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Enthalpy Based Load Estimation Methodology for Treated Fresh Air Units in Humid Climatic Conditions

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Abstract: ***The growing emphasis on indoor air quality (IAQ), coupled with stringent ventilation standards and increasing energy costs, has made treated fresh air systems a critical component of modern HVAC design. In humid and tropical climates, the treatment of outdoor air imposes significant latent and sensible loads on cooling systems, particularly during monsoon conditions. This paper presents a systematic methodology for calculating the cooling and heating loads of Treated Fresh Air (TFA) units incorporating cooling and heating coils. The analysis is based on enthalpy differences between outdoor and indoor design conditions, with monsoon climate considered as the governing design case. A sample calculation is presented and illustrated using psychometric principles. The study reinforces the continued relevance of enthalpy-based load calculations, even with the integration of energy recovery technologies.***

Keywords: Treated Fresh Air (TFA), DOAS, HVAC load calculation, psychometrics, indoor air quality, monsoon design condition

1. Introduction

The design of heating, ventilation, and air-conditioning (HVAC) systems has evolved significantly in response to heightened awareness of indoor air quality (IAQ), occupant health, and energy efficiency. Engineers and system designers are increasingly challenged to deliver solutions that can condition large volumes of outdoor air while maintaining thermal comfort, humidity control, and economic viability.

Fresh air plays a fundamental role across diverse applications, including combustion processes, dilution of contaminants, pressurization of critical spaces, and most importantly, human respiration. Poor ventilation has been directly linked to sick building syndrome (SBS), increased absenteeism, and reduced productivity. Consequently, international standards and building codes now mandate higher outdoor air ventilation rates than in previous decades.

In hot and humid climates, outdoor air carries substantial moisture content, making latent heat removal the dominant factor in HVAC load calculations. Conventional air-conditioning systems are often inadequate to independently manage these loads, leading to poor humidity control and excessive energy consumption.

Treated Fresh Air (TFA) units- also known as Dedicated Outdoor Air Systems (DOAS)- have emerged as an effective approach to address these challenges. By separately conditioning outdoor air prior to its introduction into occupied spaces, TFA units enable improved humidity control, enhanced IAQ, and optimized system performance. This paper focuses on the load calculation emphasizing monsoon design conditions that typically dictate system sizing.

The total cooling load is directly proportional to the enthalpy difference between the outdoor air condition and the desired indoor condition.

Load Calculation Methodology

The total cooling or heating capacity of a TFA unit is calculated using the following equation:

$$Q=4.5\times CFM\times (H1-H2)$$

Where:
Q = Total cooling or heating capacity (BTU/h)
CFM = Fresh air flow rate (cubic feet per minute)
H1= Outdoor air enthalpy at design condition (BTU/lb)
H2= Indoor air enthalpy at design condition (BTU/lb)

The constant 4.5 accounts for air density and specific heat under standard conditions. This formulation inherently includes both sensible and latent heat components, making it particularly suitable for fresh air treatment applications.

Sample Calculation

1) Fresh air quantity: **500 CFM**
2) Outdoor (Monsoon) condition:
   - 95°F Dry Bulb
   - 83°F Wet Bulb
   - Enthalpy = **46.79 BTU/lb**
3) Indoor design condition:
   - 75°F Dry Bulb
   - 55% Relative humidity
4) Enthalpy = **29.13 BTU/lb**

Purpose and scope of treated fresh air units

Treated Fresh Air Units are specifically designed to condition 100% outdoor air before supplying it to indoor spaces. Their primary objectives include:

- Meeting mandatory ventilation requirements
- Controlling latent and sensible loads independently
- Improving indoor air quality
- Reducing microbial growth and condensation risks

Applications

TFA units are widely used in:

- Commercial office buildings
- Healthcare and hospital facilities

- Hotels and hospitality buildings
- Airports and transportation hubs
- Pharmaceutical and cleanroom environments

These facilities require strict control of temperature and humidity to ensure occupant comfort, hygiene, and equipment reliability.

Design basis: Monsoon conditions

In tropical and subtropical regions, HVAC systems are typically designed for **monsoon outdoor conditions**, characterized by high dry-bulb temperature and elevated humidity ratios. These conditions result in maximum air enthalpy and, therefore, represent the worst-case scenario for cooling and dehumidification loads.

The basis of TFA load calculation remains unchanged regardless of system sophistication: the unit must be capable of handling peak outdoor enthalpy conditions.

System Description and Operating Principle

A typical Treated Fresh Air Unit consists of the following components:

Cooling Capacity

$Q=4.5\times500\times(46.79-29.13)$
$Q=39{,}735$ BTU/h
$Q\approx3.3$ TR

This capacity represents the cooling requirement solely for treating the outdoor air, independent of internal space loads.

Design Implications and Energy Considerations

- Fresh air latent loads dominate in humid climates
- Increased ventilation rates significantly impact HVAC capacity
- Energy recovery devices reduce operating energy but not peak design load
- Accurate psychometric evaluation is critical for coil selection
- Improper sizing leads to humidity control issues and energy penalties

Designers must carefully integrate ventilation requirements, energy efficiency strategies, and IAQ objectives to achieve optimal system performance.

2. Conclusion

The increasing demand for superior indoor air quality and compliance with modern ventilation standards has elevated the importance of Treated Fresh Air Units in HVAC system design. In humid climates, monsoon outdoor conditions govern system sizing and impose substantial latent loads on cooling equipment.

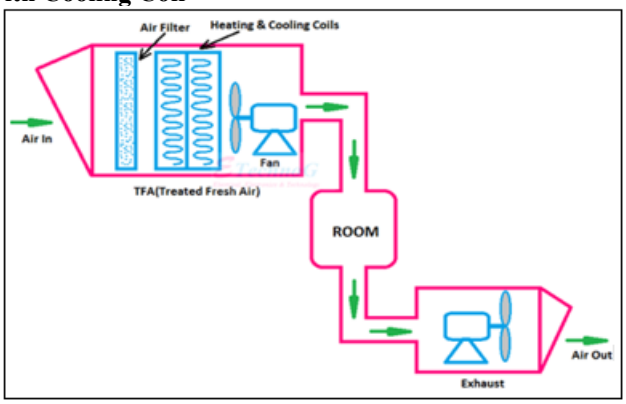
Despite advancements in energy recovery and desiccant-based technologies, the fundamental basis for TFA load calculation remains the enthalpy difference between outdoor and indoor air conditions. Accurate load estimation is essential to ensure effective humidity control, occupant comfort, and energy-efficient operation.

As building regulations continue to evolve, HVAC engineers must combine sound psychometric principles with innovative system solutions to meet future challenges.

- Outdoor air intake louver
- Multi-stage filtration system
- Cooling and/or heating coil
- Energy recovery device (optional)
- Supply air fan and control dampers

Outdoor air is drawn through filters and passed over the cooling coil, where it is cooled below its dew point temperature to remove moisture. The air may then be reheated to achieve the desired supply air condition before being introduced into the conditioned space.

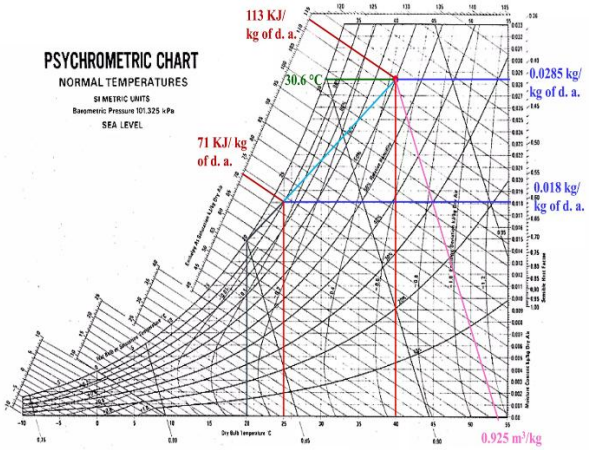
Schematic Diagram of a Typical Treated Fresh Air Unit with Cooling Coil



Psychometric Analysis of Fresh Air Treatment

Psychometric analysis forms the foundation of fresh air load calculations. The process of cooling and dehumidifying outdoor air can be represented on a psychometric chart, illustrating changes in temperature, humidity ratio, and enthalpy.

Psychometric Representation of Outdoor Air Treatment from Monsoon Condition to Indoor Design Condition



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