stack. All other losses are small in comparison to the stack loss. Additional heat is lost by radiation from the furnace walls and by blow-down from the steam drum.

Thermal stack loss is equal to the heat required to raise the flue gas from room temperature to the stack temperature measured after the last boiler heat transfer surface. Stack losses can range from 30% in boilers that are poorly designed, maintained or operated to 7% in large efficient boilers equipped with economizers and air heaters to extract all possible heat. The latent heat of the water in the stack is also considered a loss. Latent heat is the heat that would be available if all the water vapour in the flue gas were condensed into liquid water. Because the amount of water vapour corresponds to the hydrogen content of the fuel, minimum loss can also be related to hydrogen content. This minimum loss is about 13% for natural gas, 8% for oil, and 6% for coal.

Stack losses can be reduced by decreasing either the temperature or the volume of the flue gas, or both. Flue gas temperature is reduced by improving heat transfer or by reducing the amount of excess combustion air.

A certain amount of excess air is necessary to complete combustion within the confines of the combustion chamber. Only enough air to prevent incomplete combustion or flame impingement on the tubes should be provided. The more efficient the burners are from the point of view of mixing, the smaller this necessary quantity of excess air will be. Further quantities of excess air may be required for the following reasons:

- To control steam temperature
- To compensate for delays in fuel-and-air mixture controls during fluctuating loads.
- To sustain clean combustion at 1 or 2 sensitive burners in a burner array that is 'out of balance'.

Excess air is usually added as combustion air to the furnace. Another source is through leaks in the casing or through out-of-service burners. Excess air entering in this manner is known as tramp air.

Reduction of Excess Air

The reduction of excess air is a major step in improving efficiency. The lower limit of excess air is reached whenever there is incomplete combustion or flame impingement on the tubes. The main causes of excess air are:

- Air leaks
- Improper draft control
- Faulty burner operation

Before excess air can be reduced, its sources must be identified. This can be done by analysis of the flue gas for O_2 or CO_2. Analysis for O_2 is preferred because O_2 readings are more sensitive to the exact amount of excess air present. Gas samples should be taken from the firebox as well as the stack.

- Low O2 in the firebox and high O2 at the stack indicate leaks in the furnace casing or ductwork
- High O2 in both firebox and stack indicates an excessive amount of air entering the firebox

CO_2 readings would be opposite the O_2 readings in the above analysis.

Once the sources of excess air are determined, they should be eliminated. Leaks can be sealed by replacing gaskets, using aluminum tape or sealing cements to cover cracks. and by replacing badly warped doors. Excessive air entering the firebox can be reduced by adjusting the draft. Furnace draft is properly controlled when the damper is adjusted so that the pressure underneath the convection tubes is 2 and 3 mm (0.1 in) water column below atmospheric pressure. When a strong or gusty wind makes the draft fluctuate, the damper should be opened slightly so that the vacuum is not less than 2mm during the fluctuation.

Faulty Burners

Sometimes faulty burners or insufficient maintenance prevent a furnace from achieving efficient low-excess-air operation. For example, a faulty burner can have a good flame pattern but still smoke. Many times this is compensated for by the addition of excess air, which reduces efficiency.

To trace the cause of faulty burners, operate the unit so that all burners have their individual fuel shut-off valves wide open and their air registers opened the same amount. In the burners that have a poor flame pattern, the problem can usually be traced to plugging, enlarged fuel orifices, or incorrect gun position. The burner gun should be far enough into the burner so that the flame barely touches the muffler block.

Poor atomisation can be suspected if there are a large number of oil drips under the burner.

Closing the air doors of burners that are out of service, such as for cleaning, is an important practice for good burner operation. If the air registers are rusty or difficult to move, they should be replaced or covered to stop air leakage.

Cleanliness

Another factor important to boiler efficiency is the cleanliness of the heat-transfer surfaces both on the fire side and water side. All tubes should be kept clean because:

- Ash, soot, and mineral deposits are poor conductors - in fact, most are insulators. If deposits build up on or in the tubes, heat transfer from the hot gas flow to the steam, water, or air flow is retarded. The heat that should have gone into the steam ends up being lost out the stack.
- Blocking the passages in the convection section with deposits inhibits draft. Since a full volume of air is not driven into the firebox, a normal volume of fuel cannot be burned. This incomplete combustion will results in decreased steam production and increased smoke production or both.

The degree of cleanliness of the convection section can be estimated by measuring the draft loss between the firebox and the stack.. A high draft loss indicates restriction in the passageway.

Fire-side deposits are controlled by soot blowers. Placement and cycling of the blowers affect their efficiency. They should be placed where all tube surfaces can be reached by the air or steam from the blowers. The economizer and air heaters should be blown first, followed by the super heater and boiler section, then the economizer and air heater again.

Water-side deposits are controlled by a good water treatment program. Keeping the water clean and soft helps eliminate scale formation, thereby decreasing the necessity of frequent blow-down and attendant heat loss.

Table (E.1)										
Effect of Excess Air on CO_2 in Combustion Products										
		Percent Excess Air								
Fuel Oil		0	10	20	40	60	80	100	150	200
Natural Gas	$\%CO_2$	12.0	10.7	9.8	8.3	7.2	6.3	5.7	4.5	3.7
Propane	$\%CO_2$	14.0	12.6	11.5	9.8	8.5	7.5	6.7	5.3	4.4
Butane	$\%CO_2$	14.3	12.9	11.7	10.0	8.6	7.6	6.8	5.4	4.5
Distillate Oil	$\%CO_2$	15.2	13.8	12.6	10.7	9.3	8.2	7.4	5.9	4.9
Residual Oil	$\%CO_2$	15.6	14.1	12.9	11.0	9.6	8.5	7.6	6.1	5.0
Bituminous Coal	$\%CO_2$	18.4	16.7	15.3	13.0	11.4	10.1	9.0	7.2	6.0
Anthracite Coal	$\%CO_2$	19.8	18.0	16.5	14.1	12.4	11.0	10.0	7.9	6.9

Improve Burner-Boiler Efficiency

The following suggestions are recommended operating and maintenance items to increase boiler, furnace, and heating system efficiency for hot water systems, high pressure steam systems (about 15 psi), low pressure steam systems (less than 15 psi), forced warm air systems. Review the list and select those items, which are applicable to any particular system.

Increase in efficiency depends on the equipment status before and after the maintenance items have been carried out. However, each item will result in greater efficiency and consequent energy savings.

- Clean and scrape firesides to remove soot and scale.
- Clean waterside, remove built-up scale.
- Scrape scale from steam drum.
- Clean airsides, remove soot, and scrape scale in forced warm air and hot air furnaces.
- Insulate units, which are in unheated spaces, on roofs, or in air-conditioned spaces. Repair insulation where needed. (If the boiler or furnace casing is 10-15% warmer than room temperature, radiation loss could be 10% or more of the capacity of the unit.)
- Check for and seal air links between sections of cast iron boilers to improve combustion efficiency.
- If the combustion efficiency is at a maximum but stack temperatures are still too high (over 450° F), install baffles or turbulators to improve heat transfer.
- Seal all air leaks into combustion chamber, especially around doors, frames and inspection ports.

- Maintain the lowest possible steam pressure suitable for supplying radiation or coils.
- Vary the steam pressure in accordance with the space heating. If steam pressures can be reduced, standby losses are reduced.
- Maintain the lowest possible hot water temperature, which will meet space or domestic hot water needs.
- In the absence of indoor-outdoor modulating controls, raise or lower operating temperature (for hot water systems) to conform to indoor-outdoor conditions.

raise the level to

- Clean filters regularly in gravity and forced warm air units to reduce the operating time of the furnace.
- Shut down hot air furnaces completely when building is not occupied and there is no danger of freezing.
- Schedule boiler shutdown on an as-needed basis rather than on a fixed timetable. Smaller and more frequent blowdown quantities are preferable to larger quantities and less frequent blowdown.
- NOTE: Be sure that boiler blowdown procedures adhere to specifications outlined by the manufacturer and local codes. With few exceptions, it is illegal, and in all cases undesirable, to discharge boiler blowdown directly to a sanitary sewer.
- Use warm exhaust air from adjacent areas, or from the ceiling of the boiler rooms, to preheat combustion air.
- Use chemical fuel additives to reduce the flash point temperature of fuel oil, especially #4 and #6 oils. Proper chemical treatment will reduce soot deposit on #2 oil systems also.
- Interlock combustion air intake with burner operations; maintain prepurge and postpurge as required for some burners.
- Seal all air leaks into natural draft chimneys, especially where flue pipe enters the wall.
- Repair or rebuild oil burner combustion chambers to the correct size for providing optimum efficiency at 90% of the full load firing rate. Construct chambers with bricks of the refractory type, not common bricks. Incorrect matching of burner and combustion chamber and broken brickwork can result in losses of from 10 to 20%.
- Turn off gas pilots for furnaces, boilers and space heaters during the non-heating months and during long unoccupied periods.
- Provide an automatic draft damper control to reduce the heat loss through the breeching (smoke pipe) when the gas or oil burner is not in operation. Adjust draft-control with combustion testing equipment to match the firing rate.

- Adjust oil burning efficiencies to achieve proper stack temperature, CO_2 and excess air settings. Adjust setting to provide a maximum of 400 °F-500 °F of stack temperature and a minimum of 10% CO_2 at full load conditions. Excess air through a boiler can waste 10 to 30% of the fuel. Accurate testing is essential for the correct burner adjustment to attain maximum efficiency. Use appropriate instruments and institute combustion testing as part of a planned general maintenance.
- Adjusting the firing rate of gas or oil burners at too high a rate will cause short cycling and excess fuel consumption. Too low a rate will require constant operation, and inadequate heat will be delivered to the spaces. If the boiler is oversized, adjust the firing rate to the building load, not the boiler.
- If there is more than one boiler, operate one only up to its maximum load before bringing other boilers on the line. It is inefficient to operate two or more boilers at very low capacity to carry part loads.

Appendix F

Steam Theory

Introduction:

Steam is one of the most commonly used services in industry, hotels and hospitals. It allows fuel burned in a boiler to be carried as heat energy to some other point where it can provide mechanical energy through an engine or, more commonly, simply heat.

To operate effectively, steam must be available at the required time in the right quantity and pressure, and in the right condition. The parameters affecting energy consumption in steam systems are:

- Operating efficiency.
- Energy conversion in steam systems including heat transfer in the system, and sizing of steam distribution systems.
- Steam trapping and condensate recovery.

Basic Principle:

Steam is simply water in a vapour state. The first requirement in steam production is to add heat to water until it reaches its boiling point (sensible heat). A greater quantity of heat is then added to convert the water to vapour (latent heat). The steam is then said to be "Saturated". Further heat may be added to raise the steam temperature or to "Superheat" the steam. The steam is then conveyed from the heat source or boiler to the end user where heat transfer takes place. The latent heat is given up and the steam condenses at the boiling point to liquid. The resulting condensate still contains the energy added to bring the water to the boiling point, so it is good practice to ensure that it is returned to the boiler for re-use.

Steam Tables:

Steam tables provide the characteristics of steam under different conditions, for saturated steam, the most important properties are:

- Temperature
- Pressure
- Enthalpy of water (sensible heat)
- Enthalpy of evaporation (latent heat)
- Enthalpy of steam (total heat)
- Specific volume of steam

As the pressure in the steam boiler rises, the boiling point of water (and hence the steam temperature) also rises, increasing the usefulness of steam as a heating medium. However, the amount of heat required to raise water to the boiling point (sensible heat) and to convert it to steam (latent heat) changes. Since the latent heat is usually regarded as the "useful energy" in the steam, high pressure steam contains less useful energy but at a higher temperature.

Steam System Efficiency:

A typical steam system will include the following elements:

1. Boiler (or steam generator).
2. Steam network, including control valves, steam traps.
3. Condensate return, including storage tanks and pumps.
4. Steam consuming equipment (the steam users).

The overall system efficiency relates the useful work obtained by the user to the fuel burned at the boiler and may be estimated from the individual efficiencies of each element of the steam system. It is important to note that the overall efficiency is obtained by multiplying the individual efficiencies. Small improvements in the efficiency of each element can result in a significant improvement in the overall system. For example, improvements might be made to the system through closer control of operating parameters, repair of steam leaks, addition of insulation, and recovery of condensate ... etc.

Steam Traps:

It is very important that steam distribution network be properly drained. Steam traps are the key to optimum steam and condensate system operation, and they have three basic functions:

1. Remove condensate: condensate must be allowed to pass through the trap quickly and completely in order to maximize heat transfer.
2. Remove air and other gases: air and gases in the system reduce the heat transfer area, and lower the overall heat transfer temperature.
3. Prevent steam loss: the trap must minimize live steam loss while it passes condensate, air and non-condensable gases.

There are three basic types of steam traps:

- Thermostatic (temperature difference).
- Mechanical (density difference).
- Thermodynamic (change of state).

Condensate Recovery:

Steam condensate is usually high purity water at a high temperature. In all plants, the maximum amount of condensate possible should be returned for reuse in the boiler, where the boiler feedwater temperature is low. (As much condensate as is economically possible should be returned from sources where there is no likelihood of contamination). This will save heat, make-up water, chemicals used in water treatment and reduce blowdown losses.

Collecting condensate means taking the discharge from one or more steam traps into a piping system, which carry it to the boiler feed-water tank. It is important to note that the piping does not interfere with the proper operation of the steam traps.

Appendix G

Power Factor Theory

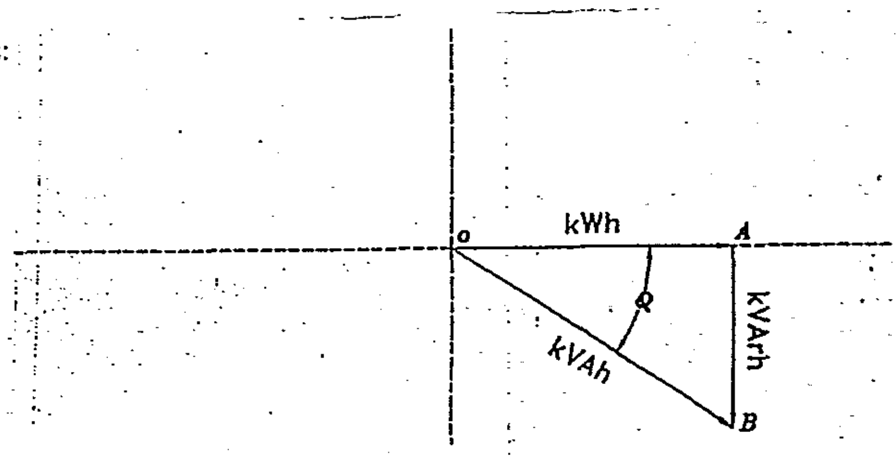
Power Factor Correction:

To achieve the most economic and efficient electrical system a good power factor is essential. Most industrial and large commercial premises utilise significant amount of A.C. electrical plant, this includes induction motors, air conditioning plant, refrigeration plant, power transformers, voltage regulators, welding machines, electric arc furnaces, choke coils and magnetic systems.

All of these draw power from the supply in terms of apparent power kilovolt amperes (kva) which is in excess of the useful power expressed in kilowatts (kW), the ratio between these two components is known as power factor (Cos).

$$\frac{\text{Useful Power (kW)}}{\text{Apparent Power (kV)}} = \text{Power Factor (Cos)}$$

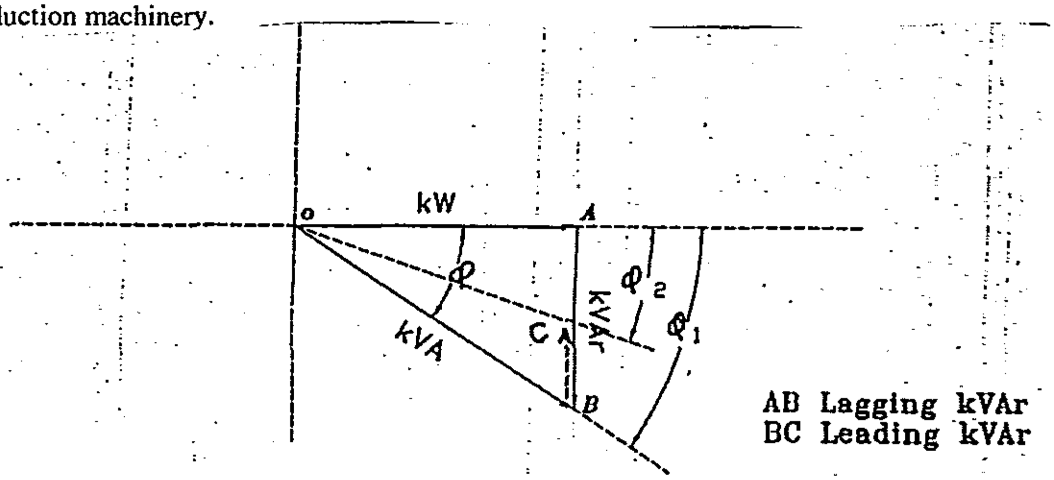
Vectorially shown as:



As can be seen from Figure above there is a third component kilovolt amperes reactive (kvar). This component represents the wattless or magnetizing load drawn in general by all a.c. induction machinery to overcome electrical inertia, this is known as lagging kvar.

This means the Power Stations, transmission lines and local area distribution networks, all have to be large enough to accommodate not only the useful power requirements (kW) of consumers but also their Wattless/Magnetizing power (kvar). Also the consumer himself, who has a poor power factor, is required to install larger transformers and cables and pay substantially more for his supply from the Electricity Authority due to the inefficiency in terms of the poor power factor generated by his plant.

In order to improve the power factor (Cos $_{1}$) leading kvar needs to be added to the system. This can be done by the addition of CAPACITORS which, although drawing kvar from the system, it is leading kvar which is exact phase opposition to the lagging kvar drawn by the a.c. induction machinery.



The benefits of improving the power factor are two field:

1. Reduction in electrical energy costs.
2. Improved efficiency and a reduction in the apparent power (kva) requirements of the electrical distribution system.

With reference to point 1, the prime reason for installing power factor correction equipment is to reduce electrical energy costs. All Supply Authorities structure their tariffs for their industrial and larger commercial consumers in such a way that a consumer will benefit financially, in terms of a reduction in his electrical energy costs, by improving or having a good Power Factor.

Reduction in energy costs also will be achieved due to the reduction in the line losses since the line currents are reduced (losses = I^2R).
Considering the second point, the system efficiency can be improved because installing the capacitors will not only improve the system voltage, but also increase the system capacity.

Power Factor in AC Systems

Ac power, as produced by generators, is in the form of sine waves, whereas dc has a steady and continuous value. Frequency in hertz is the number of complete generator electrical rotations per second and unless distorted by harmonics, power generated will have the form of a sine wave. Each voltage and current wave starts at zero, rising to a maximum value in half a cycle, then reversing polarity with the same action in the next half-cycle, repeating this variation 60 times a second in the United States and generally 50 times a second in other parts of the world. All circuits have resistance losses in supply conductors plus that of the utilizing device. This resistance produces a drop in voltage and causes a power loss (I^2R in the form of heat). It is real dollar loss, which can be reduced only by using conductors and devices with less resistance, or by reducing total current required for productive power plus reactive current with less-than-unity power factor. Improved power factor reduces total current, thereby reducing losses in the electrical system.

The electrical effect of inductance in an ac circuit comes from the magnetic field around any conductor. Recall that a magnetic field is a form of stored energy produced by dc current. Two basic magnetic principles are at work. The strength of the magnetic field established by the current is a direct function of the magnitude of current flowing. No current, no magnetic field. As current increases as with current in the form of a sine wave, the energy in the magnetic field becomes stronger. A second principle is that the polarity of the magnetic field is determined by the direction of current flow. so on ac, where current polarity varies each half-cycle, so will magnetic polarity vary with each ac cycle.

Back to the alternating current in the form of a sine wave; as current rises, the magnetic field gets stronger and stronger. More and more energy is being stored in the form of magnetism. This, the magnetic field, and the energy stored in it is at a maximum at the peak current value, at one-quarter of the current sine wave. As current passes the peak and begins to decrease, the magnetic energy is returned to the circuit trying to prevent a change in the current. At one half-cycle, the current reverses polarity; therefore, the magnetism caused by the current must switch from N-S to S-N and repeat the field buildup an collapse during the other half of the ac cycle.

The energy stored in a magnetic coil in air is rather small. But when wire is wrapped around an iron core, such as in a motor or a transformer, the magnetic energy is built to a maximum, then returned to the circuit as current decreases, trying to prevent the change in current that produced the magnetism. The concept of the electrical effect is similar to mass inertia. Current in the form of a sine wave because of magnetic inertia is caused to lag behind the voltage wave in an ac circuit. The degree of current lag behind voltage is the power factor in that circuit. Magnetic power is absolutely necessary for electrical devices such as motors and transformers to work.

A major portion of the ac current causes the motor to produce useful work. However, the reactive portion of ac current does no useful work, and with power-factor improvement is either greatly reduced or, at 100% PF, eliminated.

Capacitance is related to voltage just as current and magnetism is related to inductance. A capacitor stores electrons.(Your car mechanic and sometimes the TV repairman might call it a condenser). A capacitor is made of two electrically conductive materials separated by an insulating material. The magnitude of its electron storage capacity is a function of the area of the electron storage plates and the thickness of the insulation material that separates the plates and applied voltage. Capacitance also varies as the square of the applied voltage.

The usual construction materials are two very thin sheets of aluminum foil placed on each side of a special paper, plastic, or other insulating material. The composite is then rolled into books, leads attached to each aluminum sheet, the books compacted, and the whole arrangement placed into a steel can, with suitable electrical connections. The steel can is then filled with an additional insulating medium, probably a silicone product. Capacitor leads are then connected to porcelain bushings in the top of the sealed can.

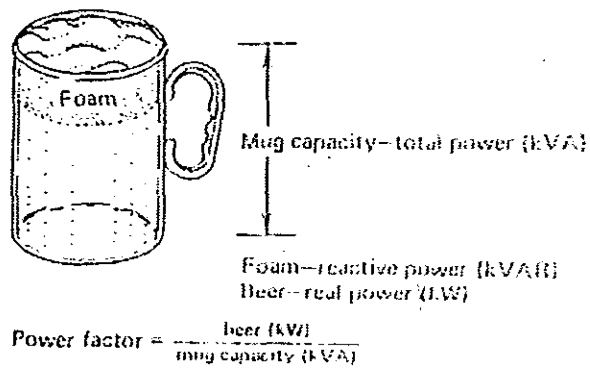
Recall that the voltage produced by an electric generator is also a sine wave. As voltage rises, more electrons are impressed and stored on the electric conductive plates of a capacitor. Electrons are stored on capacitor plates in increasing number up to the peak of the voltage sine wave. As voltage drops during the second quarter, first half of the sine wave, these stored electrons are returned to the circuit. As the voltage changes polarity in the second half of the sine wave, electron charges on the plates of a capacitor must also change polarity. The electrical effect is for the electrons to try to prevent a change in the voltages. This is a similar inertia effect as with magnetism and current, except that capacitors try to effect a change in voltage. In the sine waves of current and voltage, this effect causes voltage to lag behind current. Exactly the opposite effect is produced on current. Inductance causes current to lag voltage, whereas capacitance causes current to lead voltage. We find, then, that the effect of inductance in ac circuits is exactly the opposite effect of that produced by capacitance One can, so to speak, cancel the other out, at least as measured by utility billing meters.

In ac circuits, the effect of lagging power factor caused by wire wrapped around the iron in motors, transformers, lighting, ballasts, and such can be counterbalanced by the addition of capacitors. With some basic understanding of electrical principles in ac circuits, the calculation of power factor is not too difficult. But keep in mind that leading power factor is no better than lagging power factor. Both cause reactive currents in the electrical system which increase power loss and which do no useful work.

Power-Factor Calculations

By definition, power factor in ac circuits is determined by dividing real power in kilowatts by total power in kVA (Power factor = kW/kVA). Reactive power, either inductive or capacitive, always acts at right angles or 90° to real power. Thus power-factor calculations are only basic calculations to determine the length of sides of right triangles, which in scaler value represent electrical values, and the calculation of angles between the sides in degrees.

Sometimes two analogies are used to illustrate power factor. One analogy is to use a stein of beer. The total capacity of the stein represents total power or kVA. The foam represents reactive power and the beer represents real power. With this analogy the ratio of beer to stein capacity is the power factor.



A second analogy is to picture a horse pulling a car down a rail track, with the horse pulling at an angle to the direction of car travel. Thus the pull of the horse is total power, the tractive effort moving the car is real power, and the side pull, doing no real work, is the reactive power - both good analogies, but leaving us a bit short for actual power-factor calculations.

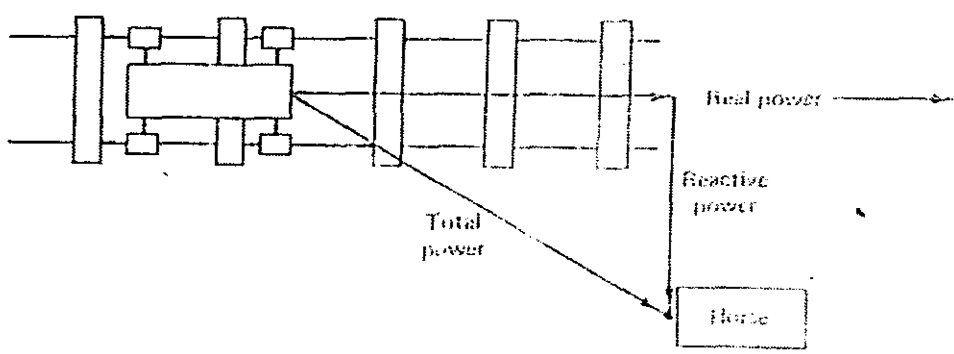


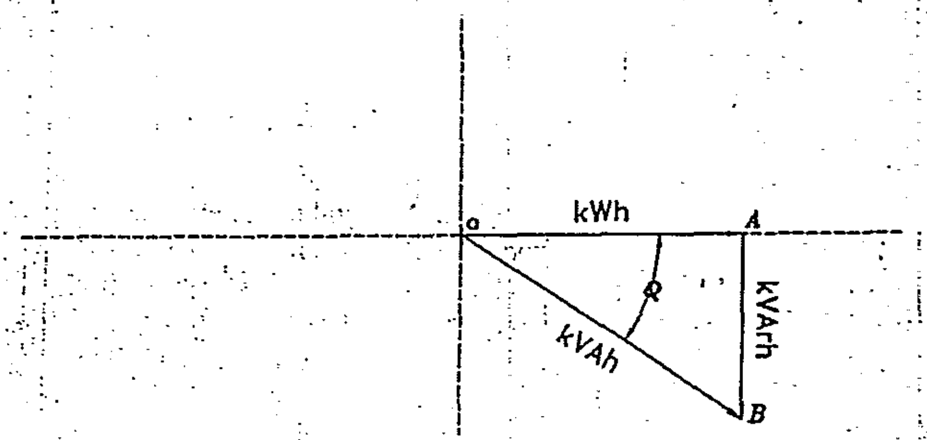
Figure (4) : Power Factor Analogy 2

In the real world where power factor involves LE's, calculation must usually be made from the utility billing meter readings. A utility meter set will normally include three meters. A demand meter will record maximum power use for the billing period for the demand interval of 30 minutes. A watt-hour meter will record kilowatt-hours for the billing period. Particularly, it records both day kWh and night kWh. And a reactive meter will record kilovolt-ampere-hours reactive (kvar)

Average power factor for the industrial plant or commercial building will then be calculated as follows:

First of all we draw the following triangle; then

$$\text{Tan} = \frac{AB}{OA}$$



Then can be determined by taking arctan (the inverse of the tangent) of both sides of the equation, i.e.

$$= \arctan \frac{(AB)}{OA}$$

After the angle is known, power factor is determined by taking the cosine of the angle .

By moving the decimal point of the trigonometric cosine of the angle two places to the right, the power factor is converted to a percentage, the usual expression used with power factor.

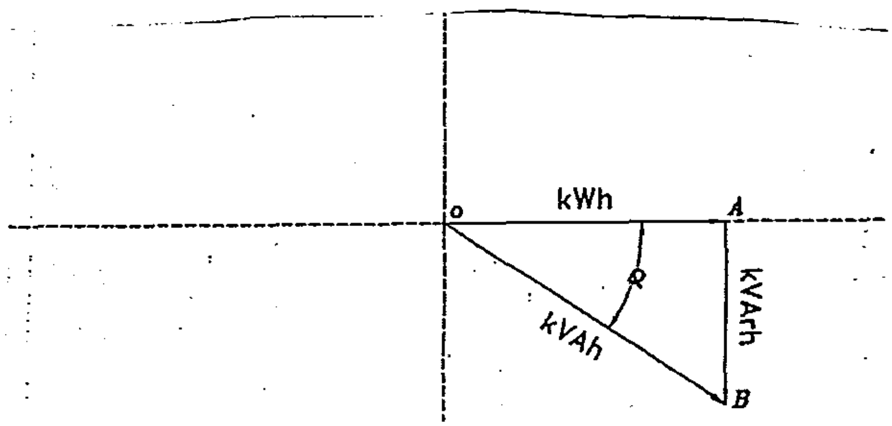
Making a Power-Factor Study

In order to make a power factor study the following electrical quantities must be known:

- System kilowatts (kW).
- system power factor or system reactive kilovolt-amperes (kvar).

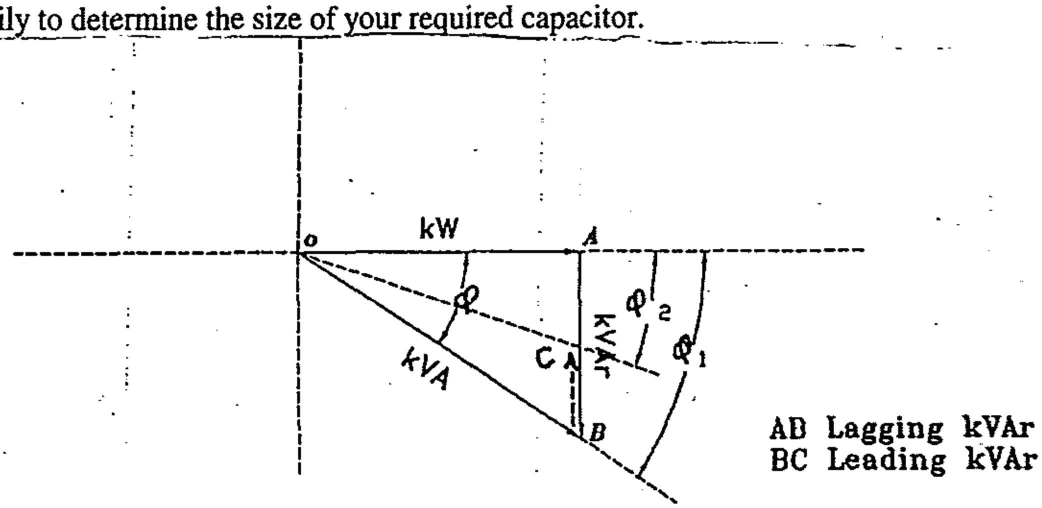
If we want to improve (raise) the power factor of a certain plant, we go into the following steps:

1. Draw what is called the power triangle which is a right triangle with sides lengths equal to plant kilowatts (kW) and kilovolt-amps (kvar) as illustrated in the following Figure:



2. Determine the angle 1 by taking the cosine inverse of the power factor if it is known or, by taking the tangent of angle 1 and then the tangent inverse (arctan).
3. Determine the required power factor after installing the capacitor.
4. Compute 2 which equals the cosine inverse of the new power factor.
5. Calculate the distance CB, this will represent the value of the size of needed capacitor in reactive kilo-volt-amperes

   Actually, the above procedure is typical and ready tables are found, you can use them easily to determine the size of your required capacitor.



Applying Capacitors

Once the size of capacitors is determined, the next selection is where to connect them on the customer's electrical system. The capacitors must, of course, be for the voltage where applied, but the user has a choice of three possible places to connect the capacitors:

1. Connect all together at any point past the utility metering (usually at the service entrance switch gear).
2. Divide the total capacitor requirement in selected amounts and connect to the system about the electrical center of power feeders.
3. Connect a large number of small capacitors on the terminals of each motor and switch motor and capacitor.

Choice 1 is often the cheapest, for the user, this selection is usually least costly. Capacitors connected at any point past the utility metering does eliminate customer reactive current from the utility system, thus releasing additional utility system capacity for other customers. However, all inductive reactive current in the customer system and switch gear still circulates between the low-power-factor-causing devices and the capacitors. Electrical losses in the user system; although comparatively small, are not reduced.

Choice 2, sometimes combined with choice 3, is the usual and most satisfactory method for applying capacitors. Usually, an industrial plant or a commercial building has several to a large number of power feeders. Thus the total capacitors required for improvement can be divided into standard kVAR sizes to be connected at approximately the electrical centers of the feeders serving the loads. One method of determining feed load is to tabulate connected motors and other loads to determine the part of the total required for a given feeder. And even simpler method would be to take clip-on ammeter feeder readings, and size capacitor banks indicated by such current breakdown.

Reactive current from electrical devices will still circulate between the devices and the capacitor bank connected to the feeder. However, such current is eliminated from going through the feeder breaker or switch, and with the bank connected at the electrical center to the feeder. Thus additional loads may possibly be added without exceeding the gear. In addition to savings in power billing, savings to add load without additional investment in electrical capacity can be a happy surprise.

Choice 3 is seldom economically desirable. This method offers the maximum improvement in the power factor. Reactive current circulates only in the very short connection between the motor and the capacitor. Unfortunately, this is also almost always by far the most expensive method. LE per kVAR for small capacitors is considerably more than LE per kVAR for large capacitor banks. In practice, PF improvement by this method is usually for motors 50hp or larger with the addition of feeder bank capacitors to take care of smaller motors. It is rarely found, the case where the power factor would be satisfactory in terms of user cost for capacitors connected on motor terminals. Except for economics, there is nothing wrong with a user obtaining power-factor improvement by motor-capacitor switching, regardless of the size of the motor.

Appendix H

Suppliers List

Electrical Suppliers List

Item	Suppliers	Prices JD
Compact. FL Lamps	ATCO Control-**Tridonic** **(UAE)** (Tel: +971-48871744/ Fax: +971-4871755)	6 - 13
	Minwer for Lighting-**Osram** (Tel: 4613746/Fax: 4643746)	
(Energy Saving Lamps)	Electrical Lighting Co. Ltd.-**Thorn** (Tel: 5538203/Fax: 5338206)	
	Union for Lighting-**Philips** (Tel: 4642364/ Fax: 4642365)	
Electronic Ballast	Soufan & Bros. Co.- **Mazda** (Tel:5680783/ Fax 5678875)	14-28
Efficient Reflectors	**ALP** Lighting Components - USA (Tel 01-7737925621/ Fax 01-7737749331)	10-24
Timers & Time Delay Timers	Billeh Electrical Co. - **ABB** (Tel 4613987 / Fax 4649216)	13-85
	Moha Est. - **Theben** Germany (Tel 5153846 / Fax 5151846)	23-76
	Minas Mizkean -**General Electric** (Tel 4613208 / Fax 5684632)	
	Erfan Industrial Components Co.- **Telemecanique** (Tel 475141 / Fax 4756601)	
	Dasouki Trading Co.- **Hagger** France (Tel 4652711 / Fax 5684632)	
Photocell	Moha Est.-**Theben** Germany (Tel 5153846 / Fax 5151846)	18-100
	Electrical Lighting Co. Ltd.-**Orbis** (Tel 5538203/Fax 5338206)	
	Minas Mizkean -**General Electric** (Tel 4613208/Fax 5684632)	
	Soufan & Bros. Co.- **Mazda** (Tel 5680783 /Fax 5678875)	
Occupancy Sensors	Moha Est.-**Theben** Germany (Tel 5153846 / Fax 5151846)	25-120
	Technical Applications Group - Tag (Tel 4619074 / Fax 461973)	
	Electrical Lighting Co. Ltd.- **Orbis** (Tel 5538203 / Fax 5338206)	

Item	Suppliers	Prices JD
Variable Frequency Drive	Younes Khader Trading Co. - **Vacon** (Tel 4612013 / Fax 4162014)	50-120 JD/kW
	Niqola Nassar - **Danfoss** (Tel 585947 / Fax 5813333)	
	Naser Bros. Trading Co. -**Control Techniques** (Tel: 4770946 / Fax: 4745044)	
	Sam Engineering & Trading Co. - **Alen Bradely** (Tel: 5812693/ Fax: 5824907)	
	F. A Kettaneh -**Siemens** (Tel 4398642 / Fax 4392582)	
High Efficiency Motor	**Brook Hansen** International - UK (Tel 484-422150 / Fax 484-516873)	50-100 JD/kW
	Baldor Motors and Drives -USA (Tel 501-6464711 / Fax 501-6485792)	
	F. A Kettaneh -**Siemens** (Tel 4398642 / Fax 4392582)	

Mechanical Suppliers List

Item	Suppliers
Steam Boilers	Advanced Industrial & Engineering Consulting Co. (Tel: 5932015/Fax: 5930435)
	S.A.M Engineering & Trade Co. (Tel: 5812693/Fax: 5824907)
	Engineering Dimension of Technology (Tel: 5519982/Fax: 5519983)
	Metalco (Tel: 5526256/Fax:5535896)
Heat Recovery System	Engineering Dimension of Technology (Tel: 5519982/Fax: 5519983)
	S.A.M Engineering & Trade Co. (Tel: 5812693/Fax: 5824907)
	Advanced Industrial & Engineering Consulting Co. (Tel: 5932015/Fax: 5930435)
	Nicola Qawar & Sons (Tel:4651691 /Fax:4651083)
Steam Traps	S.A.M Engineering & Trade Co. (Tel: 5812693/Fax: 5824907)
	Engineering Dimension of Technology (Tel: 5519982/Fax: 5519983)
	Advanced Industrial & Engineering Consulting Co. (Tel: 5932015/Fax: 5930435)
Energy Wheels	Engineering Dimension of Technology (Tel: 5519982/Fax: 5519983)
	Mona for Heating & Air Conditioning (Tel: 5695851/Fax: 5687852)
Heat Exchangers	S.A.M Engineering & Trade Co. (Tel: 5812693/Fax: 5824907)
	Advanced Industrial & Engineering Consulting Co. (Tel: 5932015/Fax: 5930435)
	Moha Est. (Tel: 5153846/Fax: 5151846)
Insulation Materials	Engineering Dimension of Technology (Tel: 5519982/Fax: 5519983)
	Mais (Tel: 4623261/Fax: 4624689)
	Jordan Rock Wool Industries Co. Ltd. (Tel: 5602139/Fax: 5686618)

	Suppliers
Sensors	S.A.M Engineering & Trade Co. (Tel: 5812693/Fax: 5824907)
	Technolinks (Tel: 4649751/Fax: 4649752)
Building Management Systems	A.B.B (Tel: 5620181/Fax: 5621369)
	S.A.M Engineering & Trade Co. (Tel: 5812693/Fax: 5824907)
	Technolinks (Tel: 4649751/Fax: 4649752)
Air curtains	S.A.M Engineering & Trade Co. (Tel: 5812693/Fax: 5824907)

Appendix I

General Questionnaire & Measures Check list

Energy Consumption Questionnaire-Commercial Buildings

Name: ....
Contact Person: .... Function: ....

Hotel Year of Construction: ....

Do you have tax exemption? ....

Energy Sources Used: 1- ....2-....................3-........................

Sub-Metering:

Meter	Energy Type	Area/System Metered

Average Occupancy Rate / Year ....

Best Occupancy Month: .... Lowest Occupancy Month: ....

Electrical Transformers:

Qty.	Voltage	KVA	% of Loading

Generators:

Quantity: ....kVA or kW: ....Operating Hours/Month: ....

Boilers:

Total No. of Boilers: Steam = ... Hot Water = ...
Steam Pressure: .... bar

Condensate returned: Yes .... No .... %

....

Condensate used for: ....

Steam used for:..

Note:

Please Photocopy tables if you needed extra spaces

Boiler Data:

No.	Fuel	Capacity	Burner Nozzle	Working	TDS
				Hrs/Year	
1					
2					
3					

Please mention units of values filled in the table header

Bare hot, condensate and steam pipes:

Well Insulated: .... Moderately Insulated: .... Not Insulated: ....

Compressed Air:

Qty	Type	Capacity	Power	Pressure (bar)			Operating
			kW	Design	Work	Required	Hrs/Day

Refrigeration Systems: *(Main refrigerators & Ice Makers)*

Qty	Type	Capacity	Power	Temperature (°C)			Operating
			kW	Design	Work	Required	Hrs/Day

Heating & Air Conditioning System (HVAC):

Chillers, Package Units or Split Units:

Qty	Type	Brand	Power	Operation			Temp.
		& Model	kW	Hour	Day	Month	(°C)

Chilled Water & Circulating Pumps: Qty = ... Total kW = ...

Air Handling Units (AHU):

No.	Area Served	Power	Operating Time		
		KW	Hour	Day	Month
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Exhaust & Extraction Fans: ***(Only major fans with power higher than 3 kW)***

No.	Area Served	Power	Operating Time		
		KW	Hour	Day	Month
1					
2					
3					
4					
5					
6					
7					
8					

Main Water Pumps: (Domestic or any others not mentioned above)

No.	Area Served or Description		Qty	Power	Operating Time		
				kW	Hour	Day	Month
1							
2							
3							
4							
5							

Laundry Section: No. of Machines: .... Use Steam/Hot Water

Average Working Hours/Day: .... Use Electrical Heating

Lighting System: ***(Approximate figures can be used)***

Type	Lamp Watt	Total Qty.	Area (s)	Hours/Year

Areas with similar lamps type can be filled as one raw

Measures Check List

A) Lighting Measures

No.	Measure Name	Check
1	Excess Lighting	
2	Occupancy Detectors	
3	Time Control	
4	Photocells	
5	Replace Lamps	
6	Install Efficient Reflectors	
7	Electronic Ballast	
8	Time Delay Timers	

B) HVAC And Refrigeration Measures

No.	Measure Name	Check
1	Temperature Settings	
2	Shut Down Exhaust Fans During Unoccupancy	
3	Increase Condenser Efficiency	
4	Air Curtains	
5	Reduce Solar Heat Gain	
6	Oil Additives-Frigaid	

C) Motors Measures

No.	Measure Name	Check
1	Energy Efficient Motors (EEM)	
2	Variable Speed Drives (VSD)	
3	Automatic Control	

D) Steam Measures

No.	Measure Name	Check
1	Burner Calibration	
2	Reduce Pressure Settings	
3	Pipes And Surfaces Insulation	
4	Condensate Heat Recovery	
5	Steam Traps	
6	Steam Leak	
7	Water Saving Devices	
8	Blowdown Control	
9	Heat Recovery	

Appendix J

Audit Forms

Audit Forms

PROJECT NAME :

BOILERS AND AUXILIARIES

TOTAL No OF BOILERS ________

STEAM ________ PSIG. BAR

CONDENSATE RETURNED : ________ YES ________ NO ________ %

CONDENSATE USED FOR : ________________________________

____

STEAM USED FOR :

________________ BAR ________________ BAR

________________ BAR ________________ BAR

BOILER DATA

BOILER No	FUEL TYPE	CAP KG/HR	NOZZEL GPH	OPERAT HOURS	B.D SEC/HR	T.D.S B.D	T.D.S F.W.T	T.D.S SOFT W.
1								
2								
3								
4								
5								
6								

BOILER FEED PUMPS

PUMP No	MOTOR KW	FLOW M^3/HR	HEAD M	MODEL No
1				
2				
3				
4				
5				
6				

FEED WATER TANK

LENGTH ________ WIDTH ________ HIEGHT ________ DIAM ________

TEMP IN ________ SURFACE TEMP ________ HEATING SOURCE ________

NOTES ________________________________

____

____

DATE (/ /199) PAGE No ( ) E.M.

PROJECT NAME :

HEAVEY FUEL OIL

FUEL TEMP AT: MAIN TANK ________ DAILY TANK ________

BURNER ________

HEAT SOURCE : MAIN TANK ________ DAILY TANK ________

BURNER ________ TRACING ________

HEATER CAP : MAIN TANK ________ DAILY TANK ________

BURNER ________ TRACING ________

MAIN TANK : LAGGED ________ THICKNESS ________

DAILY TANK : LAGGED ________ THICKNESS ________

FUEL PIPES : DIAMETER ________ LENGTH ________

LAGGED ________ THICKNESS ________

FUEL PUMP : MOTOR ________

UNINSULATED PIPES

DIAM	LENGTH	TEMP	FLUID	DIAM	LENGTH	TEMP	FLUID

CONDENSATE TO DRAIN

DEVICE NAME	FLOW	TEMP	HRS	DAYS	MONTHS

PROJECT NAME :

FAULTY STEAM TRAPES

DIAM	TEMPRETURE		PRESSURE		OPERATION		
	BEFOR	AFTER	BEFOR	AFTER	HOUR	DAY	MONTH

MACHINES COOLING

TYPE	CAP	POWER	TEMPERATURE		OPERATION		
			IN	OUT	HOUR	DAY	MONTH

MACHINES COOLING PUMPS

QTY	POWER	CAP	HEAD

HOT STREAMS

STREAM TYPE	STREAM FLOW	STREAM TEMP	STREAM QUALITY	OPERATION		
				HRS	DAYS	MONTHS

NOTES

PROJECT NAME :

COLD STORES

LENGTH	WIDTH	HIEGHT	DOOR WIDTH	DOOR HIEGHT	PROD. TYPE	DOOR OPEN TIME

COMP. POWER KW	COMP CAP TON	COMP QTY	EVAP CAP	EVAP QTY	DEFROS TYPE	DEFROS TIME

COTROL TYPE	TEMPRATURE		RELATIVE HUMMID	
	SET	ACTUAL	SET	ACTUAL

AMBIENT	
TEMP	RH %

LIGHT TYPE	LIGHT UNIT QTY	LIGHT UNIT POWER	OPERATION		
			HOUR	DAY	MONTH

BARE PIPES

DIAM						
LENGTH						
TEMP						

E.M.S

DATE (/ /199) PAGE No ( )

170

PROJECT NAME :

FUEL CONSUMPTION

MONTH	HEAVEY FUEL OIL		LIGHT FUEL OIL		KEROSEEN	
	1994	1995	1994	1995	1994	1995
JAN						
FEB						
MAR						
APR						
MAY						
JUN						
JUL						
AUG						
SEP						
OCT						
NOV						
DEC						

TOTAL						

PRODUCTION

MONTH	PRODUCTION TYPE					
	1994	1995	1994	1995	1994	1995
JAN						
FEB						
MAR						
APR						
MAY						
JUN						
JUL						
AUG						
SEP						
OCT						
NOV						
DEC						

TOTAL						

NOTES

PROJECT NAME :

AIR HANDLING UNITS

No	POWER	CFM	AREA SERVED	HEAT CAP	COOL CAP	GPM	CONTROL TYPE
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

FAN COIL UNITS

QTY	CFM	HEAT CAP	COOL CAP

SPLIT UNITS

QTY	POWER KW	HEAT CAP	COOL CAP

E.I

PROJECT NAME :

AIR CONDITIONING SYSTEM

DESCRIBE SYSTEM

TYPE	POWER KW	CAP TON	OPERATION			QTY
			HOUR	DAY	MONTH	

SUPPLLY AIR TEMP ______ RETURN AIR TEMP ______

SUPPLY WATER TEMP ______ RETURN WATER TEMP ______

No OF ZONES ______ HOW CONTROLLED ______

CONTROLS

TYPE	CONTROL AREA	SETTING	TEMP	R.H %	QTY

BARE PIPES

DIAM						
LENGTH						

BARE DUCTS

SIZE						
LENGTH						

CIRCULATING PUMPS

LOCATION	POWER	GPM	HEAD	TYPE	AREA SERVED

UNCOOLED AREAS

LOCATION						
AREA						

E

PROJECT NAME :

MISC.DEVICES

FURNECES, HEATERS, DRYRES

DEVICE NAME	FUEL TYPE	CAP KCAL/HR	OPERATION			NOZZEL GPH
			HOURS	DAYS	MONTHS	

HOT SUFACES

DEVICE	TEMP	DIMENSIONS			OPERATION		
		LENGTH	WIDTH	HIGHT	HOURS	DAYS	MONTHS

COMPRESSED AIR

TYPE	FLOW	POWER	WORKING HOURS	PRESSURE			INLET TEMP
				DESIGN	WORK	REQ'D	

LEAKAGE AREA : ________ ________ ________

AIR VELOCITY : ________ ________ ________

F-14

DATE (/ /199)

Motors	Motor No.	Motor No.	Motor No.	Motor No.
Function description				
Motor brand				
Motor model				
Serial No.				
Open or closed motor				
Capacity (HP) amp.				
Voltage / Phase / Cycle				
Frame				
Type				
Insulation grade				
Service factor code (1.15 - 1.25)				
Nominal rotation speed (RPM)				
Measured rotation speed (RPM)				
Measured ampers - Phase 1 - Phase 2 - Phase 3				
Operating hours - Annually - Weekly				
Drive or direct fan belt				
Remarks				

VENTILATION SYSTEMS SURVEY FORM

A complete system survey form

SYSTEM NO.: --------------

PREHEAT:
Type of coil : ------------------------------ glycol, hot water, vapour, electricity
Setting: -- face or face with bypass
Control type: ------------------------------ temperature according to serpentine
Constant temperature maintained: --
Operating Schedule: --

Mixing (Melange):
Control type: Fixed % of fresh air, mixing temperature, thermostat, return temperature, zone analyser
----

Fixed % or temperature maintained: --
Control of high exterior temperature: ◊ Thermostat ◊ enthalpy ◊ none
Control adjustment of high temperature: --
Operation schedulefor mixing: --

SUPPLY TEMPERATURE:
Heating: Primary coil tubing: -------------------------- glycol, hot water
Secondary coil -------------------------- vapour, electric
Control: -------------------------- fixed, room air return temperature, room thermostat, zone analyser, variable according to exterior temperature, sequential control at mixing.
Temperature maintained: --------------------------
Cooling: Coil: -------------------------- cold water, glycol, DX
Control: -------------------------- fixed, room or return air temperature, sequence with heating coil and mixing dampers.
Maintainedtemperature: --------------------------

HUMIDIFICATION:
Equipment type: ------------------------------------ squirt water, vapour injection, basin
Heating: ------------------------------------ non-heat, vapour, hot water, electricity
Humidity maintained: --

Control: Humidistat in the return or the room re adjusted according to the exterior temperature.

Control Box:
Temperature control: Room thermostat
Coil: Glycol heating, hot water, vapour electricity
Cooling: Cold water, glycol, DX
Ventilator Control; Thermostat, clock, centralisation.

PROJECT NAME :

COLD STORES

LENGTH	WIDTH	HIEGHT	DOOR WIDTH	DOOR HIEGHT	PROD. TYPE	. DOOR OPEN TIME

COMP. POWER KW	COMP CAP TON	COMP QTY	EVAP CAP	EVAP QTY	DEFROS TYPE	DEFROS TIME

COTROL TYPE	TEMPRATURE		RELATIVE HUMMID	
	SET	ACTUAL	SET	ACTUAL

AMBIENT	
TEMP	RH %

LIGHT TYPE	LIGHT UNIT QTY	LIGHT UNIT POWER	OPERATION		
			HOUR	DAY	MONTH

BARE PIPES

DIAM						
LENGTH						
TEMP						

A QUESTIONNAIRE OF CHILLERS COMPRESSORS CHARACTERISTICS

Descriptive Parameters	Comp. #	Comp. #	Comp. #	Comp. #
Function Description				
Connected to Chiller #				
Compressor Brand				
Compressor Model				
Serial No.				
Refrigerant Pressure • Suction • Discharge				
Refrigerant Temp. • Suction • Discharge				
Motor				
Motor Brand				
Motor Model				
Serial No.				
Motor, Open or Shut				
Power (hp) (amp.)				
Voltage/Phase/Cycle				
Frame				
Type				
Insulation Class				
Service Code Factor(1,15 - 1,25)				
Measured Speed Rotation (RPM)				
Measured Amp. • Phase 1 • Phase 2 • Phase 3				
Operating Hours • Annual • Daily				
Remarks				

A QUESTIONNAIRE OF AN ELECTRIC INPUT CIRCUIT

DESCRIPTIVE LIST OF (A) GENERATOR(S)

Descriptive Parameters	Generator No. 1	Generator No. 2
Generator Brand		
Generator Model		
Generator Serial No.		
Nominal Real Power (kW)		
Nominal Reactive Power (KVA)		
Power Factor: COSØ(%)		
Voltage/Phase/Cycle		
Generator Rotation (RPM)		
Amperage (amp)		
Used Fuel		
Motor Block Brand		
Motor Block Model		
Motor Block Serial No.		
Motor Block Cylinder Capacity		
Consumption 100% load (USGPH) 75% load (USGPH) 50% load (USGPH)		
Other relevant information		
Maintenance service (Co. & Address)		
Telephone Number of Service		
Remarks		