Energy Audit of Electric and Thermal Utilities

Click to begin

TOPICS

Click on the ***Action Buttons*** *to directly jump to respective sections*

Introduction to Energy Audit

WHAT IS ENERGY AUDIT?

- Energy Auditing serves to identify all energy usage in a facility and quantifies it according to its discrete functions. It basically attempts to balance the total energy input with its use.
- Energy auditing also monitors the performance of various energy consuming equipment in a facility and identifies opportunities for energy conservation.
- Energy auditing helps develop a strategic approach to energy management.
- It is key to development of comprehensive energy management programme for industries.

NEED FOR ENERGY AUDIT

- Energy (both electrical and thermal) is one of the top three operating expenses in any facility, the other two being labor and materials.
- Energy Auditing helps to understand the way, this energy is used in any industry and identifies areas of energy wastage and suggests any scope for improvement that exists.
- Potential cost savings can thus be realized by implementing energy efficiency measures leading to reduction in energy and hence energy cost.
- By reducing the energy utilized per unit of product output, it can help facilities make significant gains.

Types of Energy Audit

PRELIMINARY ENERGY AUDIT/ WALK THROUGH AUDIT

Preliminary energy audit is relatively a quick way to assess energy consumption in any facility and identify energy savings.

- It identifies the most likely and easiest areas for attention
- Uses existing or easily obtained data for analysis
- Identifies savings (especially immediate/low cost savings)
- Identifies area for more detailed study/measurement.

DETAILED ENERGY AUDIT

Detailed energy audit attempt to evaluate all major energy consuming systems in a facility. Some of its salient features are:

- It offers the most comprehensive and accurate estimate of energy savings and cost.
- It takes into account the inventory of all energy using systems and estimates energy consumption based on current operating conditions. The energy consumption is also compared to utility bill charges.
- Involves detailed analyses of process flow diagrams and energy utility diagrams for optimization of energy.
- Operating performance of all energy consuming equipment is evaluated to estimate loss in the system
- Identifies savings (immediate, low/high cost) and provides detailed cost-benefit analysis.

Energy Audit Methodology

METHODOLOGY FOR ENERGY AUDIT

The activities performed during energy audit can be categorized in three phases:

PRE AUDIT PHASE

Key Activities Performed	Purpose
❖ Planning and Organization	❖ To organize energy audit team ❖ Establish time frame for work execution ❖ Organize instruments ❖ Macro data collection based on the type of industry
❖ Walk through Audit ❖ Meeting with facility In charge (Energy Manager/Plant Manager/ Project Head)	❖ Familiarization with activities/ processes in the facility. ❖ To acknowledge the location and condition of various energy consuming equipment to plan for measurement ❖ Preliminary observation and assessment of operating practices ❖ Discussion of work plan with facility officials and finalization of schedule ❖ Apprising facility officials about the audit team and their responsibilities
❖ Brief meeting with divisional heads and persons concerned	❖ Awareness creation (Audit objectives and scope of work) ❖ Building up cooperation ❖ Acknowledge concern of all stake-holders

AUDIT PHASE (1/5)

Key Activities Performed	Purpose
❖ Primary data collection	❖ Primary data is collected to acknowledge: ▪ Inventory of all energy consuming equipment ▪ Design specifications ▪ Historical energy consumption data ▪ Current specific energy consumption of the facility ▪ Operational & log book data of various equipment/operations ▪ Maintenance plans & procedure
❖ Preparing process flow and energy utility diagrams (single line power distribution diagram, compressed air line diagram etc.)	❖ To understand energy usage in every process ❖ To understand flow of energy in complete system
❖ Field measurements: survey and monitoring	❖ To obtain operating data of all energy consuming equipment ❖ Acknowledge load variations trends for pumps, compressors etc. ❖ Power monitoring to estimate load.

AUDIT PHASE (2/5)

Key Activities Performed	Purpose
❖ Analysis of collected data	❖ Equipment performance assessment ❖ Identification of possible measures for : ▪ De – bottlenecking for improving yields ▪ Maintenance practices ▪ Fuel switching ❖ Establish specific energy performance indicators ❖ Review of energy conservation ideas initially suggested by unit personnel ❖ Estimation of reduction of GHGs emissions by implementing identified EE measures
❖ Cost-Benefit analysis of Energy Conservation (ENCON) measures	❖ To assess techno-economic feasibility of suggested ENCON measures and their prioritization for implementation ❖ To select most promising projects ❖ Prioritize by low, medium, long term measures
❖ Reporting and Presentation to Top Management	❖ Apprise facility officials about suggested EE measures ❖ Discuss the action plan for implementation ❖ Provide list of suitable vendors and technology providers

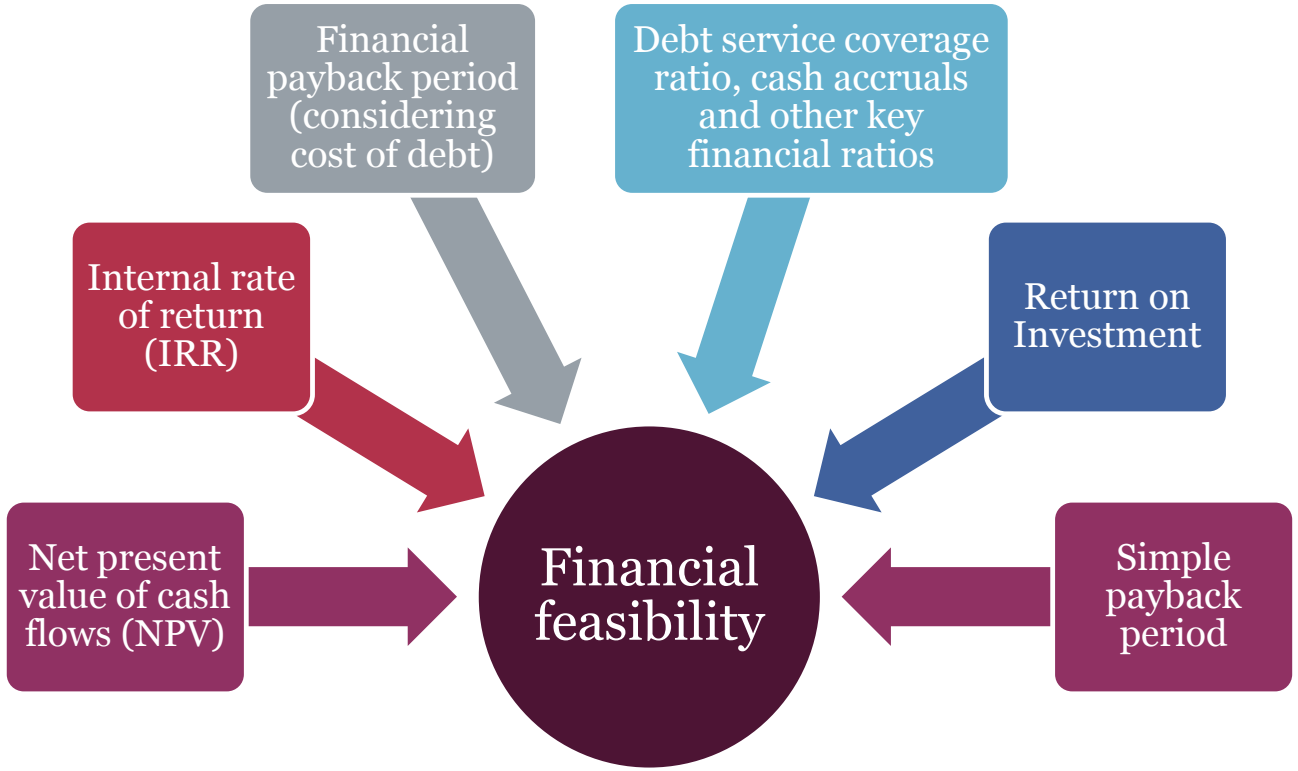
AUDIT PHASE - TECHNO-ECONOMIC ANALYSIS (3/5)

Techno-economic analysis involves development of a robust financial model which shall consider various costs and benefit components, cash flow projections, capital and operating costs, etc. The two cost elements which shall be considered for the preparation of the realistic model are:

- Capital cost / first cost of the equipment
- Installation costs

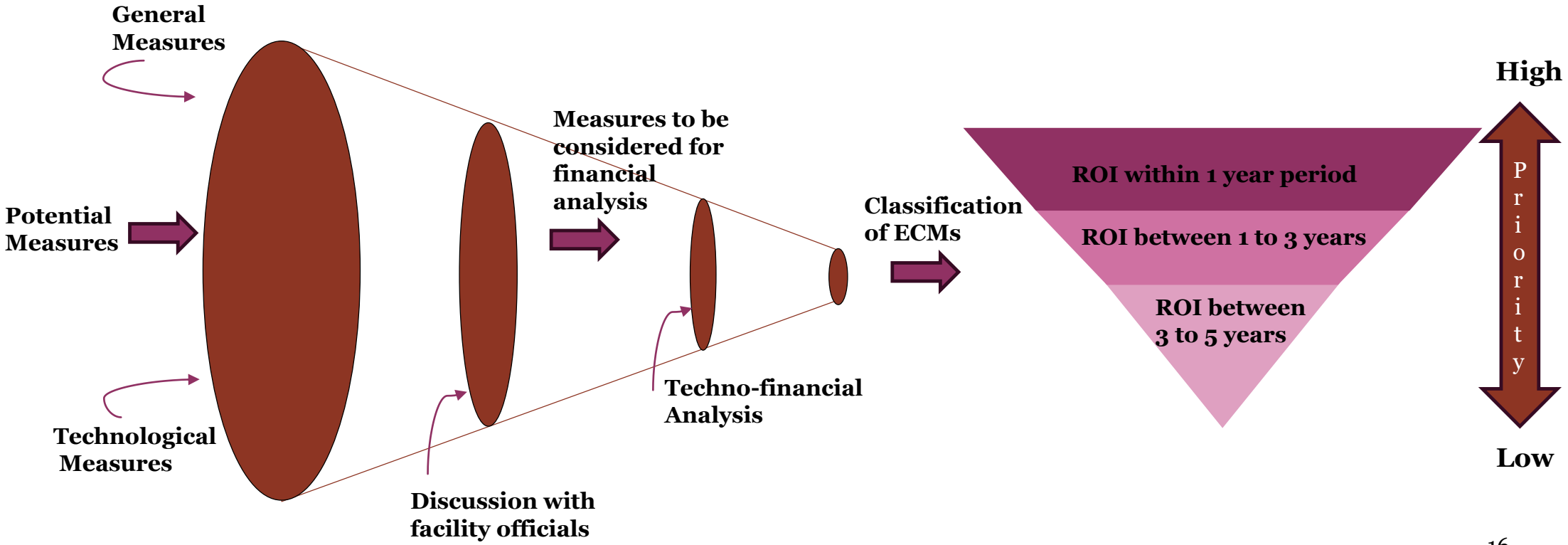
AUDIT PHASE - RESULTS OF FINANCIAL MODELLING (4/5)

The financial model for techno-economic analysis must provide as outcome, some of the financial parameters critical to decision making. Some of these are mentioned in the below schematic.



AUDIT PHASE - PRIORITIZATION OF ENERGY CONSERVATION MEASURES (5/5)

Prioritization of ECMs based on results of techno-economic analysis is one of the crucial activities in any energy audit study. ECMs must be classified after discussion with concerned facility officials.



POST AUDIT PHASE

Key Activities Performed	Purpose
❖ Implementation and follow-up	❖ Assist facility officials in proper implementation of suggested EE measures ❖ Monitor the performance

Energy Audit of Electrical and Thermal Utilities

ENERGY AUDIT OF PUMPS (1/3)

- Pumps facilitate the flow of water or any liquid in a facility. They come in variety of sizes for a range of applications.
- ***Pump affinity laws:***

  The affinity laws guide the influence on volume capacity, head or power consumption of a pump or fan with change in speed of wheel or change in the impeller diameter.

Effect on volume: $\frac{q_1}{q_2} = \left(\frac{n_1}{n_2}\right) * \left(\frac{d_1}{d_2}\right)$

Effect on head: $\frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2 * \left(\frac{d_1}{d_2}\right)^2$

Effect on power: $\frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3 * \left(\frac{d_1}{d_2}\right)^3$

Here, q is flow, H is head (m), n is speed (rpm), d is diameter (m) and P is power (kW)

Example: If there is 10% increase in pump speed, with constant impeller diameter, then flow volume increases by 10%, head increases by 21% and Power increases by 33%.

ENERGY AUDIT OF PUMPS (2/3)

Key observations to be made to assess energy efficiency in pumping system:

- Are pumps installed that are not sized correctly for the task?
- Are pumps being throttled in order to control the flow rate?
- Is bypass control being utilized to vary the flow out of the pump?

For performance evaluation of pumps following shall be covered during an audit:

- Flow and head measurement
- Measurement of power parameters (kW, kVA, pf, frequency, current, voltage)
- Evaluation of efficiency of pumps
- Application and matching of drive
- Application of flow control methods
- Application of VFD retrofit for energy savings

ENERGY AUDIT OF PUMPS (3/3)

- The following formulae can be used to assess the performance of pumps:

$$Hydraulic\ Power(P_h) = \frac{Q\left(\frac{m^3}{s}\right) * Total\ Head\ (h_d - h_s) * \rho\left(\frac{kg}{m^3}\right) * g\left(\frac{m}{s^2}\right)}{1000}$$

- Where h_d - discharge head, h_s – suction head, ρ - density of the fluid, g – acceleration due to gravity.
- The efficiency of the pump can be determined as:

$$\eta_{Pump}(\%) = \frac{Hydraulic\ Power\ (P_h)}{Pump\ Shaft\ Power\ (P_s)} * 100$$

- The operating efficiencies (calculated from the above formula) shall be compared with the design efficiency and recommendation for improving the energy efficiency/ reducing input power consumption shall be made.

ENERGY AUDIT OF FANS

- Fans provide air for ventilation and industrial process requirements. They are used to generate pressure to counter the resistance offered by dampers, ducts or other components in a damping system. Volumetric flow and efficiency estimation of fans can be done using the following formulas.

$$Fan\ Mechanical\ Efficiency, (\eta_{mech}) = \frac{Volume\left(\frac{m^3}{s}\right) * \Delta p\ (\text{total pressure in mmwc})}{102 * Power\ input\ to\ the\ fan\ shaft} * 100$$

$$Volumetric\ flow\left(\frac{m^3}{s}\right) = Velocity\ \left(\frac{m}{s}\right) * Area\ (m^2)$$

where, Area is the area of the duct and velocity is the air flow rate.

ENERGY AUDIT OF BOILERS (1/2)

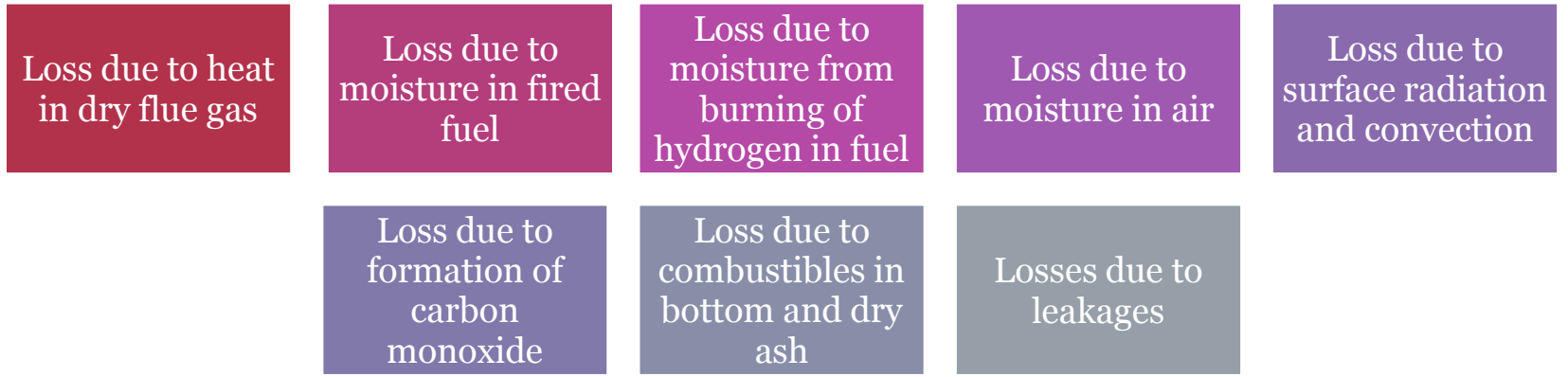
- Boiler is an enclosed vessel, facilitating transfer of combustion heat into water. The heated water or steam produced under pressure is then used to transfer the heat to a process.
- There are two methods to assess thermal efficiency of the boiler:
  - Direct Method
  - Indirect Method
- ***Direct Method:*** In this method, the energy gained by the working fluid is compared to the energy expensed in combustion of fuel. The efficiency can be evaluated using the following formula,

$$Boiler\ Efficiency(\eta) = \frac{Heat\ Output}{Heat\ Input} * 100 = \frac{Q * (h_g - h_f)}{q * GCV} * 100$$

where, Q is quantity of steam generated per hour in kg; q is quantity of fuel used per hour in kg; h_g is enthalpy of saturated steam in kCal/kg of steam; h_f is enthalpy of feed water in kCal/kg of water; GCV is gross calorific value of fuel in kCal/kg

ENERGY AUDIT OF BOILERS (2/2)

- ***Indirect Method:*** Also known as the heat loss method, the efficiencies are arrived at by subtracting the heat loss fractions from 100:



- The data requirement for calculating boiler efficiency through this method include:
  - Ultimate analysis of fuel (H2, O2, S, C, moisture content, ash content)
  - Percentage O2 in flue gas ascertained through its analysis at around 9 to 15 points in flue gas duct cross section before and after APH to eliminate effect of gas stratification as per international practice
  - Flue gas temperature
  - Ambient temperature & humidity of air in kg/kg of dry air
  - GCV of fuel in kCal/kg
  - Percentage combustible in ash
  - GCV of ash in kCal/kg

ENERGY AUDIT OF COMPRESSED AIR SYSTEM (1/2)

Compressed air system is a plant/industry is an important area to explore energy savings. All three aspects of compressed air system, namely, compressed air generation (air compressors), compressed air distribution, and compressed air utilization must be studied in detail.

The description of work to be carried out during audit is as follows:

- Free air delivery assessment (output of compressors by adopting pump up method or suction air velocity method if pump up method is not applicable)
- Estimation of specific energy consumption (kW consumption per cfm)
- Quantification of compressed air leakages (No load test if applicable) alternatively survey should be carried out to identify the leakage points if any
- Study of distribution network for Pressure drop, leakages, etc.
- Recording of loading and unloading pattern of compressors
- Optimization of compressed air utilization
- Application potential for energy saving retrofits- replacement with screw or centrifugal compressors
- Adequacy of receivers sizing and location of receivers
- Compressed air dryers for energy efficiency aspects
- Power consumption measurement for operating compressor for loading and unloading pattern study to explore VFD retrofits for compressors to avoid unloading.

ENERGY AUDIT OF COMPRESSED AIR SYSTEM (2/2)

Some of the important formulas for performance assessment of compressors are:

- **Free Air Delivery (Q):** It is the full rated volume of flow of gas compressed and delivered at conditions of total temperature, total pressure, and composition prevailing at the compressor inlet. It is given by:

$$Q\left(\frac{Nm^3}{min}\right) = \frac{P_2 - P_1}{P_0} * \frac{V}{T}$$

Where, P_2 is the final pressure after filling (kg/cm^2), P_1 is initial pressure (kg/cm^2) after bleeding, P_0 atmospheric Pressure (kg/cm^2), V = Storage volume in m^3 which includes receiver, after cooler, and delivery piping

T = Time take to build up pressure to P_2 in minutes

- **% Air Leakage:** Preventing leaks in the compressed air system can save a lot of energy. Percentage of leakage is identified by performing a simple test when no equipment is consuming the compressed gas. The formula used to determine air leakage is as follows

$$\%Leakage = \frac{T}{(T + t)} * 100$$

Where, T is total load time, and t is total unload time

ENERGY AUDIT OF AIR CONDITIONING SYSTEM (1/2)

The cooling effect produced by air conditioning system is quantified as tons of refrigeration (TR).
1 TR of refrigeration = 3024 kCal/hr heat rejected.

The refrigeration TR/chiller tonnage is assessed as

$$TR = \frac{Q * C_p * (T_i - T_0)}{3024}$$

Where, Q is mass flow rate of coolant in kg/hr; C_p is coolant specific heat in kCal /kg deg C
T_i is inlet, temperature of coolant to evaporator (chiller) in °C
T_o is outlet temperature of coolant from evaporator (chiller) in °C.

Refrigeration load in TR is also assessed using the following formula:

$$TR = \frac{Q * \boldsymbol{\rho} * (h_{in} - h_{out})}{3024}$$

Where, Q is the air flow in m^3 at Air Handling Unit;
ρ is density of air in kg/m^3;
h_{in} is enthalpy of inlet air in kCal/kg;
h_{out} is enthalpy of outlet air in kCal/kg

ENERGY AUDIT OF AIR CONDITIONING SYSTEM (2/2)

For centralized AC systems, all operating chillers need to be studied with measurements of actual TR generation. The following aspects of the chillers shall be covered:

- Measurement of water flow and temperature at condenser & evaporator inlet & outlet of chillers to estimate actual TR generation and comparison with rated.
- Measurement of power consumption of chillers to evaluate specific energy consumption (SEC).
- Analysis of condenser & evaporator refrigerant temperature and pressure to find effectiveness of chiller evaporators, & condensers.
- Measurement of flow, pressure and power consumption of chilled water (CHW) pump, condenser water pump (CW) to evaluate the efficiency.
- Measurement of air flow, DBT, WBT in all the operating AHUs to find TR consumption.
- Study of present flow, temperature and control methodologies adopted at AHU to explore opportunities for better control.
- Study of excess steam or waste heat from plant for installation VAM for air conditioning instead of electrical chillers

ENERGY AUDIT OF MOTORS (1/2)

Motors consume significant amount of power in any industry. Large energy savings can be realized by implementing energy efficiency in motors.

Key activities performed to assess energy efficiency in motors are:

- Motor load survey is carried out to measure the operating load of different motors installed in the facility. The results are used to identify motors that are undersized (causing motor burn out) or oversized (resulting in inefficiency).
- Possibility of replacement of old inefficient motors with new energy efficient motors is assessed.
- Other energy conservation options such as star- delta-star changeover, use of variable speed drives, soft starters- cum-controllers, improved transmission drives (like fluid couplings, eddy current couplings, modern flat belts etc.) are explored

Key formulae related to motors:

$$\%\ Loading = \frac{Input\ power\ drawn\ by\ the\ motor\ at\ existing\ load}{Name\ plate\ full\ load\ kW\ rating} * 100$$

$$\eta_{motor} = \frac{Power\ available\ at\ shaft}{Input\ power\ drawn\ by\ motor} * 100$$

ENERGY AUDIT OF MOTORS (2/2)

- Energy savings in replacing an old inefficient motor with energy efficient motor can be determined using the following formula:

$$Annual\ Energy\ Savings(kW) = \text{hp} * \text{L} * \text{H} * 0.746 * \left(\frac{1}{E_1} - \frac{1}{E_2}\right) * 100$$

- Where, hp denotes motor rated horsepower, L denotes load factor (percentage of full load), H is annual operating hours and E1 and E2 are energy efficiency ratings of old and new motor respectively at a given load.

$$Annual\ Bill\ Savings = Annual\ Energy\ Savings\ * Per\ unit\ energy\ cost$$

$$Simple\ Payback\ Period = \frac{Incremental\ Cost}{Annual\ Cost\ Savings}$$

ENERGY AUDIT OF LIGHTING (1/2)

- Lighting essentially is a significant power consumer in any facility. For industries, lighting power consumption may vary from 2-10% of total power.
- Energy efficiency in lighting can be achieved by incorporating modern energy efficient lamps, luminaries etc. along with implementation of good operational practices

In order to assess energy conservation for lighting system, following observations shall be made:

- Are incandescent lights installed?
- Are standard fluorescent lamps installed?
- Are lights on in unoccupied areas?
- Is the exterior lighting on during the day?
- Are existing lighting levels higher than the recommended levels?
- Are magnetic ballasts installed on the existing fluorescent lights?
- Are Mercury Vapour lights installed?

ENERGY AUDIT OF LIGHTING (2/2)

Key activities involved in detailed audit of lighting system are:

- Study of existing inventory (details of conventional lights installed). Power measurements are done to assess power consumption of existing lighting fixtures.
- Analysis of present lighting performance indices like Lux/m2, lux/watt, lux/watt/m2 and comparison with norms
- Detail lux level survey at various locations and comparison with acceptable standards
- Lighting feeder power measurements to study operating voltage to explore opportunities for installation of lighting energy saver.
- Estimation of lighting load at various locations
- Exploring opportunities for dimming, occupancy sensors, timer controls, voltage optimization etc., in plant lighting system.
- Possibility of retrofitting, replacement, solar lighting need to be studied.
- Study of present lighting control system and recommendation for improvement

Energy Audit Instruments

ENERGY AUDIT INSTRUMENTS

Flue gas Analyzer

Water flow meter

S – Type pitot tube

3 – Phase power analyzer

Digital Manometer

Temperature logger

Digital pressure gauge

Anemometer

High temperature thermocouples

QUIZ TIME

Lets check what you have learnt till now.

Answer the questions correctly OR

Consider revising this section … All the Best !!

NOTE: Click on the suitable option for answering the question

Q 1. Which of the following is **not** among the activities performed **during an Audit Phase** of an Energy Audit?

1. Walk through Audit
2. Preparing process flow and energy utility diagrams
3. Field measurements: survey and monitoring
4. Cost-Benefit analysis of Energy Conservation (ENCON) measures

QUIZ TIME

Q 2. If the pump speed **is halved** and diameter of impeller **is doubled**, the head (H1) and input power (P1) requirement of the new pump becomes –

1. 8 H1 and 32 P1
2. 16 H1 and 64 P1
3. H1 and P1
4. 1/16 H1 and 1/64 P1

QUIZ TIME

Q 3. Which of the following statement indicates a **poor** boiler efficiency?

1. CO_2 is in the optimum range and no black smoke coming from the chimney
2. All the pipelines and valves are properly insulated and jacketed with no leakages
3. Gross calorific value of the fuel meets the prescribed standards
4. Bottom ash contains a high quantity of unburnt fuel

QUIZ TIME

Q 4. If the refrigerant quantity is increased by 2 times and the difference in outlet and inlet temperatures ($T_i - T_o$) is increased to 4 times, the new refrigeration load (TR) of the system becomes

1. Eight (8) times
2. One fourth (1/4) times
3. One eighth (1/8) times
4. Four (4) times

End of Training Module

THANK YOU

Congratulations !!

That's a correct response…

Next question

Sorry !!

That's incorrect…

Try again

Next question

Congratulations !!

That's a correct response…

Next question

Sorry !!

That's incorrect…

Try again

Next question

Congratulations !!

That's a correct response…

Next question

Sorry !!

That's incorrect…

Try again

Next question

Congratulations !!

That's a correct response...

Exit

Sorry !!

That's incorrect…

Try again

Go to the beginning of the module

Exit