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HVAC SYSTEMS - CEM REFRESHER
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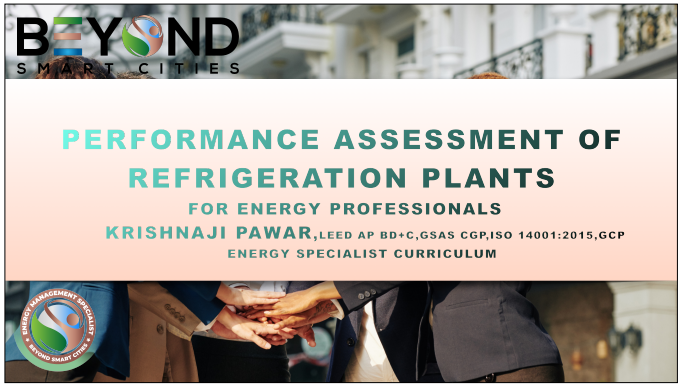
ENERGY SPECIALIST CURRICULUM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PERFORMANCE ASSESSMENT OF
REFRIGERATION PLANTS
FOR ENERGY PROFESSIONALS
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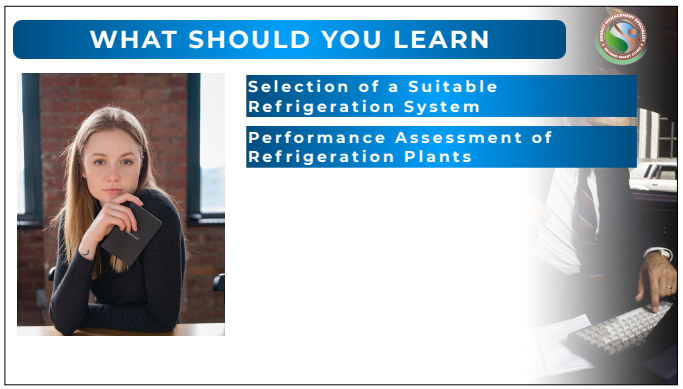

WHAT SHOULD YOU LEARN
Selection of a Suitable Refrigeration System
Performance Assessment of Refrigeration Plants

SELECTION OF A SUITABLE REFRIGERATION SYSTEM

A clear understanding of the cooling load to be met is the first and most important part of design- ing / selecting the components of a refrigeration system. Important factors to be considered in quantifying the load are the actual cooling need, heat (cool) leaks, and internal heat sources (from all heat generating equipment).

Consideration should also be given to process changes and / or changes in ambient conditions that might affect the load in the future. Reducing the load, e.g. through better insulation, maintaining as high a cooling temperature as practical, etc. is the first step toward minimizing electrical power required to meet refrigeration needs.

With a quantitative understanding of the required temperatures and the maximum, minimum, and average expected cooling demands, selection of appropriate refrigeration system (single-stage / multi-stage, economized compression, compound / cascade operation, direct cooling / secondary coolants) and equipment (type of refrigerant, compressor, evaporator, condenser, etc.) can be undertaken.

PERFORMANCE ASSESSMENT OF REFRIGERATION PLANTS

- The cooling effect produced is quantified as tons of refrigeration.(TR). 1 TR of refrigeration = 3024 kCal/hr heat rejected.
- The refrigeration TR is assessed as
  TR = Q x Cp x (Ti – To) / 3024
  Where
  Q is mass flow rate of coolant in kg/hr
  Cp is coolant specific heat in kCal /kg deg C
  Ti is inlet, temperature of coolant to evaporator (chiller) in °C
  To is outlet temperature of coolant from evaporator (chiller) in °C.

  The above TR is also called as chiller tonnage.
- The specific power consumption kW/TR is a useful indicator of the performance of refrigeration system. By measuring refrigeration duty performed in TR and the kiloWatt inputs, kW/TR is used as a reference energy performance indicator.

PERFORMANCE ASSESSMENT OF REFRIGERATION PLANTS

- In a centralized chilled water system, apart from the compressor unit, power is also consumed by the chilled water (secondary) coolant pump as well condenser water (for heat rejection to cooling tower) pump and cooling tower fan in the cooling tower. Effectively, the overall energy consumption would be towards:

  – Compressor kW
  – Chilled water pump kW
  – Condenser water pump kW
  – Cooling tower fan kW, for induced / forced draft towers
- The specific power consumption for certain TR output would therefore have to include:
  Compressor kW/TR
  Chilled water pump kW/TR
  Condenser water pump kW/TR
  Cooling tower fan kW/TR
  The overall kW/TR is the sum of the above.

PERFORMANCE ASSESSMENT OF REFRIGERATION PLANTS

The theoretical Coefficient of Performance (Carnot), COPCarnot - a standard measure of refrigeration efficiency of an ideal refrigeration system- depends on two key system temperatures, namely, evaporator temperature Te and condenser temperature Tc with COP being given as:

COPCarnot = Te / (Tc - Te)

This expression also indicates that higher COPCarnot is achieved with higher evaporator temperature and lower condenser temperature.

But COPCarnot is only a ratio of temperatures, and hence does not take into account the type of compressor. Hence the COP normally used in the industry is given by

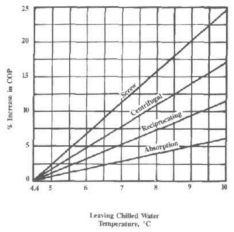
COP = Cooling effect (kW) / Power input to compressor (kW)

where the cooling effect is the difference in enthalpy across the evaporator and expressed as kW.

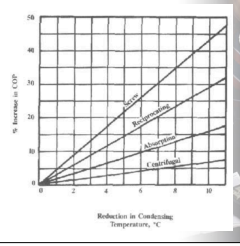
PERFORMANCE ASSESSMENT OF REFRIGERATION PLANTS

The effect of evaporating and condensing temperatures are given in the Figure 2 and Figure 3 below:

Effect of Evaporator Temperature on Chiller COP



Effect of Condensing Temperature on Chiller COP



PERFORMANCE ASSESSMENT OF REFRIGERATION PLANTS

In the field performance assessment, accurate instruments for inlet and outlet chilled water temperature and condenser water temperature measurement are required, preferably with a least count of 0.1°C. Flow measurements of chilled water can be made by an ultrasonic flow meter directly or inferred from pump duty parameters. Adequacy check of chilled water is needed often and most units are designed for a typical 0.68 m3/hr per TR (3 gpm/TR) chilled water flow.

Condenser water flow measurement can also be made by a non-contact flow meter direct- ly or inferred from pump duty parameters. Adequacy check of condenser water is also needed often, and most units are designed for a typical 0.91 m3/hr per TR (4 gpm / TR) condenser water flow.emperature On Chiller COP

PERFORMANCE ASSESSMENT OF REFRIGERATION PLANTS

In case of air conditioning units, the airflow at the Fan Coil Units (FCU) or the Air Handling Units (AHU) can be measured with an anemometer. Dry bulb and wet bulb temperatures are measured at the inlet and outlet of AHU or the FCU and the refrigeration load in TR is assessed as ;

$$TR = Q \times \rho \times (h_{in} - h_{out}) / 3024$$

Where, Q is the air flow in m3/h
ρ is density of air kg/m3
hin is enthalpy of inlet air kCal/kg
hout is enthalpy of outlet air kCal/kg

PERFORMANCE ASSESSMENT OF REFRIGERATION PLANTS

Use of psychometric charts can help to calculate hin and hout from dry bulb, wet bulb temperature values which are, in-turn measured, during trials, by a whirling psychrometer.

Power measurements at, compressor, pumps, AHU fans, cooling tower fans can be accomplished by a portable load analyzer.

Estimation of air conditioning load is also possible by calculating various heat loads, sensible and latent based on inlet and outlet air parameters, air ingress factors, air flow, no. of people and type of materials stored.

INTEGRATED PART LOAD VALUE (IPLV)

Although the kW/ TR can serve as an initial reference, it should not be taken as an absolute since this value is derived from 100% of the equipment's capacity level and is based on design conditions that are considered the most critical.

These conditions occur may be, for example, during only 1% of the total time the equipment is in operation throughout the year. Consequently, it is essential to have data that reflects how the equipment operates with partial loads or in conditions that demand less than 100% of its capacity. To overcome this, an average of kW/TR with partial loads ie Integrated Part Load Value (IPLV) have to be formulated.

The IPLV is the most appropriate reference, although not considered the best, because it only captures four points within the operational cycle: 100%, 75%, 50% and 25%. Furthermore, it assigns the same weight to each value, and most equipment usually operates at between 50 % and 75% of its capacity.

This is why it is so important to prepare specific analysis for each case that addresses the four points already mentioned, as well as developing a profile of the heat exchanger's operations during the year.

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