How to use Energy Audit Instruments Effectively

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Instruments

- Ultrasonic non-contact type flow meters for liquids
- Clamp-on type power / energy meters
- Anemometers / Pitot tube – to measure velocity of gases
- Digital Manometer
- Tachometers – Contact / Non-contact type
- Digital thermometers for liquid / surface temperature
- Pyrometer
- Thermal imagers
- Lux meter
- Combustion Gas Analyzer
- Pressure Gauges
- Digital Hygro-temp Meter (for Temp & RH measurement)
- Measuring tapes / scales
- Stop Watch

Basic Precautions

- Calibration
- Condition
- Battery
- Range
- Least count
- Accuracy
- Location
- Placement / fixing
- Span / interval of measurement
- Duration of the data collection
- External environment – especially for air conditioning systems
- Validation of the measurement – check for abnormalities
- Plant operation while carrying out measurement

Clamp-on type power / energy meters

- Single Phase Load - One CT with Voltage probes for Phase and Neutral

- Three Phase Balanced Load - One CT with Voltage probes for two Phases

- Three Phase Unbalanced Load – Three / Four CTs with Voltage probes for three Phases (and) neutral

Special Precautions:

- Always measure line current and related parameter.
- Check current direction while clamping the CT(s).
- Clamp the voltage probes on to the appropriate phases

Clamp-on type power / energy meters

Lux meters

- To Measure illumination level

Special Precautions:

- Place the meter in working horizontal plane
- Factor for solar light gains, if any.
-

Lux meters


DIGITAL LUX METER
1237
HOLD
ON
OFF


Lux Meter
Lumen: 172 lm
Candela: 14 cd
Lux: 120 lx
Kalibrierung: 1,9 1=100%
Lux (Lumen/m²): 1,20 m x m
Beenden
Menü


142.0
OFF

Anemometers / Pitot tube

- Vane Type Anemometer – to measure velocity of air for open discharge / suction as well as ducts (requires 50 NB flanged opening)

- Hot Wire Anemometer - to measure velocity of air inside duct under ambient / low temperature conditions (requires 15 NB opening)

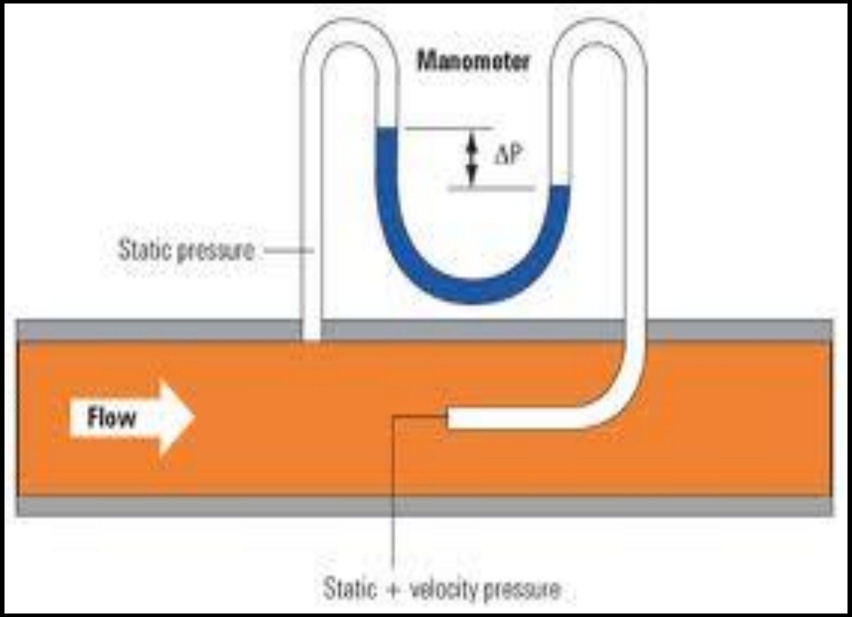
- Pitot Tube – to measure velocity of fluid inside duct (requires 50 NB or lager flanged opening depending on the duct size)

Special Precautions:

- Probe must be located at proper position and proper orientation
- Check flow direction while placing the meter

Anemometers

Pitot tube


Manometer
ΔP
Static pressure
Flow
Static + velocity pressure

Digital Manometer

- Measure suction pressure & discharge pressure (total as well as static) across the fan

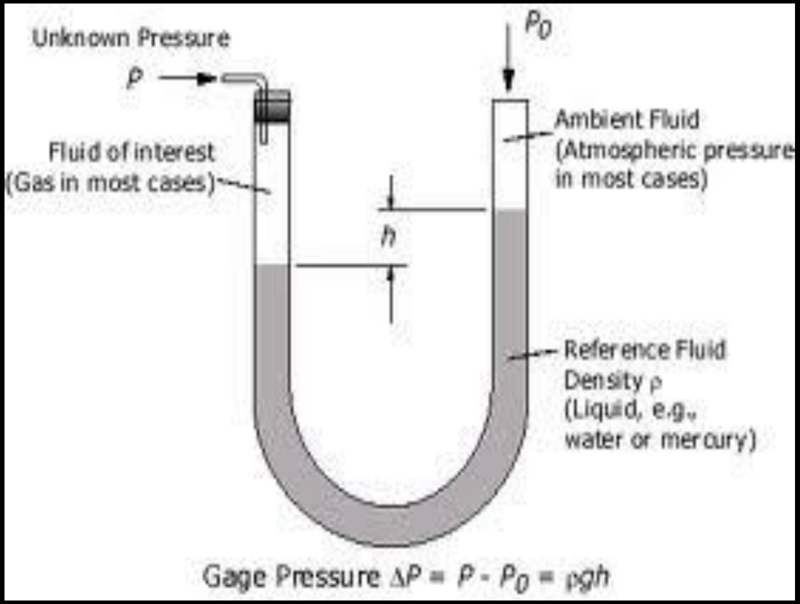
Special Precautions:

- Place the probes properly
- Locate the probes in correct position
- Ensure that there is no clogging / bending of the tubes

Note:

This data is used to compute enthalpy of air with the help of Psychrometric charts / software.

Digital Manometer



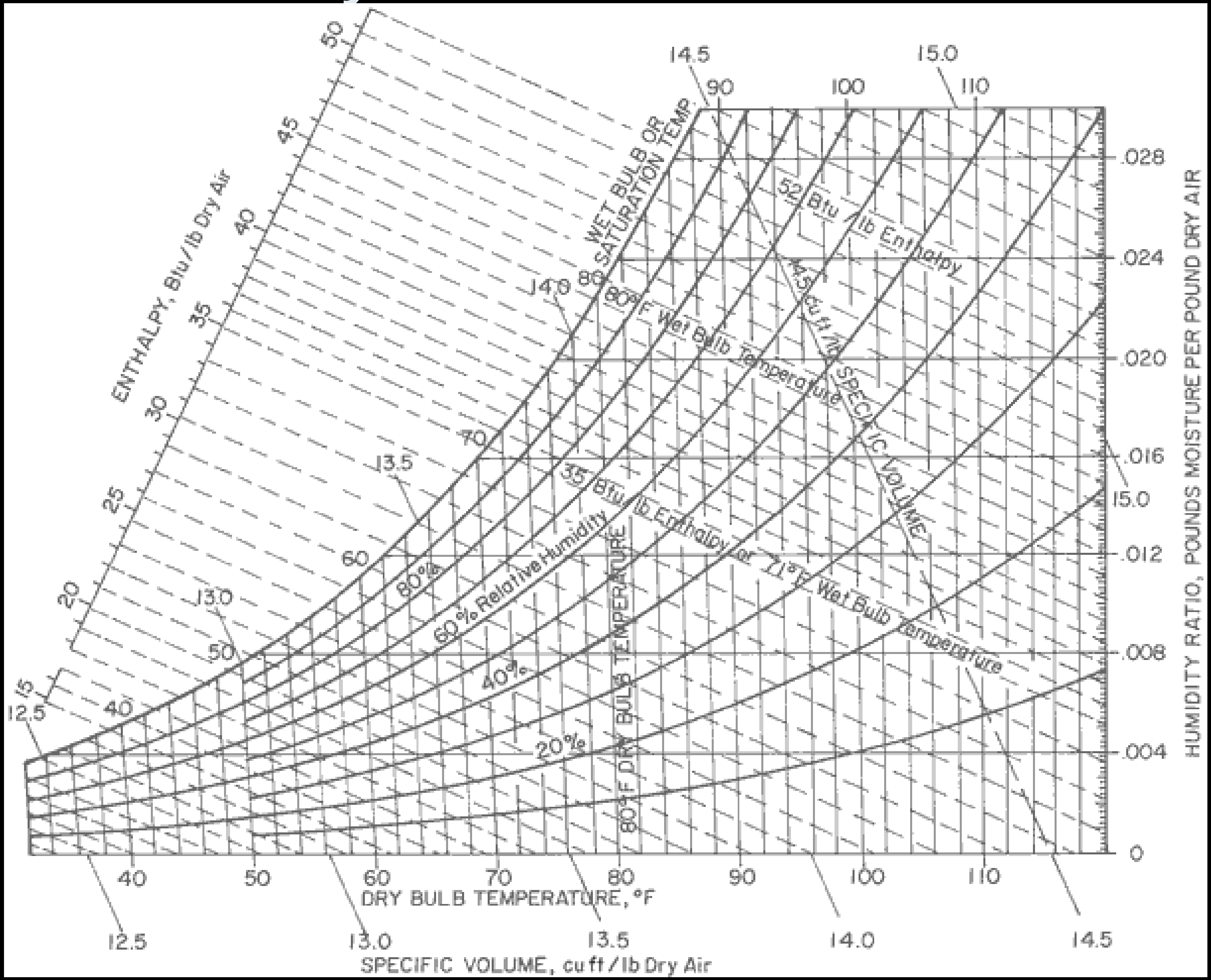
Digital Hygro-temp Meter

- Measures Dry bulb (ambient) temperature
- Measure relative humidity in atmosphere at the temperature

Special Precautions:

- Wait for readings to stabilize
- Place the probe at appropriate position
- Ensure that the probes are not exposed to relative humidity beyond design limits

Psychrometric Charts



Digital Hygro-temp Meter

Ultrasonic non-contact type flow meters

- **Transit Time**

- Suitable for clean liquids (without suspended particles)
- The measurement is based on the travel time of two sound waves.
- One wave travels the same direction as the flow and the other beam travels against the flow.
- The measured difference of the time taken to travel upstream verses downstream is a function of the process' velocity and direction.
- The transducer pairs can be mounted outside the pipe.
- The pipe surface need to be cleaned properly.
- A layer of grease / sealant is provided between the probe and surface to eliminate air gaps.
- The scaling on internal pipe surface also affects measurement.
- The flow is computed by keying in internal diameter of the pipe.

Ultrasonic non-contact type flow meters

Doppler Effect

- Suitable for liquids with suspended particles or air bubbles.
- The flow measurement is based on the Doppler-shift, the phenomenon.
- The wavelength of an approaching sound source is shorter than the wavelength of that same source as it is moving away.
- The transducer emits a sonic beam into the process and entrained particles or bubbles reflect the beam back to the transducer.
- The measured difference in the wavelengths (transmitted verses reflected) is proportional to the velocity.
- The transducer pairs can be mounted outside the pipe.
- The pipe surface need to be cleaned properly.
- A layer of grease / sealant is provided between the probe and surface to eliminate air gaps.
- The scaling on internal pipe surface also affects measurement.
- The flow is computed by keying in internal diameter of the pipe.

Ultrasonic non-contact type flow meters

Special Precautions

- Select the location with proper straight length on upstream and down stream side.
- Determine internal diameter of the pipe correctly, avoid making any assumptions.
- Ensure that the pipe is completely filled with liquid
- The external surface of pipe must be properly cleaned
- Apply adequate quantity of grease / sealant over the pipe surface.
- Place the probes on the lateral surfaces (avoid top / bottom)
- Clamp the probes securely.
- Adjust the probe to achieve requisite signal strength.
- Take cumulative readings of flow (flow totalizer); especially if there are variations.

Ultrasonic non-contact type flow meters

Pressure Gauges

- Suction / discharge pressure of the liquids
- Suction / discharge pressure of the refrigeration gas
- Discharge pressure of the compressed air

Pressure Gauges

Ultrasonic Leak Detector

- Compressed air leakages
- Steam leakages
- Steam trap functioning

Ultrasonic Leak Detector

Combustion Gas Analyzer

Measures

- Flue gas temperature
- Oxygen contents
- Carbon monoxide contents
- Carbon dioxide contents
- Other Combustibles

Special Precautions:

- Place the probe properly – no air ingress if point in on suction side
- Allow sufficient time for reading to stabilize

Combustion Gas Analyzer

Pyrometer

- A pyrometer is a non-contacting device that intercepts and measures thermal radiation.
- This device can is used to determine the surface temperature of an surface.
- Also used to measure temperature of furnace openings and flame temperature of over 7000 ºC.

Special Precautions:

- Set correct emissivity.
- Ensure that the target completely fills the field view.

Pyrometer

Thermal imagers

- Lux meter
- Anemometers / Pitot tube – to measure velocity of gases
- Digital Manometer
- Tachometers – Contact / Non-contact type
- Digital thermometers for liquid / surface temperature
- Digital Hygro-temp Meter (for Temp & RH measurement)
- Ultrasonic non-contact type flow meters for liquids
- Pressure Gauges
- Ultrasonic Leak Detector
- Combustion Gas Analyzer
- Pyrometer
- Thermal imagers
- Measuring tapes / scales
- Stop Watch

Thermal imagers

Miscellaneous

- Measuring tapes / scales
- Stop Watch
- Scales

Motor Load

Measure

- Operating parameters like Voltage, Current, Power Factor and Power
- Note down Motor Rating, Efficiency, type of Application and Operating Period

Instruments:

- Clamp on power meter (Three phase balanced / unbalanced)

Outcome

- Load / Loading Pattern of the motors
- Approximate breakup of overall power consumption
- Identification on under-loaded motors
- Potential saving with cost benefit analysis

Motor Load Calculations

Motor Load =

Input Power / (Motor Rating x Motor Efficiency)

Analysis:

- Motor efficiency drops down considerably below 50% load; leading to losses of 5 to 10% of the actual power.
- Identify motors which are loaded below these values.

Corrective Action:

- Replace the motor
- Connect the motor in star mode, if possible
- Install Star delta controller, if the motor has star delta starter
- Install voltage optimizer like intelligent soft starter

Special Precaution

- Direction of CT
- Motor efficiency drops down considerably below 50% load; leading to losses of 5 to 10% of the actual power.
- Identify motors which are loaded below these values.

Corrective Action:

- Replace the motor
- Connect the motor in star mode, if possible
- Install Star delta controller, if the motor has star delta starter
- Install voltage optimizer like intelligent soft starter

Motors Efficiency

Measure

- Electrical parameters (three phases) at operating load
- Electrical parameters (three phases) at no load – decouple
- Motor speed at operating load
- Motor speed at no load

Instruments:

- Clamp on power meter (Three phase unbalanced)
- Tachometer

Outcome

- Motor Efficiency
- Identification on inefficient motors
- Potential saving with cost benefit analysis

Motors Efficiency

- scpl motor efficiency.pdf

Pumps

Measure

- Velocity of liquid to determine flow rate
- Differential Pressure
- Power drawn by motor
- Note down Motor Efficiency and Specific gravity of Liquid

Instruments

- Clamp on power meter
- Pressure gauge (-1.0 to 1.0 kg/cm^2 suction and as required for discharge)
- Ultrasonic flow meter (Transit time or Doppler effect)

Outcome

- Present pump efficiency
- Operating parameters – Flow, differential head and power.
- Potential saving with cost benefit analysis

Pumps

Pump Efficiency (η_P) =
Hydraulic Power / Pump Input (shaft) Power

Q : Flow rate (M^3/sec)

ΔH : Differential head developed by the pump (M)

ϱ : Specific gravity of fluid

P_M : Motor input power (kW)

η_M : Motor efficiency

$$\eta_P = 9.8 \times Q \times \Delta H \times \varrho / (P_M \times \eta_M)$$

Fans & Blowers

Measure

- Velocity of gas to determine flow rate
- Differential Pressure
- Power drawn by motor
- Note down Motor Efficiency, Temperature and Specific gravity of gas

Instruments

- Clamp on power meter
- Digital manometer (-1000 to +1000 mm WG or s required
- Anemometer (Vane / Hot Wire) or Pitot tube

Outcome

- Operating efficiency (at Static pressure) of fan
- Operating parameters – Flow, Diff Pressure & Power
- Potential saving with cost benefit analysis

Fans & Blowers

Fan Efficiency (η_F) =
Pneumatic Power / Fan Input (shaft) Power

Q : Flow rate (M^3/sec)

ϱ : Specific gravity of the fluid

P_s : Differential Static head developed by the fan (mm WG)

P_d : Rise in static pressure if velocity head is brought to zero, without losing any mechanical energy (mm WG)

P_T : $P_s + P_d$

P_M : Motor input power (kW)

η_M : Motor efficiency

$$\eta_F = Q \times P_T \times \varrho / (P_M \times \eta_M)$$

Refrigeration Compressors

Measure

- Velocity of liquid to determine flow rate through chiller
- Differential Temperature across chiller
- Power drawn by compressor motor
- Suction & Discharge Pressure / temperature
- Note down Motor Efficiency, Specific gravity and Specific heat of Liquid, Speed of Compressor

Instruments

- Clamp on power meter
- Digital temperature gauge
- Pressure gauge
- Ultrasonic flow meter (Transit time or Doppler effect)

Outcome

- Operating capacity
- Specific Power Consumption / Energy Efficiency Ratio
- Saving Potential

Refrigeration Compressors

Refrigeration Effect (RE)

Q : Flow rate (M^3/sec)

ΔT : temperature drop across the evaporator of the refrigeration system (^oC)

ϱ : Specific gravity of fluid

C_p : Specific Heat of the fluid (kCal/kg/^oC)

P_M : Motor input power (kW)

η_M : Motor efficiency

$$RE = 3600 \times Q \times \Delta T \times \varrho \times C_p / (3.024)$$

$$\text{Specific Power (kWh/TR)} = (P_M \times \eta_M) / RE$$

Vapour Absorption machine (Steam)

Measure

- Velocity of liquid to determine flow rate through chiller
- Differential Temperature across chiller
- Quantity of condensate generated during the specified period
- Steam Pressure
- Note down Specific gravity and Specific heat of Liquid

Instruments

- Digital temperature gauge
- Pressure gauge
- Ultrasonic flow meter (Transit time)
- Drum for condensate collection
- Stop watch

Outcome

- Operating capacity
- Specific Steam Consumption
- Saving Potential

Vapour Absorption machine (Steam)

Refrigeration Effect (RE)

Q : Flow rate (M^3/sec)
ΔT : temperature drop across the evaporator of the refrigeration system (^oC)
ϱ : Specific gravity of fluid
C_p : Specific Heat of the fluid (kCal/kg/^oC)
P_M : Motor input power (kW)
η_M : Motor efficiency
M : Mass of steam collected (kg/hr)

$$RE(TR) = 3600 \times Q \times \Delta T \times \varrho \times C_p / 3.024$$

Specific Steam (kg/TR) = M / RE

Air Conditioners (Window / Split / Ductable Split)

Measure

- Air velocity and cross-sectional area to determine flow rate
- Dry Bulb Temp & RH of supply air to determine enthalpy
- Dry Bulb Temp & RH of return air to determine enthalpy
- Power consumed by the machine

Instruments

- Power meter
- Anemometer / pitot tube
- Hygrotemp Meter (for relative humidity and temperature)
- Psychrometric Chart / data

Outcome

- Air Conditioning Effect
- Operating parameters – Flow, Temp, RH
- Specific Power Consumption / Energy Efficiency Ratio
- Saving Potential

Air Conditioners
(Window / Split / Ductable Split)

Air Conditioning Effect (ACE)
Energy Efficiency Ratio (EER)

Q : Flow rate (M^3/sec)
ΔH : Enthalpy drop across evaporator of the air conditioning system (kCal/kg)
ϱ : Specific gravity of fluid
P_i : Input power (kW)

ACE = 3600 x Q x ΔH x ϱ / (3.024)

Specific Power (kWh/TR) = P_M / RE

EER = 3.51 / Sp Power

Air Handling Units

Measure

- Air flow rate
- Dry Bulb Temp & RH of supply air to determine enthalpy
- Dry Bulb Temp & RH of return air to determine enthalpy

Instruments

- Anemometer / pitot tube
- Hygrotemp Meter (for relative humidity and temperature)
- Psychrometric Chart / data

Outcome

- Load / Refrigeration effect on individual AHU
- Operating parameters – Flow, Temp, RH
- Saving Potential

Air Handling Units

Air Conditioning Effect (ACE)

Q : Flow rate (M^3/sec)

ΔH : Enthalpy drop across evaporator coil of Air handing Unit (kCal/kg)

ϱ : Specific gravity of fluid

$$ACE = 3600 \times Q \times \Delta H \times \varrho / (3.024)$$

Air Compressors (Pump up Test)

Measure (By isolating & depressurizing the receiver)

- Volume of receiver & auxiliaries till receiver
- Pressure - Initial & Final
- Time to raise the pressure during the test
- Power drawn by compressor motor
- Note down Motor Efficiency, Speed of the compressor / Motor

Instruments

- Power meter
- Stop watch
- Pressure gauge
- Stop watch

Outcome

- Operating capacity
- Specific Power Consumption
- Saving potential

Air Compressors (Pump up Test)

Free Air Delivery (FAD)

V_T : Total Volume of Receiver and Piping till the receiver (M^3)

p_i : Initial Pressure (kg/cm^2_A)

p_f : Final Pressure (kg/cm^2_A)

p_A : Atmospheric Pressure (kg/cm^2_A)

t : Time to raise the pressure from P_i to P_f (Seconds)

P_M : Motor input power (kW)

η_M : Motor efficiency

T_A : Ambient temperature (K)

T_R : Receiver air temperature (K)

C_D : Compressor Displacement (M^3/hr)

FAD (M^3/sec) = $V_T \times (p_f - p_i) / (p_A \times t \times T_A)$

Specific Power Consumption (kWh/M^3) = $(P_M \times \eta_M) / (3600 \times \text{FAD})$

Volumetric Ratio = FAD / C_D

Air Compressors
(Isothermal Efficiency)

Isothermal Power (η_I)

Isothermal Efficiency (P_I)

FAD : free Air Delivery (M^3/hr)

p_i : Initial Pressure (kg/cm^2_A)

p_f : Final Pressure (kg/cm^2_A)

p_A : Atmospheric Pressure (kg/cm^2_A)

P_M : Motor input power (kW)

η_M : Motor efficiency

$P_I = FAD \times LN(P_f / P_i) \times P_A / 36.7$

$\eta_I = P_I / (P_M \times \eta_M)$

Cooling Towers

Measure (during a specified period of time)

- Air velocity & Cross-sectional area to determine air flow rate at exhaust
- Ambient Conditions - DBT, WBT
- Inlet and outlet temperature of water
- Flow rate of the water
- Power drawn by Fan

Instruments

- Anemometer
- Hygrotemp meter / sling type thermometer
- Digital temperature indicator
- Ultrasonic flow meter

Outcome

- Operating capacity
- Range, Approach & Effectiveness
- Water to Air (L/G) Ratio
- Saving Potential

Cooling Towers

Cooling Effect (CE)

Q : Flow rate of Water (M^3/hr)
T_I : Temperature of incoming water to the cooling tower (^oC)
T_O : Temperature of outgoing water from the cooling tower (^oC)
T_{DB} : Dry Bulb Temperature (^oC)
T_{WB} : Bulb Temperature (^oC)
ϱ : Specific gravity of fluid
C_p : Specific Heat of the fluid (kCal/kg/^oC)

CE (TR) = $Q \times (T_I - T_O) \times \varrho \times C_p / (3.024)$

Range (^oC) = $T_I - T_O$

Approach (^oC) = $T_O - T_{WB}$

Illumination

Measure

- Lux level at various places
- Room Dimensions
- Note down type and no of fittings – installed / operating

Instruments

- Photometer (Lux meter)
- Measuring tape / scales
- Power meter

Outcome

- Illumination level
- Installed Power Density / Operating Power Density
- Installed Load Efficacy Ratio / Operating Load Efficacy Ratio
- Correctness / appropriateness of existing fittings
- Saving Potential

Illumination

L_A : Average illuminance on horizontal working place (Lux)
P_C : Power consumption by the circuit (W)
A : Area (M^2)
D_L, : Length (M)
D_W, : Width (M)
D_{HM} : Height above working plane (M)

Room Index (RI) = $(D_L \times D_W / (D_{HM} \times (D_L + D_W))$

Installed Load Efficacy = $A \times L_A / P_C$

Installed Power Density = $100 \times P_C / (L_A \times A)$

Lamp Circuit Efficacy = $Q \times (T_I – T_O) \times ϱ \times C_p / (3.024)$

Installed Load Efficacy Ratio =
Installed Load Efficacy / Target Load Efficacy

Turbine – Back Pressure

Measure

- Steam Pressure & Temperature at the turbine inlet
- Steam Pressure & Temperature at the turbine outlet
- Steam Flow (existing flow meter)
- Note down efficiency of alternator & gear box
- Actual power generated

Instruments

- Power meter
- Pressure gauges
- Temperature Indicators
- Steam table

Out Come

- Efficiency - Isentropic as well as Thermal
- Saving Potential

Turbine – Back Pressure

Q : Flow rate of steam (kg/sec)

H_I : Enthalpy of steam at turbine inlet (kJ/kg) – (T_I & p_I)

H_O : Enthalpy of steam at turbine outlet (kJ/kg) - (T_O & p_O)

H_{OE} : Enthalpy of steam at turbine outlet at isentropic condition (kJ/kg) - (p_O)

η_A : Alternator efficiency

η_G : Gearbox efficiency

Isentropic Efficiency = $(H_I – H_O) / (H_I – H_{OE})$

Power Generation (kW) = $\eta_G \times \eta_G \times Q \times (H_I – H_O)$

Turbine – Condensing

Measure

- Steam Pressure & Temperature at the turbine inlet & Outlet
- Steam (existing flow meter) / condensate flow (Volumetric Measurement)
- Quality (Wetness) of exhaust steam from turbine (Only for large turbines)
- Note down efficiency of alternator & gear box
- Actual power generated

Instruments

- Power meter
- Pressure gauges
- Temperature Indicators
- Instrument for wetness of steam
- Steam table

Out Come

- Efficiency - Isentropic as well as Thermal
- Saving Potential

Turbine – Condensing

Q : Flow rate of steam (kg/sec)

H_I : Enthalpy of steam at turbine inlet (kJ/kg) – (T_I & p_I)

H_O : Enthalpy of steam at turbine outlet (kJ/kg) - (T_O & p_O)

H_{OE} : Enthalpy of steam at turbine outlet at isentropic condition (kJ/kg) - (p_O)

η_A : Alternator efficiency

η_G : Gearbox efficiency

Isentropic Efficiency = $(H_I – H_O) / (H_I – H_{OE})$

Power Generation (kW) = $\eta_G \times \eta_G \times Q \times (H_I – H_O)$

Turbine – Gas

Measure

- Flow rate of gas (existing flow meter)
- Actual power generated
- Note down efficiency of alternator & gear box
- Analyze Gross calorific Value of the gas

Instruments

- Power meter

Out Come

- Thermal Efficiency
- Saving Potential

Turbine – Gas

Q : Flow rate of fuel (kg/sec)

H_F : Gross Calorific Value of (kJ/kg)

P : Actual Power Generated (kW)

η_A : Alternator efficiency

η_G : Gearbox efficiency

Turbine Efficiency (Thermal) = $P / (Q \times H_F \times \eta_G \times \eta_G)$

Boiler (Excluding Coil type)

Measure (during the specified period of time)

- Actual Generation of Steam (existing flow meter) / feed water quantity
- Fuel consumed in the boiler (flow meter / weighment)
- Combustion gas analysis –O_2, CO, CO_2
- Stack temperature & Flow rate
- Feed water / Steam temperature & Steam Pressure
- Carry out tests to determine Proximate Analysis and Gross Calorific value
- Surface area and temperature of boiler

Instruments

- Flue gas analyzer
- Ultrasonic flow meters
- Anemometer
- Temperature & Pressure indictors

Outcome

- Operating efficiency by direct & indirect method
- Saving potential

Boiler (excluding Coil type)

Q_F : Flow rate of fuel (kg/hr)
Q_S : Flow rate of steam (kg/hr)
H_F : Gross Calorific Value of (kJ/kg)
H_S : Enthalpy of Steam (kJ/kg)
H_W : Enthalpy of Water (kJ/kg)

Boiler Efficiency (Direct) = $Q_S \times (H_S - H_W) / (Q_F \times H_F)$

Boiler Efficiency Indirect

Boiler BEE.pdf

Furnace

Measure (during the specified period of time)

- Quantity of input material
- Fuel consumed in the furnace (flow meter / weighment)
- Combustion gas analysis –O_2, CO, CO_2
- Stack temperature & Flow rate
- Temperature of material at the inlet & outlet
- Carry out tests to determine Proximate Analysis and Gross Calorific value
- Surface area and temperature of furnace
- Openings with internal temperatures
- Evaporation with relevant data, if applicable

Instruments

- Flue gas analyzer
- Ultrasonic flow meters
- Anemometer
- Temperature indictors / pyrometers

Outcome

- Operating efficiency by direct & indirect method
- Saving potential

Furnace

Similar manner as boiler

Thank You!