PERFORMANCE EVALUATION AND RETROFITTING OPTIONS

Description given in this section may be used for analysing various energy consuming equipment in a building:

a) <u>Air Conditioning Unit</u>

The major parameters for evaluating performance of air conditioning unit are:

- Indoorand outdoordesign conditions
- Measured flows and capacities of all equipments used in the system
- Comparison of the measured and design capacities
- Comparison of energy consumption with the design value

An air conditioner is efficient when all of its components i.e. compressor, condenser, evaporator and condenser cooling (heat rejection) system are working in matched conditions. This means that under peak operating conditions, they must perform to their optimum output. To evaluate the performance following approach may be followed:

Compressor:

From the operating suction and discharge pressure, the capacity may be evaluated from the rating charts. The operating kilowatt input can give the value of input power. This can be compared with the rated input power.

Condenser:

Flow rate of cooling medium (air or water) and temperature rise across the condenser gives the heat rejection rate. The flow rates and temperature rise can be compared with the design parameters and any variation must be analysed. Following equation can be used for water-cooled condenser: Heat rejected (kW) = 4.182 X water flow rate in liter per second X temperature rise in°C

Heat rejected in air cooled condenser can be calculated by the following equation: Heat rejected (kW) = 1.20 X airflow rate in liter per second X temperature rise in °C Heat rejected must be compared with the rated heat rejection rate as per the rating chart.

Cooling coil:

Air flow rate and enthalpy drop across the cooling coil gives the cooling load. The flow rates and enthalpy drop should be compared with the design parameters. The equation for cooling coil is given below:

Cooling produced (in kW) = 1.2 X air flow rate in liter per second X enthalpy drop Enthalpy difference between the return air and supply air and measured in kilo joules per kilogram in SI units.

Coolingtower:

Heat rejected at the condenser must match the heat rejected at the cooling tower. The equation for cooling tower is same as the equation for water cooled condenser as given above. Efficiency of cooling tower can be calculated as:

$$\text{Efficiency} = \frac{\text{Entering water temperature-leaving water temperature}}{\text{Entering water temperature - ambient wet bulb temperature}}$$

The efficiency thus obtained must be compared with the rated efficiency.

Following are major energy conservation opportunities in air conditioning systems:

Installation of variable speed drives:

Variable speed drives typically use electronic circuitry to vary the output frequency, which, in turn, varies the speed of motor. Since the power required by the fan or pump is proportional to cube of its speed, significantly large reduction in power consumption can be obtained by reducing the speed. Since the air handling units are designed for peak load conditions, if the Variable Speed Drives (VSDs) are installed at different air handling units of the HVAC system, the daily and seasonal variation in the required CFM can be translated into energy savings.

Similar to other components, the design of cooling towers is also done to meet the worst combination of peak load and wet bulb temperature. Howeverthe condition of water entering the tower varies with time, day and season that change the operating conditions for the tower. In order to operate the tower efficiently, the fan output must be optimally adjusted according to the cooling requirement governed by the climatic conditions and load.

Low leakage dampers:

If the dampers are not closed properly, unwanted outdoor air can enter the building and increase the load on cooling system. Use of low leakage dampers restrict air leakage to less than 1% as compared to common dampers allowing 5 to 30% air leakage even in closed position.

Reduced minimum outdoor air:

Use of outdoor air must be minimized to its minimum as per the ventilation requirements. Any extra outdoor air (except for moderate outdoor temperature and humidity condition) usually increases load on heating or cooling system. This can be done by adjusting the damper linkage to minimum position.

Unoccupied ventilation reduction:

Outdoor air is to be supplied to meet the ventilation requirement as mentioned above. In unoccupied spaces, such use of outdoor air should be reduced to minimum possible (or even eliminated altogether) to reduce the load. By the addition of the time clock or the occupancy sensors based automation system, provisions must be made to shut the outdoor air during unoccupied period and during the night hours.

Enthalpy control/dry bulb economizer

Under special circumstances, such as morning/evening of March/April when humidity is not very high, using outside air to cool a building can result in lower mechanical cooling costs wherever the outdoor air has a lower total heat content (enthalpy) than the return air. This can be accomplished by an 'integrated economizer' or enthalpy control. The dry-bulb economizer or the integrated economizer can be made to operate automatic by providing dampers capable of providing 100% outdoor air with local controls that sequence the chilled water or DX coil dampers. During the operation of economizer, when space temperature rises, the outdoor air damper opens first, then on a further rise, the cooling coil is switched on. Economizer operation is activated by outside air temperature say 23°C. If the outside air temperature is below 23°C, the above described economizer operation takes place. At outdoor temperature above 23°C, cooling by using outside air is not economical and the outdoor air damper opening reduces to its minimum position as per ventilation requirement only.

If an economizer is equipped with an enthalpy control system, energy savings will be registered due to a more accurate change-over point. The load on a cooling coil of air handling system is a function of the total heat (enthalpy) of air entering the coil. The total heat is a combined function of dry bulb temperature and relative humidity. In a typical enthalpy control system both the conditions DBT and RH are measured in the return air path and outdoor. Enthalpy control systems calculate best route for cooling of air to keep lowest load on the machine.

Exhaust air control

Energy can also be saved by controlling operation of exhaust fans in such a way that it operates only when there is requirement. Under normal situations, exhaust fans operate for much more duration than their requirement for removal of odor/fumes and to remove heat built-up. The operation of removal of fumes/odor can be scheduled automatically in such a way that they operate only when objectionable air contaminants are getting generated. Exhaust fans of laboratory hoods, kitchen vents and toilets for example can be coupled with facility usage. This can be done through integration of exhaust fans operation with sensors such as C02 sensor or with occupancy sensors. The other family of exhaust fans that is used to avoid heat built-up, can be automated by thermostatic control.

Retrofit of central fans for variable air volume usage

Conversion of constant speed fans or constant volume air distribution system to a variable air volume (VAV) system can be helpful in saving energy. Such retrofitting also results into considerable reduction in fan power. Fans with air foil or backward curved impellers without vortex vanes require additional vanes or some means to control flow volume, such as eddy current clutch or variable speed drive, for realizing the advantages of VAV system. Fans with forward curved impeller may just require the addition of a damper in the return duct system if building statics become objectionable. This damper can be controlled by space static sensor referenced to outdoor condition.

Fans with vortex vanes require a different approach. In this scheme, the supply fan static control maintains the minimum supply duct static required for delivering the minimum CFM. The return fan static control senses change in space pressure relative to outdoors and maintains the space at slightly positive pressure to prevent infiltration of outdoor air. A VAV system delivers air corresponding to the actual instantaneous load requirements. Amount of energy saved by VAV system is proportional to variation in building load, typically in offices the savings of the order of 30% can be achieved. This system is much efficient than the dual duct system in which air from hot and cold ducts are mixed to achieve desired temperature.

Advanced heat exchangers

The availability of air-to-air heat exchangers namely, air-to-air heat plate exchangers, heat pipes, heat wheels offer energy savings in the field of air conditioning. The air-to-air plate heat exchanger has a series of plates to provide large area to facilitate heat transfer over low temperature differences. These systems are very energy efficient in low-humidity conditions.

Heat pipes are devices that usually consist of sealed finned tube with a wick lining on the inner side. The tube contains a working fluid, which evaporates from the hot end of the tube and condenses at the cold end, thus transferring heat. The working fluid is returned to the hot end by capillary action of the wick. The conductivity of heat pipes is about 1000 times of copper and the system offers ability to operate at very low temperatures even.

Heat recovery wheels are rotary heat exchangers packed with aluminum honeycomb fill.

One half of the wheel is in contact with warm air and the other half with cold air. The sensible heat of the incoming warm air is given to the aluminum and the wheel rotates slowly releasing the heat to the exhaust cold air during the second half of the revolution. Desiccant coated heat wheels are also available where, in addition to sensible heat transfer, latent heat transfer also takes place as the desiccant absorbs moisture in one half of the revolution and releases it in the second half of the revolution.

Operation and maintenance practices to be ensured:

- The system should be reset and rebalanced at regular intervals. Often the initial balancing gets disturbs with passage of time.
- Provisions should be made for shutting down equipment when not needed.
- Set back temperatures should be assigned when space is not occupied.
- Shut down should start shortly before the occupants leave and it should start as late as possible before the occupants arrive.
- Cool night air should be utilized for pre-cooling of space through ventilation.
- Solarshading devices must be working properly.
- Air filters must be checked and replaced if chocked.
- Coils and tubes of all heat transfer surfaces must be clean.
- Water treatment plant should work properly to avoid scale formation in tubes.
- Air-vents should be working properly.
- In case of multiple equipment sequential starting should be adopted.
- Lubrication, belt tension should be checked periodically
- Room thermostat and humidistat should be at temper proof locations and should remain clean.

b) Lighting system

Lighting is a very important area for energy auditors. It involves several issues such as use of daylight, choice and proper installation of luminaries, operation and control of lighting devices. Due to special importance of this field, in this handbook, a separate chapter has been given to this topic. However, to maintain comprehensiveness of this chapter, salient points related to lighting are being covered again from the point of view of energy audit.

For evaluating efficiency of lighting system, the total installed load should be divided by the floor area of the building to determine the loading in watts per square meter. This value can be compared with typical values of good lighting practices recommended in various lighting codes. A lighting scheme loading in the range of 7-llW/m2 is considered an efficient scheme. However, besides comparing lighting load a comparison with power consumption for lighting per unit floor\ area is another important criteria for lighting evaluation. This energy consumption can be derived from the multiple of lighting load and usage duration. The chapter on building energy code contains a table that presents recommended lighting energy consumption per unit floor area for different types of building usages. The efficient lighting scheme should however ensure right lighting levels at the work plane or working area. For example office tables, conference rooms, shops require 300 lux level, whereas, corridors etc. require only 70 lux. Drafting tables, operation tables etc require illumination level of 750-1500 lux and efficient lighting scheme should not compromise on this level.

Over the time, luminaries and room surfaces get dirty and the light output of the lamp decreases. Simple cleaning of lamps and luminaries can substantially improve the lighting of space and help to reduce energy wastage.

Following are potential energy saving actions related to lighting:

- remove unnecessary lamps
- turn-off lights near windows
- turn-off lights when an area is unoccupied
- keep lamps and fixtures clean
- eliminate unnecessary outside lighting
- install high efficiency fluorescent lamps to replace standard ones
- replace conventional ballast with conventional one
- install dimmer switches
- install timers for external lighting
- install task lighting replacing general lighting

c) Pumps and motors

Efficiency of a pump is defined as ratio of useful power output to the power input to the pump shaft. The input power can be estimated by measurement of current drawn and supplied voltage. The power output of a pump is basically the energy delivered to the fluid:

$$\mathbf{P_{out} = \rho QH}$$

Where ρ is density of fluid (N/m^3), Q is volumetric flow rate (m^3/s) and H is total dynamic head (m) which is the sum of total static head, entrance head-loss, frictional head-loss, head-loss due to fittings and valves, velocity head in discharge pipe.

It has been observed that large safety margins are kept on the head of the pump that results in a condition in which the pump does not operate at specified most energy efficient duty point. Large differences are found in the efficiency of pumps manufactured by organized sector and small-scale manufacturers. Selection should not be only based upon the initial cost alone, efficiency and running costs should also be given due weight. In case where the operating condition is unclear or is likely to be variable, effective method of efficient modulation like variable speed drives should be used.

The case of motors is quite similar to pumps. Motor efficiency, avoiding partial loading condition, are similar measures for ensuring energy efficiency.