PN-ADC-276

WEPIA

Water Efficiency and Public Information for Action

مشروع الكفاءة المائية والتوعية

AED

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PN-ADC-276

Energy Conservation workshop
EMS

February 6th , 7th ,2002

Lighting Survey

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

Energy Management in Lighting

- Background -

Evaluation ..

- o Evaluation of Individual Spaces
- o Study Possible Improvements
  - Different Options
  - Most Economical & Practical

Introduction

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

Two Choices to be Made in Making Changes in a Lighting System :

- o Modification of Existing System
  - Simplest Way
  - Examples :
    - Replacing Lamps
    - Change Switching Circuits
- o Replacement with Another System

Building or Entity Analysis

- o Recommended Procedure
  - Conduct a Survey OR
  - Review Project Plans
    - Less Satisfactory
    - Random Check

Initial Cost VS. Annual Operating Cost

- Initial Costs Include :
  - Lamps or Fixtures
  - Wiring
  - Installation
- Annual Costs Include :
  - Failure Lamp Replacement
  - Maintenance
  - Electricity (Energy)

Lighting 10

Replacement of Existing System

- Requires Higher Investment
- Should Be Economically Justified
  - Example
    - 1000W Mercury Lamp - 44700 L
    - 400W H P Sodium - 45000 L
    - Savings = 605 W Per Fixture
    - Same Light Level

Lighting 7

Task Lighting Objective

To Provide;

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

Lighting 11

Cont.. Example

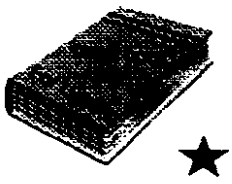
- Annual Savings = JD 223
- Investment = JD 267
- P B Period = 14 Months

- Result Proposal is Justified

Lighting 8

Lighting Levels

- Recommended Illuminance Levels
  - IES Lighting Handbook (USA)
  - CIBSE Code (UK)
- Consider Both
  - Quantity of Light
  - Quality of Light



Lighting 12

Priorities

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

Lighting 9

Reflectance ..

- As a Guide IES Recommends,
  - For Office-Type Spaces :
    - Ceiling : 80 - 90 %
    - Walls : 40 - 60 %
    - Floors : 20 - 40 %

Lighting 16

System Modifications

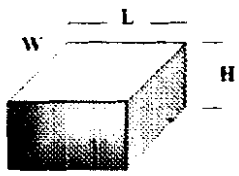
Examples

- Lower Luminaires Closer To Work Surface
  - Use Lower Wattage Lamps
- Relocation of Luminaires
  - Remove Unnecessary Luminaires

Lighting 13

Space Geometry

- Space Dimensions:
  - Length
  - Width
  - Height



Affect the Distribution of Light in The Area.

Lighting 17

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

Lighting 14

Space Geometry ..

- 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.

Lighting 18

Reflectance

- Reflectance of Walls, Ceilings, and Floor Affect The Illumination Levels
- Light Colors Have Higher Reflectance.
- Avoid Excessively Bright Surfaces.

Lighting 15

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

Lighting 22

Families Of Lamps

- Any Lighting Unit Usually Consist of Part or All of The Following
  - Lamp
  - Special Equipment - Control Gear
    - Ballast, Ignitor, Capacitor
  - Luminaire
    - Sockets, Body, Reflector, Cover

Lighting 19

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

Lighting 23

Families of Lamps

- Incandescent & Tungsten Halogen
- Fluorescent
- High Intensity Discharge Lamps
  - Mercury Vapor Lamps
  - Metal Halide Lamps
  - High Pressure Sodium Lamps
  - Low Pressure Sodium Lamps

Lighting 20

HID - Metal Halide Lamps

- Very Similar in Construction to Mercury Lamps.
- Major Difference :
  - Contains Various Metal Halide Additives in Addition to Mercury Vapor
- Rating : 70 - 3500W

Lighting 24

Incandescent & Tungsten Halogen

- 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.

Lighting 21

By Model No.

Manufacturer	Incandescent	Halogen	Fluorescent	Blended Mercury
Philips	Standard A	500 T3Q CL P	TL D16 W 25	ML 160 W
Osram	HR IM	64702 HaloLINE	L 36 25	HWL

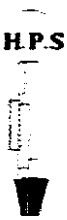
Manufacturer	Mercury	Metal Halide	H P Sodium	L P Sodium
Philips	HPL	HPI MBD	SON SDW	SOX
Osram	HQL	HQI	NAV	SOX

Lighting 28

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

H.P.S



Lighting 25

Energy Saving Opportunities in Lighting

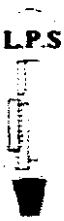
What To Look For ?

Lighting 29

HID - Low Pressure Sodium

- 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

L.P.S



Lighting 26

How to Define Lamp Type ?

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

Lighting 27

ENERGY
MANAGEMENT
SERVICES

Energy Management in Motors

Background

Motors

ENERGY
MANAGEMENT
SERVICES

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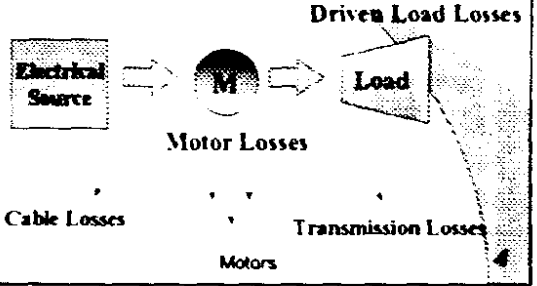
Electric Motors

Motors

Motor Performance

Typical Motor Setup



Motors 4

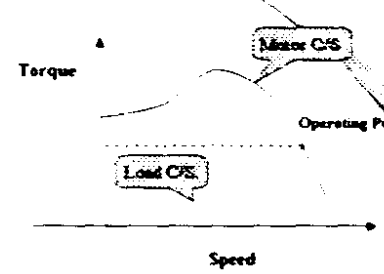
Types of Motors

- Squirrel Cage Induction Motors
  - 90 % of Existing Motors
- Synchronous Motors
- Slip-Ring Motors
- DC Motors

} 10 %

Motors 3

Torque Speed C/S's.



Motors 6

Motor Performance ..

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

Motors 5

Motor Losses

- Magnetic (Core) Losses
  - Hysteresis Losses

Energy Required to Magnetize Core Material

  - 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

Motor Performance ..

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 ..

- Friction (Mechanical Losses)
  - Windage Losses
  - Bearing Losses
  - Brush Friction Losses

Function with the Motor Speed

  - Fixed Losses : 5 - 10 % of Total Losses

Motor Losses ..

- 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

Example :

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

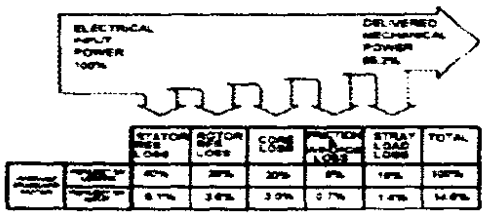
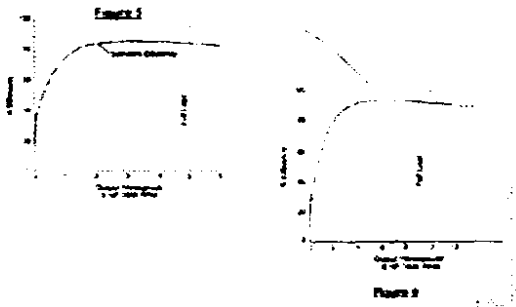


FIGURE 4

Motor Losses ..

- Stray Losses
  - Result of Leakage Flux Induced by the Load Currents
  - Difficult to be Measured or Calculated
  - Generally : Proportional to (I rotor)^2
  - 10 - 15 % of Total Motor Losses

Motor C/S's.



Motor Characteristics

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

- Motor Efficiency (vs) % Loading
- Power Factor (vs) % Loading

Determine Motor Efficiency

Input Power Method

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

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

Frequently, Manufacturer Data are Not Available

- Use General Curves Available or Make Approximations

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

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

Determine Motor Efficiency

Speed Measurement Method

- Using a Tachometer Measure Motor Speed (RPM)
- Using Speed vs Motor Load % Curve Determine the Loading of the Motor
- Using Efficiency vs Motor Loading % Determine Motor Efficiency

Factors Affecting Motor Performance

- Maintenance
- Rewinding
- Power Supply Quality
  - Voltage Variations -- 6 %
  - Frequency Variations --3 %
- Age

Determine Motor Efficiency

P out = % Loading * P rated

Eff = P out P in

Motors - Check List

- 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

ENERGY
MANAGEMENT
SERVICES

Energy Management in Motor

Energy Saving

Turn OFF When Not Needed

- Sometimes Motors are Left Operational Without Need For That
- Examples :
  - Air Compressors
  - Exhaust Fans
  - Air Handling Units
  - Ventilation Units

Main ECO's

- Automatic Control Of Motor Operation
- Matching Motor to Load Or Replacing Oversized Motors
- Install High Efficiency Motors
- Control Motor Speed (VFD)

Calculations

➢ Calculate Existing Motor Consumption

Annual Savings in kWh = Motor kW x (H1-H2)

Where:

- H1 : Existing Motor Operating Hours
- H2 : New Proposed Motor Operating Hours
- Motor kW from measurements or 70% of Rated kW

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

Turn OFF When Not Needed

Turning Off Those Motors Will Save a lot of Energy, While No or Low Investment is Required

- Programmable Timers
- Temperature Controllers
- Level Switches
- Pressure Controllers

Identifying the Measure

❖Electrical Measurements

- Power (kW)
- Power Factor

❖Speed Measurements (RPM)

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

Matching Motor to Load

Motors are Usually Oversized

- Safety Factors
- Over Estimated Loads
- Wrong Calculations
- Voltage Drop
- Selecting Non Suitable Type of Motor
  - Ex : High Starting Torque

Calculations

❖Existing Motor Load & Consumption

❖Proposed Motor Load & Consumption

❖Savings = Difference

Identifying the Measure ..

If Motor Loading Ratio < 50 %

- Efficiency Will be very Low
- Calculate for Replacing it

High Efficiency Motors

- ✓ 3 -5 % More Efficient
- ✓ Better Efficiency C S's
- ✓ Similar or Higher P F
- ✓ Lower Temp. & Noise
- ✓ Less Affected by Supply Fluctuations

Motors 32

ENERGY
MANAGEMENT
SERVICES

Energy Management in Motors

High Efficiency M

Motor Losses

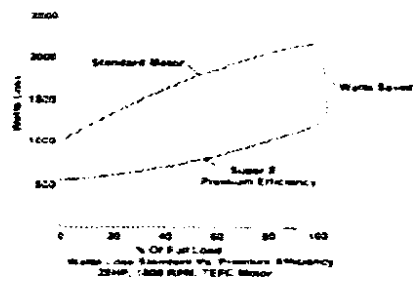


Figure 1

Motors 34

More Efficient

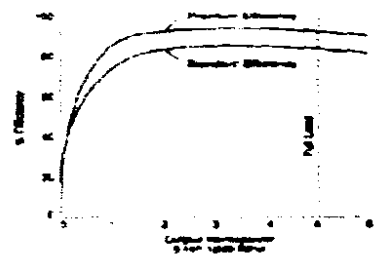


Figure 3

Motors 33

Energy Saving

% of Savings =

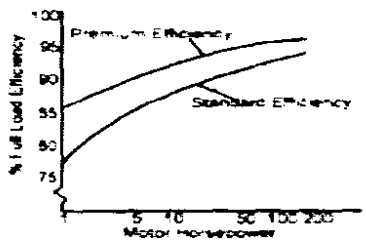
$$= 1 - \frac{\text{Existing Motor Efficiency}}{\text{Proposed Motor Efficiency}}$$

Example :

% of Savings = 1 - (0.88 / 0.93)
= 5.4 %

Motors 36

Efficiency (vs) Horsepower



Efficiency Vs. Motor HP
General Trend

Figure 2

Motors 35

Example ..

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

= 25 / (1 732 x 400 x 45 x 0 85)
= 25 / 26 5
= 0 94

Motor Eff = Pout / Pin
= 0 94 x 22 5 / 25
= 0 846 = 84 6%

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, Vr = 400, Ir = 45A, P Fr = 0 85)

Energy Saving

% of Savings =

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

= 1 - (0 846 / 0 92)

= 8 0 % of Existing Input Power

Example ..

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

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

Example ..

Savings in electrical power = 8 0 % * 25
= 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

Introduction

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

Motors - VSD

ENERGY MANAGEMENT SERVICES

Energy Ma[illegible]gement in Motor[illegible]

= Variable Speed [illegible]

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

Motors - VSD

Examples

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

Motors - VSD

Requirements for VSD Control

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

Motors - VSD

Typical Applications

Variable Torque

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

Constant Torque

- Conveyors, Agitators, Crushers
- $P = k \times n$

Motors - VSD

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

Motors - VSD

Example Cases

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

Motors - VSD

Calculations

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

Motors - VSD

VFD Control

- VFD can control motor speed and load in three ways
  - Manual from the VFD Control Panel
  - Remote from external control signal (temp, level,)
  - Time Schedule

Motors - VSD

Time Schedule Control

Time	Hours	Speed %	Speed kW	Net kW	kWh
7:00 - 14:30	7.5	80%	3.222	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	60%	8.773	2.42	2.4
20:00 - 23:00	3	80%	5.461	5.73	17.2
23:00 - 12:00	1	60%	8.773	2.42	2.4
12:00 - 4:00	4	70%	7.152	3.84	15.4
4:00 - 7:00	3	60%	8.773	2.42	7.3
Total	24				128.2
Existing kWh/Day	268.8				
Average % of Savings	52.0%				

Motors

Example : Heating Ventilation Fan

1. Computation Parameters

- Motor Measured Load = 11.19 kW
- Existing Operating Time = 24 Hrs/Day
- Operating Days/Month = 30 Days
- Operating Months/Year = 12
- Estimated Percentage Of Savings = 53 %

Motors - VSD

Example ..

Existing Energy Cost
= Electrical Consumption * Electrical Tariff
= 98035 kWh * 0.063 JD/kWh
= 6176 JD/Year
Saving In Electrical Consumption
= Estimated Saving % * Existing Electrical Consumption
= 53% * 98035 kWh
= 51959 kWh

Example ...

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

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

Example ..

3. **Annual Monetary Savings**
Savings In Energy Cost
= Savings In Electrical Consumption * Electrical Tariff
= 51959 kWh* 0.063 JD/kWh
= 3273 JD/Year
Investment = JD 2500
P/B Period = 9 Months

ENERGY
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SERVICES

Energy Management in Motors

Exercise

ENERGY
MANAGEMENT
SERVICES

Energy Management in Motors

Question

ENERGY
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Energy Management in Motors

Background

ENERGY
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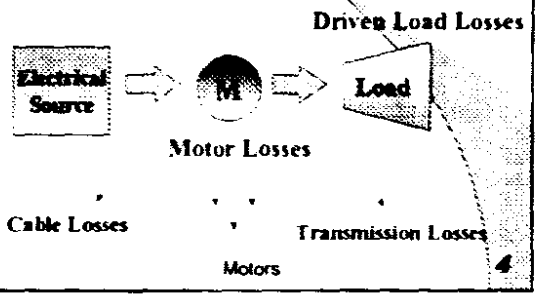
Electric M

Motor Performance

Typical Motor Setup

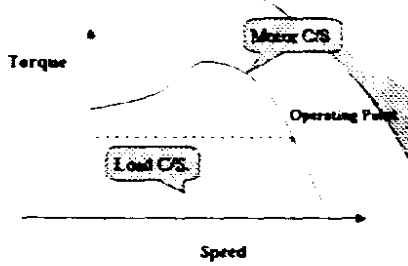


Types of Motors

- Squirrel Cage Induction Motors
  - 90 % of Existing Motors
- Synchronous Motors
- Slip-Ring Motors
- DC Motors

} 10 %

Torque Speed C/S's.



Motor Performance ..

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

Motor Losses

- Magnetic (Core) Losses
  - Hysteresis Losses

Energy Required to Magnetize Core Material

  - 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

Motor Performance ..

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 ..

- Friction (Mechanical Losses)
  - Windage Losses
  - Bearing Losses
  - Brush Friction Losses

Function with the Motor Speed

  - Fixed Losses 5 - 10 % of Total Losses

Motor Losses ..

- Copper Losses (I^2R Losses)
  - I^2R Losses in Rotor & Stator
  - Proportional to the Load Current
  - Stator Losses 40 - 45 % of Total Losses
  - Rotor Losses 20 - 25 % of Total Losses

Example :

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

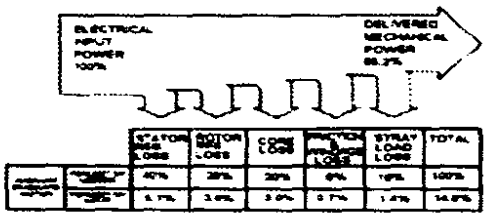
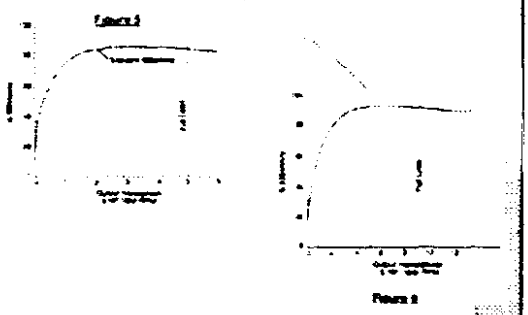


FIGURE 4

Motor Losses ..

- Stray Losses
  - Result of Leakage Flux Induced by the Load Currents
  - Difficult to be Measured or Calculated
  - Generally Proportional to (I rotor)^2
  - 10 - 15 % of Total Motor Losses

Motor C/S's.



Motor Characteristics

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

- Motor Efficiency (vs) % Loading
- Power Factor (vs) % Loading

Determine Motor Efficiency

Input Power Method

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

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

Frequently, Manufacturer Data are Not Available

- Use General Curves Available or Make Approximations

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

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

Determine Motor Efficiency

Speed Measurement Method

- Using a Tachometer Measure Motor Speed (RPM)
- Using Speed vs Motor Load % Curve Determine the Loading of the Motor
- Using Efficiency vs Motor Loading % Determine Motor Efficiency

Factors Affecting Motor Performance

- Maintenance
- Rewinding
- Power Supply Quality
  - Voltage Variations --6 %
  - Frequency Variations --3 %
- Age

Motors 20

Determine Motor Efficiency

P out = % Loading * P rated

Eff = P out / P in

Motors 19

Motors - Check List

- 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

Motors - VSD 22

ENERGY MANAGEMENT SERVICES

Energy Management in Motors

Energy Saving

Turn OFF When Not Needed

- Sometimes Motors are Left Operational Without Need For That
- Examples :
  - Air Compressors
  - Exhaust Fans
  - Air Handling Units
  - Ventilation Units

Motors 24

Main ECO's

- Automatic Control Of Motor Operation
- Matching Motor to Load Or Replacing Oversized Motors
- Install High Efficiency Motors
- Control Motor Speed (VFD)

Motors 23

Calculations

- Calculate Existing Motor Consumption

Annual Savings in kWh = Motor kW x (H1-H2)

Where

- H1 : Existing Motor Operating Hours
- H2 : New Proposed Motor Operating Hours
- Motor kW from measurements or 70% of Rated kW

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

Motors 28

Turn OFF When Not Needed

Turning Off Those Motors Will Save a lot of Energy, While No or Low Investment is Required

- Programmable Timers
- Temperature Controllers
- Level Switches
- Pressure Controllers

Motors 25

Identifying the Measure

- Electrical Measurements
  - Power (kW)
  - Power Factor
- Speed Measurements (RPM)

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

Motors 26

Matching Motor to Load

Motors are Usually Oversized

- Safety Factors
- Over Estimated Loads
- Wrong Calculations
- Voltage Drop
- Selecting Non Suitable Type of Motor
  - Ex : High Starting Torque

Motors 27

Calculations

- Existing Motor Load & Consumption
- Proposed Motor Load & Consumption
- Savings = Difference

Motors 30

Identifying the Measure ..

If Motor Loading Ratio < 50 %

- Efficiency Will be very Low
- Calculate for Replacing it

Motors 29

High Efficiency Motors

- ✓ 3 -5 % More Efficient
- ✓ Better Efficiency C S's
- ✓ Similar or Higher P F
- ✓ Lower Temp & Noise
- ✓ Less Affected by Supply Fluctuations

Motors

ENERGY
MANAGEMENT
SERVICES

Energy Management in Motors

High Efficiency Mo

Motor Losses

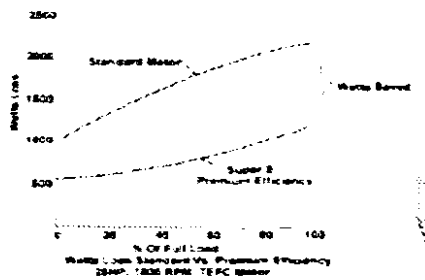


Figure 1

Motors

More Efficient

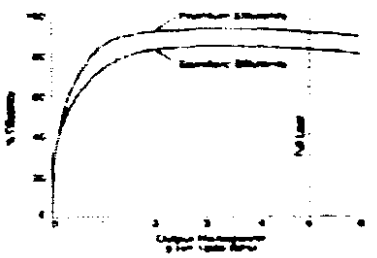


Figure 2

Motors

Energy Saving

% of Savings =

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

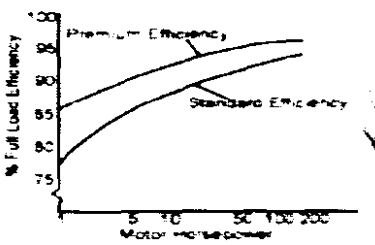
Example :

% of Savings = 1 - (0.88 / 0.93)

= 5.4 %

Motors

Efficiency (vs) Horsepower



Efficiency Vs. Motor HP
General Trend

Figure 2

Motors

Example ..

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

= 25 / (1 732 x 400 x 45 x 0 85)
= 25 / 26 5
= 0 94

Motor Eff = Pout / Pin
= 0 94 x 22 5 / 25
= 0 846 = 84 6%

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.Vr = 400. Ir = 45A. P Fr = 0 85)

Energy Saving

% of Savings =

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

= 1 - (0.846 / 0 92)

= 8 0 % of Existing Input Power

Example ..

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

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

Example ..

Savings in electrical power = 8 0% * 25
= 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

Introduction

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

Motors - VSD

ENERGY MANAGEMENT SERVICES

Energy Management in Motor

= Variable Speed

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

Motors - VSD

Examples

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

Motors - VSD

Requirements for VSD Control

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

Motors - VSD

Typical Applications

Variable Torque :

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

Constant Torque :

- Conveyors, Agitators, Crushers
- $P = k \times n$

Motors - VSD

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

Example Cases

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

Calculations

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

VFD Control

- VFD can control motor speed and load in three ways
  - Manual from the VFD Control Panel
  - Remote from external control signal temp, level
  - Time Schedule

Time Schedule Control

Time	Hours	Speed %	Speed kW	Net kW	kWh
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]				[illegible]
Existing kWh/Day	[illegible]				
Average % of Savings	[illegible]				

Example : Heating Ventilation Fan

1. **Computation Parameters**

- Motor Measured Load = 11.19 kW
- Existing Operating Time = [illegible] Hrs/Day
- Operating Days Month = 30 [illegible]
- Operating Months Year = 12
- Estimated Percentage Of Savings = 53 %

Example ..

Existing Energy Cost
= Electrical Consumption * Electrical Tariff
= 98035 kWh * 0.063 JD/kWh
= 6176 JD/Year
Saving In Electrical Consumption
= Estimated Saving % * Existing Electrical Consumption
= 53% * 98035 kWh
= 51959 kWh

Example ...

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

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

Example ..

3. **Annual Monetary Savings**
Savings In Energy Cost
= Savings In Electrical Consumption * Electrical Tariff
= 51959 kWh* 0.063 JD/kWh
= 3273 JD/Year
Investment = JD 2500
P/B Period = 9 Months

ENERGY
MANAGEMENT
SERVICES

Energy Management in Motors

Exercise

ENERGY
MANAGEMENT
SERVICES

Energy Management in Motors

Questions

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*

ENERGY MANAGEMENT SERVICES

HVAC

Air Conditioning

A / C EQUIPMENT'S

2) Split Units

- *There is no chilled water system since the system operates with direct expansion*
- *Manufacturer claim first cost savings of 20% and power savings up to 25% due to the elimination of the chiller and water pump*

A / C EQUIPMENT'S

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*

A / C EQUIPMENT'S

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 weather proof enclosure.*

A / C EQUIPMENT'S

- *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/h/watt-hr*
- *Newer and more efficient units will have an EER of 10, or above*

A / C EQUIPMENT'S

- *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*

A / C EQUIPMENT'S

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*

COEFFIICIENT OF PERFORMANCE

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

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

A / C EQUIPMENT'S

4) 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 circuit tanks with Lithium Bromide*

COEFFIICIENT OF PERFORMANCE

Air cooled chillers, generally have a lower C.O.P. than water cooled units.

COEFFIICIENT OF PERFORMANCE

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

  Absorption Chiller - 0.50

  Electric Drive Compression - (2.40 - 5)
- *C.O.P will vary significantly based upon a number of factors :*

  The type of refrigerant

  Motor efficiencies

  Pump efficiencies

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.*

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

- *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 [illegible]16 F degree approach.*

COOLING TOWERS

- *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).*

METHODS TO REDUCE ELECTRICITY COSTS FOR *HVAC*

- *Savings can be divided into two general areas*

1. *Reducing the cost of generating heating and cooling.*
2. *Reducing the amount of heating and cooling required.*

DISTRIBUTION SYSTEMS

Single Zone Systems
Terminal Reheat Systems
Multi Zone Systems.
Dual Duct Systems
Variable Air Volume Systems
Fan Coil System
Two, Three or Four Pipe Systems

REDUCING COSTS OF GENERATING COOLING

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*

REDUCING COSTS OF GENERATING COOLING

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

1) Operate the temp. of the conditioned space as high as possible

2) Lower the temp in the heat rejection process to minimum

REDUCING COSTS OF GENERATING COOLING

%AGE SAVINGS FROM INCREASING CHILLED WATER TEMPERATURE

Chilled Water Temperature Increase °F

	1	2	3	4	5	6	8	10
Medium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Absorption	8%	16%	24%	32%	4%	49%	65%	81%
Centrifugal	1.4%	3.2%	4.8%	6.4%	8%	9.6%	12.8%	16%

REDUCING COSTS OF GENERATING COOLING

- *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 design Max. 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*

REDUCING COSTS OF GENERATING COOLING

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

  = 5062.5 kWh

  *= 5062.5*0.063*

  = 318.94 JD/yr

REDUCING COSTS OF GENERATING COOLING

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?*

REDUCING COSTS OF GENERATING COOLING

Percent Savings from Reducing Condenser Temperature

	Condenser Temp Reduction °F							
	1°F	2°F	3°F	4°F	5°F	6°F	8°F	10°F
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%	6.6%	8.8%	11.0%

REDUCING COSTS OF GENERATING COOLING

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*

REDUCING COSTS OF GENERATING COOLING

- *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*

REDUCING COSTS OF GENERATING COOLING

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*

REDUCING COSTS OF GENERATING COOLING

POTENTIAL 5

Heat Recovery System

- *Exhaust air temp. from any air-conditioned space always less than the ambient fresh air temp.*
- *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*

REDUCING COSTS OF GENERATING COOLING

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*

REDUCING COSTS OF GENERATING COOLING

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*

REDUCING COSTS OF GENERATING COOLING

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*

REDUCING A/C LOADS

- *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*

REDUCING A/C LOADS

There are many opportunities for reducing the load required for cooling.

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 (figure [illegible])*

REDUCING A/C LOADS

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.*
- *e.g., 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.*

REDUCING A/C LOADS

Recommended Inside Design Conditions
Summer

	Dallas		Continental	
	D.B °F	RH %	D.B °F	RH %
Apt., hotel, office, school, hos	76-78	45-60	77-79	45-60
Shops, barber, supermarket	76-78	45-60	76-80	45-60
Auditorium, restaurant	76-78	50-55	76-80	50-60
Factory assembly area	77-80	45-60	80-85	50-60

REDUCING A/C LOADS

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

REDUCING A/C LOADS

- *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 R.H (latent heat load) between the two streams

(2) Enthalpy Control

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

REDUCING A/C LOADS

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

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

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

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

REDUCING A/C LOADS

Effect of %Outside Air on Cooling Coil Load

% Outside Air	Room Sensible Load (Tons)	Room Latent Load (Tons)	Room Total Load (Tons)	Cooling Coil Load (Tons)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REDUCING A/C LOADS

POTENTIAL NO. 3

Use Temperature Reset

- *In many reheat systems the chilled water coil is operated at a fixed leaving temp.*
- *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.*

REDUCING A/C LOADS

Reduced Load = 35.6-31.1
= 5.5 TR
= (5.5 TR*12000 BTU/TR)/3412 BTU/kWh
= 19.34 kWh

C.O.P = 3

Power Consumed = 19.34/3
= 6.45 kWh

Power Cost = 6.45*0.063 JD/kWh
= 0.406 JD/hr
= 0.406*10*25*5
= 507.5 JD/yr

REDUCING A/C LOADS

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

REDUCING A/C LOADS

- *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*

REDUCING A/C LOADS

- *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.*

REDUCING A/C LOADS

Example Showing savings due to Reset

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REDUCING A/C LOADS

Other Potentials

- *Insulation (pipes, ducts etc)*
- *Reducing infiltration (doors, windows)*
- *Reducing Solar heat gain through windows (solar films, curtains etc)*
- *Installing air curtains on main entrance doors and on cold stores.*
- *Efficient lighting system will reduced cooling load.*
- *Controlling exhaust fans operation during night period*

REDUCING A/C LOADS

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/kWh/hr * 3))*

= 1.225 JD/hr

Total Saving = 0.406+1.225

= 1.631 JD/hr

REDUCING A/C LOADS

- *Using oil additives*
- *Cleaning condensers*
- *Checking control system accuracy (timers, thermostats, etc.)*

Petroleum Products Tariff & Specifications.

el Type	Sp.Weight Kg/liter	Lower C.V Kcal/Kg	Tariff JD
rosene	0.79	10350	0.110 /Ltr.
el Oil #2	0.835	10200	0.110 /Ltr.
y Oil #6	0.968	9680	72.5 /Ton
PG	-	10960	0.192 /Kg

ENERGY MANAGEMENT SERVICES

Combustion

1- CALIBRATION

- Fuel consumption is affected directly by combustion efficiency
- Combustion efficiency depends on
  - Exhaust gas temperature
  - O2 % in flue gases
  - CO2 % in flue gases
  - CO % in flue gases

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_xH_y + Air (O2 + N2 + Other Gases) → CO2+CO+O2+SO2+SO3+NOx+Heat

1.1 FLUE GAS ANALYSIS

- Percent of CO and CO_2 are indicators of the completeness of combustion
- Good mixing = perfect combustion when flue gas analysis shows min 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

1.1 FLUE GAS ANALYSIS

- The product of any combustion process are 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 O2 & CO2 are indicators of the amount of excess combustion air

1.1 FLUE GAS ANALYSIS

Effect of Excess Air on CO2 in Combustion Products

% Excess Air	0	10	20	40	60	80	100	150	200
Natural Gas	12	10.7	9.8	8.3	7.2	6.5	5.7	4.8	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	13.3	12.6	10.7	9.3	8.3	7.4	5.9	4.9
Residual Oil	15.4	14.1	12.9	11	9.6	8.5	7.6	6.1	5
Bituminous Coal	15.4	14.7	13.3	11	11.6	10.1	9	7.2	6
Anthracite Coal	19.8	18	16.5	14.1	12.4	11	10	7.9	6.9

1.1 FLUE GAS ANALYSIS

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

1.2 STACK TEMPERATURE

- High stack temperature (400 °C or above) indicate one of the following conditions

Excessive draft (Poor draft regulation)

Dirty heating surfaces

Poor design of heat exchange surfaces

Undersized furnace

Over-firing

1.2 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
- $SO_2 + \frac{1}{2} O_2 = SO_3$
- $SO_3 + H_2O$ vapor $= H_2SO_4$

1.3 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.

1.2 STACK TEMPERATURE

- 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

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 fire box.

1.3 SMOKE MEASUREMENTS

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

1.5 STACK LOSSES

- Main source of heat losses is through stack.
- Additional heat lost by radiation from furnace walls and by blow-down
- Stack losses 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%

1.4 DRAFT MEASUREMENTS

- 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

1.5 STACK LOSSES

- 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.

1.5 STACK LOSSES

- 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

1.5 STACK LOSSES

- 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

1.5 STACK LOSSES

- 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

1.6 REDUCING EXCESS AIR

- Only enough air should be supplied to completely combust the fuel,since more than this amount increases the heat rejected to the stack resulting in greater fuel consumption
- 10-20% excess air (2-4% O_2) is acceptable

1.6 REDUCING EXCESS AIR

- Excess air air introduced above the stoichometric or theoretical requirements to effect complete and efficient combustion of the fuel
- There is an optimum level of excess-air operation for each type of furnace design and fuel type

1.7 CLEANLINESS

- Blocking passages in the convection section will affect the DRAFT by reducing the incoming combustion air causing incomplete combustion (low steam generation and smoky exhaust)
- Fire-side deposits and SOOT should be cleaned manually.

1.7 CLEANLINESS

- Another factor important to boiler efficiency is the cleanliness of the heat-transfer surfaces
- Heat transfer surfaces both on fire side and water side should be clean
- Ash ,soot ,scale and mineral deposits are poor conductors (Insulators) They reduce heat transfer from hot gases to steam,water, or air,increasing looses from stack

1.7 CLEANLINESS

Scale and Soot effect on fuel consumption

Scale (mm)	0.5	1	2	3
Fuel Loss (%)	1.1	2.2	4	6.3
Soot (mm)	0.5	1	2	3
Fuel Loss (%)	1.2	2.4	4.5	8.4

1.7 CLEANLINESS

- Water-side deposits are controlled by a good water treatment program
- Build up SCALE removed by chemicals only

1.8 HEAT LOSSES DUE TO BURNER CYCLING

- The burner should not start more than 2–3 times per hour
- For gas burners a loss of 2–3% may occur when the burner starts 10 times or more / Hr
- For oil burners the losses due to cycling are even higher

1.8 HEAT LOSSES DUE TO BURNER CYCLING

Energy losses occur when the boiler operate at a low load in an intermittent way

1) When the burner stopped the airflow must continue for a short time

2) Upon ignition the combustion is incomplete which result in a high smoke formation

3) Before ignition the burner must purge (the fan pumps air inside boiler to remove gases and combustion residuals) this will reduce the temp of the inside surfaces

1.9 TOTAL HEAT LOSSES

	% OF LOSS	
TYPE OF HEAT LOSS	MIN	MAX
SURFACE LOSS	1%	3%
IN FLUE GASES	7%	30%
FOR OIL ATOMIZATION	0%	3%
BY BLOW DOWN	2%	5%
HEATING (HFO) TANK	0%	2%
BOILER CYCLYING	0%	3%
WHEN BOILER STOPPED	0%	2%
BY NON BURN FUEL	0%	2%
BY SOOT AND SCALE	2%	15%
TOTAL LOSSES	10%	65%

1.8 HEAT LOSSES DUE TO BURNER CYCLING

- There are two ways to reduce energy losses due to cycling of the boiler

1- Replace (ON - OFF) , (HIGH- LOW - OFF) burners with modulating burners

2- Reduce nozzle flow during periods of low steam demand

1.11 EXAMPLE CASE

- Measured efficiency 79.3 %
- Measured stack temp 475 °F
- Measured room temp 75 °F
- Measured O2 % 11%
- Diesel Cons 350000 ltr / yr
- Diesel Cost 0.110 JD / ltr

1.10 COMBUSTION EFFICIENCY TABLES

EXHAUST GAS HEAT LOSSES %

EXCESS AIR %	CO %	CO2 %	300	350	400	450
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1.11 EXAMPLE CASE

- Annual savings = 33162 ltr/yr
- Annual monetary savings
  = 33162 * 0.110 JD / ltr
  = 3648 JD / yr
- Investment
  Labor 150 JD
  Calibration 75 JD / visit

1.11 EXAMPLE CASE

- It is suggested to reduce O_2% from 11% to 3 % (15.5% excess air) and to reduce net stack temp to 300 °F
- From the combustion tables, the expected combustion efficiency will be 87.6%
- Annual savings = annual consumption * (1 - Old Eff / New Eff)
- Annual savings = 350000*(1-0.793/0.876)

Combustion

END

1.11 EXAMPLE CASE

- Total Investment= 150 + 12*75
  = 1050 JD
- Pay Back = (Investment / Savings)
  = 1050/3648
  = 0.3 year
  = 3.5 months

3.14 Combustion Air & Waste Gas Volumes (Theoretically)

	m^3n/kg	m^3n/kg
KEROSENE	11.4	12.17
Diesel Oil # 2	11.2	11.98
HEAVY OIL # 6	10.3	10.96
GASOLINE	11.6	12.45

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

ENERGY MANAGEMENT SERVICES

HVAC

Heating Systems

Heating Systems

- 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

Heating Systems

Heating System Types

- Hot water heating systems

  Operated by oil, gas or electricity

  Temperature of the water normally below (100 °C)

  Operating pressure normally atmospheric pressure

Heating Systems

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.

Heating 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

Heating Systems
Energy Saving Measures

1) Boiler Plant

Improve Operating Efficiency

a- Regular maintenance

b- Improve thermal insulation of boilers, pipes and fittings "valves"

c- Isolate inoperative boilers

d- Replace old inefficient boilers

Heating Systems

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 temp a supplementary resistance heater is needed

Heating Systems
Energy Saving Measures

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.

Heating Systems
Energy Saving Measures

2) Space heating systems

Avoid Overheating

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

Heating Systems
Example 1

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

Heating Systems
Energy Saving Measures

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.

Heating Systems
Example 1

Savings = {(Current D Hrs-Proposed D Hrs) / Current D Hrs}*Current Fuel cost

$$\text{Savings} = \frac{18000-13500}{18000} * 1000$$

Heating Systems
Example 1

- **Calculate fuel savings when inside temp. is reduced to 20 °C and the operating hours decreased to 9 hrs/day ??**

Current degree hours = 10*25*4*(23-5)
= 18000 D Hrs

Proposed degree hours = 9*25*4*(20-5)
= 13500 D Hrs

Heating Systems
Example 1

$$\text{Pay-back} = \frac{\textit{Investment}}{\textit{Savings}}$$

Heating Systems
Example 1

Savings = 250 JD/yr
= 25%

Investment required

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

Heating Systems
Example 2

Water and Energy savings by using :

Water Saving Devices

	Shower	Basin	Toilet
Daily Usage / person	5 min	3 min	3 times
Water quantity / day / person	58 liter	15 liter	27 liter
Water quantity / year / person	18.25 m^3	5.48 m^3	9.86 m^3

Heating Systems
Example 1

Pay-back = 185/250
= 0.74 year

Suppliers

SAM Engineering

MOHA Est

Heating Systems
Example 2

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

Heating Systems
Example 2

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

= 11.75 *1 JD/m^3

= 11.75 JD/yr

Heating Systems
Example 2

Heat QTY = 107200 Kcal/yr/person

Diesel QTY = 107200 / (10200*0.835*0.8)

= 15.73 liter/yr/person

Diesel cost = 15.73 * 0.11 JD/liter

= 1.75 JD/yr/person

Total saving = 11.75 + 1.75

= 13.5 JD/year/person

Heating Systems
Example 2

- Hot water QTY = 18.25*75%+5.48*30%

  = 15.3 m^3/yr/person
- Hot water saving = 35%

  = 5.36 m^3/yr/person
- Heat required to heat this water quantity from 25°C to 45°C = m Cp (T_2-T_1)

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

Heating Systems
Example 2

Pay-back = 15 / 13.5

= 1.11 years

Suppliers

Al Rawnak hardware stores

Heating Systems
Example 2

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

Basic Principles

- Steam is simply water in vapor state.
- Heat is add 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.

ENERGY MANAGEMENT SERVICES

Steam System

Steam Tables

- Provide the characteristics of steam under different conditions.
- Temperature
- Pressure
- Enthalpy of water (sensible heat)
- Enthalpy of evaporation (latent heat).
- Enthalpy of steam (total heat).
- Specific volume of steam.

Basic Principles

- 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

- 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 Tables

- 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

Steam System Main Components

Steam system Consists of

- Steam Generator (Boiler)
- Steam network (pipes , valves , steam traps)
- Condensate return (tanks , pumps)
- Steam consuming equipment's (steam users)

Steam Tables

Steam System 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) Steam Boiler 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.

1) Steam Boiler a- Combustion Efficiency

It has been discussed in the previous session

1) Steam Boiler
b- Blow Down

Percentage B.D = 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.

1) Steam Boiler
b- Blow Down

- 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

1) Steam Boiler
c- Reduce Boiler Pressure

- 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

1) Steam Boiler
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

1) Steam Boiler
c- Reduce Boiler Pressure

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

1) Steam Boiler
c- Reduce Boiler Pressure

- 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

1) Steam Boiler
c- Reduce Boiler Pressure

- Energy Saving = Heat required at 9 bar - Heat required at 8 bar
- Heat required at 9 bar = $(Q_2 * m) / f$

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

= 1659102 kcal/hr

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

1) Steam Boiler
c- Reduce Boiler Pressure

- 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 P_3 8 bar
- Total steam enthalpy (8 bar) Q_2 2774 KJ/kg

1) Steam Boiler
c- Reduce Boiler Pressure

- 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* 11

= 280 JD/yr

Investment required = 0

1) Steam Boiler
c- Reduce Boiler Pressure

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

= 1656713 kcal/hr

- Energy Saving = 1659102 - 1656713

= 2389 kcal/hr

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

$$= \frac{2389}{10200 * 0.835 * 0.793}$$

2) Steam Network "Distribution"
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

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

2) Steam Network "Distribution 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

2) Steam Network "Distribution 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

2) Steam Network "Distribution c- 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	58	850	90
6"	170	24	600	78	1200	120

) Steam Network "Distribution c- Insulation

- 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

2) Steam Network "Distribution c- Insulation

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

2) Steam Network "Distribution c- Insulation

Example

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

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:

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

2) Steam Network "Distribution c- Insulation

Insulation material 150 JD

Labor Cost 50 JD

Total Investment 200 JD

Pay-back = (Investment / Savings)

= 200 / 754.7

= 0.11 year

Suppliers

Rock-Wool Industrial Co

3) Steam Utilization a- Reducing Steam Leaks

Orifice	Steam Pressure (Kpa)				
Da (mm)	105	170	345	520	690
0.80	0.38	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

3) Steam Utilization a- 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

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.

3) Steam Utilization a- Reducing Steam Leaks

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

The energy loss will be 120 JD/Yr

4) Condensate
Steam Traps

- There are three basic types of steam traps
  1- Thermostatic (Temp Difference)
  2-Thermodynamic (Change of the state)
  3- Mechanical (Density Difference)

4) Condensate
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

4) Condensate
a- Condensate Recovery

- **Example Case:**

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

4) Condensate

- 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
- The fuel savings resulting from increasing condensate return may be estimated as follows

4) Condensate
a- Condensate Recovery

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

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

4) Condensate
a- Condensate Recovery

Heat losses $= M * H * S * (T_1 - T_2)$

$= 250 * 1 * (95 - 25) * 7200$

$= 126{,}000{,}000$ kcal / yr

Fuel Cost =

4) Condensate
a- Condensate Recovery

- 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

4) Condensate
a- Condensate Recovery

- Fuel Cost (saving) = 2052 JD/Yr
- Water Treatment Cost Savings

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

4) Condensate
a- Condensate Recovery

Suppliers
SAM (Spirax Sarco)
EDT (TLV)

4) Condensate
a- Condensate Recovery

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

Steam cost

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 Cost

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

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

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%

Steam Cost

- 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	15%	20%
Shell losses	2%	3%
B D Losses	2%	3%
Net Boiler Efficiency	81%	74%

2) Distribution

Insulation	4%	6%
Net Distribution Eff	96%	94%

Overall System Efficiency

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%

Overall System Efficiency

Fuel Savings = {1 - (old Eff / new eff)}*100%
= {1 - (0 575 / 0 716)*100%
= 19 7 %

Overall System Efficiency

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 %

Energy Conservation Measures

- 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

Energy Conservation Measures

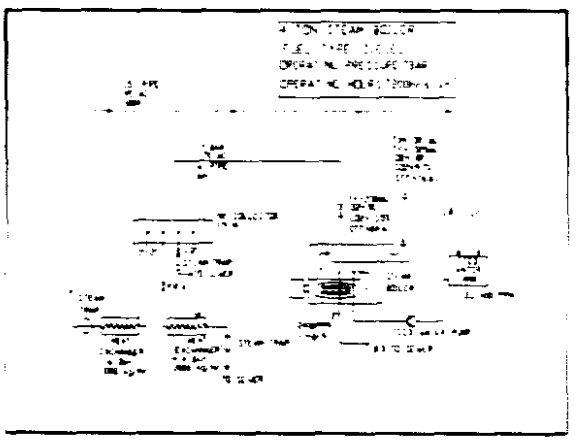
- Boiler Calibration
- Boiler cleaning
- Improve Boiler Shell Insulation
- Control and Reduce Boiler B D According to Manufacturer Recommendations
- Heat Recovery from B D, Chimney and any waste heat source
- Reduce Boiler Pressure where possible

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 temp
  1.25% Fuel saving
- Per 2% of blow down rate reduction
  0.32 % Fuel saving (F.W.T. 70 °C)

Energy Conservation Measures

- Prevent burner recycling
- Recover the flash steam
- Check and Maintain all steam traps periodically
- Use cheap energy sources



Steam System

END

4) Condensate
b- Flash Steam

- This steam in turn condenses in the atmosphere to form clouds of steam wherever hot condensate is discharged
- The designer should take account of this problem and ensure that flash steam is collected for re-use
- Flash steam is as useful as steam from the boiler

4) Condensate
b- Flash Steam

- The previous section considered the collection of condensate and its return to the boiler feed tank
- However, it did not take into account the important problem of flash steam
- The problem arises from the relatively high temperature of condensate
- Steam at 7 bar , will condense to water at 170.5 °C
- The excess temp provides the heat which re-evaporates part of the condensate to form flash steam

4) Condensate
b- Flash Steam

- Example Case
- The condensate at steam trap under a pressure of 7 bar gauge will have an enthalpy of saturated water of 721.4 kJ/Kg
- At 0 bar gauge (100 °C) the maximum enthalpy of saturated water is 419.04 kJ/Kg.
- The difference is 302.36 kJ/Kg.
- This difference is the surplus enthalpy which is converted to enthalpy of evaporation in evaporating some of the condensate

4) Condensate
b- Flash Steam

- Using it will reduce steam demand
- It will prevent the loss of treated water and eliminate the clouds of white vapor which are often synonymous with steam waste

4) Condensate
b- Flash Steam

- The amount of flash steam formed at atmospheric pressure each hour is

  1000 * 0.134 = 134 Kg
- It must be realized that if the steam trap does not discharge condensate as soon as it forms, some of the sensible heat in the condensate will be given up before it passes to the lower pressure and so the amount of flash steam will be reduced.

4) Condensate
b- Flash Steam

- At atmospheric pressure, steam has an enthalpy of evaporation of 2257.0 kJ/Kg
- With 302.36 kJ/Kg available, the amount of flash steam formed at atmospheric pressure from each kilogram of condensate is

  = (302.36 kJ/Kg - 2257 kJ/Kg) * 1 Kg

  = 0.134 Kg
- If the plant is using 1000 Kg/h of steam for indirect heating (thru heat exchangers)

GLOBAL SUCCESS STORIES

Carrier Corp.-USA:

Total Saving Percentage 36%
Total Monetary Savings USD 293,000
Investment Payback slightly more than one year

SUCCESS STORIES

REGIONAL SUCCESS STORIES

Duxal Aluminum Factory - Lebanon:

Total Saving Percentage 25.5%
Total Monetary Savings USD 135000
Investment Payback Less than one ye

GLOBAL SUCCESS STORIES

Wheeling University - USA:

Total Monetary Savings USD 108,000
Investment Payback 5 years

REGIONAL SUCCESS STORIES

A.K Ceramics - UAE:

Total Saving Percentage 10%
Total Monetary Savings USD 737,000
Investment Payback 1.5 Years

REGIONAL SUCCESS STORIES

Sheraton Hotel, Abu Dhabi - UAE:

Total Saving Percentage 37.6%
Total Monetary Savings USD 150,000
Investment Payback 2.9 Years

JORDANIAN SUCCESS STORIES

rdan Ceramic Company

ng Percentage Achieved 12%
l Monetary Savings JD 55,000
stment Payback less than one year

JORDANIAN SUCCESS STORIES

-Zay Ready Wear Mfg Co. :

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l Monetary Savings JD 10,900
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JORDANIAN SUCCESS STORIES

he Sanctuary Zara Spa (hotel):

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REGIONAL SUCCESS STORIES

rab Contractors Medical Hospital - Egypt:

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Investment Payback 2 Years

JORDANIAN SUCCESS STORIES

rdan New Cables :

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JORDANIAN SUCCESS STORIES

-Keena Hygienic Paper Mill Co.:

Saving Percentage 6.5%
Total Monetary Savings JD 96,000
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Coffee Break

11:00 - 11:15

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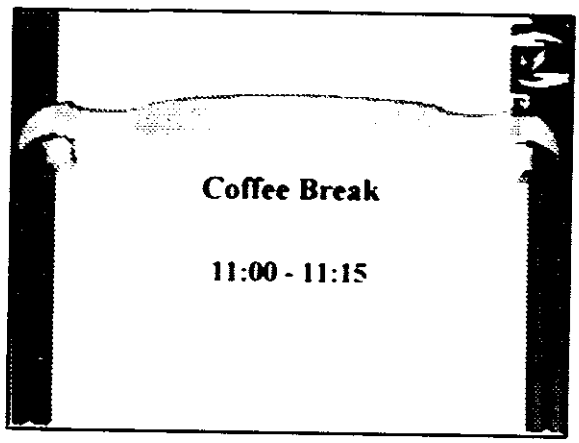
Coffee Break
11:00 - 11:15

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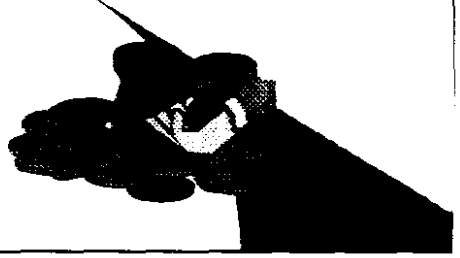
Why Are We Here .....?



WEPIA

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Energy Conservation
and
Management Program workshop

AED

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How much are you paying for energy ?

60% of executives around world take energy bills fo granted..... Do you?

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How much are you paying for energy

?

And Wh ?

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Workshop Agenda

Second Day

9:00-11:30	Heating & air conditioning system Naim Awadallah
11:30-11:45	Coffee break
11:45-13:30	Electrical motors Amjad Alkam
13:30-14:30	Lunch break
14:30-15:30	cont. Electrical motors
15:30-16:30	Energy labeling Nedal Zatari
16:30-17:00	Discussion and test

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Workshop Agenda

First Day

8:30-9:00	Introduction
9:00-11:00	Energy Conservation Pr Eng. Nedal Zatari
11:00-11:15	Coffee Break
11:15-13:30	Lighting System Eng. Amjad Alkam
13:30-14:30	Lunch Break
14:30-17:00	Combustion & Steam System Eng. Naim Awadallah

Energy Conservation Program

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

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Energy Conservation Program

Energy Conservation and Management

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- 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 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

Business Objectives

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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.

Why energy efficiency is a winner (BENEFITS)

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- 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

THE CONCEPT OF ENERGY MANAGEMENT

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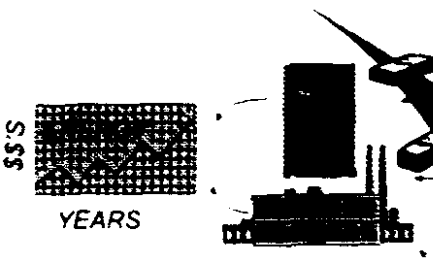

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Energy Conservation & Environment

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BARRIERS

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

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Energy Conservation & Environment

- Saving **100** liter of Diesel will reduce the gases emissions by **273 kg CO2** equivalent
- Saving 100 kWh will reduce the gases emissions by **100 kg CO2** equivalent

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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

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Energy Conservation Program

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

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Energy Conservation Program

Introduction

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- Energy Audit means :

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

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Rapid Energy Audit

Energy Saving Measures

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

The Goal

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- 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 <u>without</u> loss of comfort to the occupants operation

Action Plan

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

AUDIT PROCEDURE

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- Action Plan and Walkthrough
- Measurements and Data Collection
- Monitoring
- Analysis and Calculations
- Investment and Pricing
- Measures Evaluation
- Audit Report
- Presentation

WALK-THROUGH

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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 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

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WALK-THROUGH PROCEDURE

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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

WALK-THROUGH PROCEDURE

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6 Observations and identified opportunities may be in three main areas

- *A Losses in Auxiliaries*
- *B Main Energy Consumers*
- *C Old Facilities*

WALK-THROUGH PROCEDURE

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

WALK-THROUGH PROCEDURE

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B Main Energy Consumers such as

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

Analysis of Energy Bills

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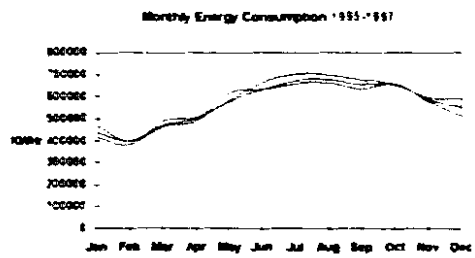

WALK-THROUGH FINDINGS

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

ON-SITE MEASUREMENTS AND DATA COLLECTION

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

Sectorial Distribution of Energy Consumption (kWh)

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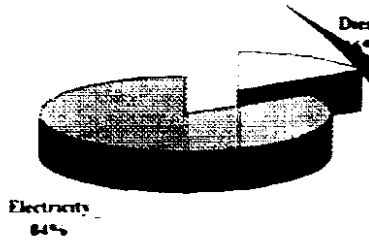

Energy Bill Sectorial Distribution

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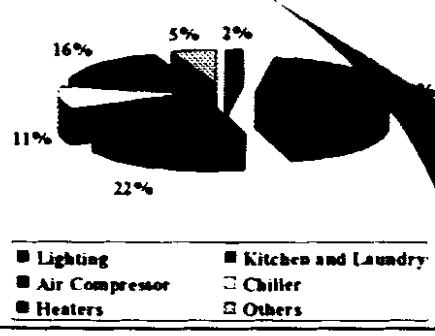

MEASUREMENT AND DATA COLLECTION

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- This include measurements to ensure the savings, and searching for new measures
- This step would require mostly instal ous measurement, and quantifying measu
- Proving the savings to client based on
  - Theoretical method (scientific equations)
  - Actual consumption production

Energy Consumption & Pattern

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Monitoring

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- 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

Measures Evaluation

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

ANALYSIS AND CALCULATIONS

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- 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 implementation of the measure

Investment and Pricing

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- 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, professional installation, labor, commissioning)
- Running costs (Spare Parts, maintenance, labor, utilities)

MEASURES EVALUATION PROCEDURE

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- SAVINGS AND INVESTMENT
- ABILITY TO MEASURE AND AVAILABILITY OF MEASURING INSTRUMENT
- TECHNOLOGY AND KNOW HOW
- SPACE
- IMPLEMENTATION
- FOLLOW - UP

Audit Report

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Pay-Back Period

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- 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

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- Energy Saving Measures :
  - Summary description
  - Measurement & Reference Data
  - Analysis
  - Recommendations
  - Savings sample calculation
- Energy conservation theory

Audit Report

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A typical audit report should include the following sections

- Introduction
- Executive Summary
- Establishment General Description
- Energy consumption analysis and breakdown

SEQUENCE OF THE PRESENTATION

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- Introduction
- Energy Audit Findings & Results
- Energy Conservation Proposals
- Audit Conclusion
- Discussion
- Audit Report Submittal
- Minuets of Meeting

Audit Presentation

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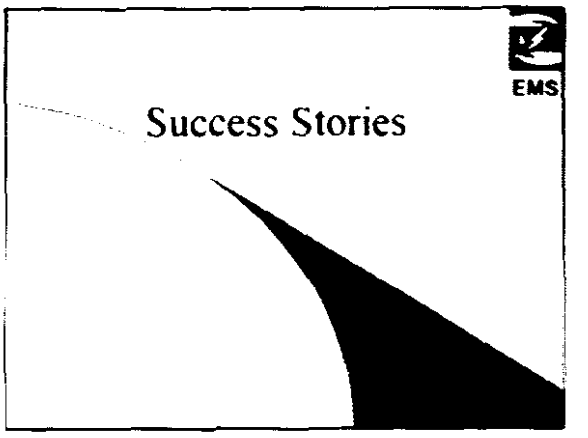
- Once the audit report is completed and ready to be submitted to the client, set a date and place for submitting the audit report and performing the presentation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Success Stories