# ASHRAE Certified HVAC Designer (CHD) Study Guide

Welcome to the ASHRAE Certification Study Guide for Certified HVAC Designers (CHD). This comprehensive guide will help you prepare for the CHD certification exam by providing a framework to assess your knowledge and create a customized study plan. The guide covers all four domains of the exam, with practice questions, self-assessments, and resource recommendations to ensure you're fully prepared.

The CHD certification validates your competency as an HVAC designer working under the responsible charge of an engineer to design HVAC systems that meet building requirements, including load calculations, equipment selection, mechanical room design, and duct and piping layout for permit and construction.

# How to Use This Study Guide

### Self-Assessment Tools

Each domain includes Quick Quizzes and Self-assessments to help you identify your strengths and weaknesses. These tools will guide you to the specific ASHRAE resources you need to review.

### Practice Exam Questions

Test your knowledge with domain-specific practice questions that mirror the format and content of the actual CHD exam. Answers include references to help you locate relevant study materials.

### Study Map

Create a personalized study plan based on your self-assessment results. The Study Map helps you organize your preparation and focus on areas where you need the most improvement.

The guide is organized by domains and tasks, matching the structure of the CHD certification exam. This approach allows you to systematically review all the knowledge areas required for certification while focusing your efforts on the areas where you need the most preparation.

# CHD Exam Preparation Resources

## Primary Publications

- 2019 ASHRAE Handbook—HVAC Applications
- 2017 ASHRAE Handbook—Fundamentals
- 2016 ASHRAE Handbook—HVAC Systems & Equipment

## Secondary Publications

- ANSI/ASHRAE Standard 15, Safety Standard for Refrigeration Systems
- ANSI/ASHRAE Standard 55, Thermal Environmental Conditions for Human Occupancy
- ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality
- ANSI/ASHRAE/IES Standard 90.1, Energy Standard for Buildings

## Additional Resources

- Standard 90.1 User's Manual
- ANSI/ASHRAE/IES Standard 202, Commissioning Process for Buildings and Systems
- ANSI/ASHRAE Standard 209, Energy Simulation Aided Design
- ASHRAE Guideline 36, High-Performance Sequences of Operation for HVAC Systems
- Principles of Heating, Ventilating, and Air-Conditioning
- Air-Conditioning Systems Design Manual, 3rd Edition
- ASHRAE Learning Institute (ALI) courses
- ASHRAE eLearning On Demand courses
- CHD Practice Exam

# Domain 1: System Design Overview

### Conceptualization

Begin with a blank canvas and develop abstract design intent into a solid foundation for your HVAC system design.

### System Components

Break out your concept into individual segments that can be expanded upon later, identifying zones and equipment locations.

### Distribution Planning

Determine the best way to route supply and return ducts to effectively serve spaces while using the least amount of energy.

### Coordination

Identify potential interferences with other disciplines and plan for serviceability and noise considerations.

Domain 1 focuses on the art of HVAC design, involving conceptualization and higher-level design decisions. Your competency in these skills will distinguish you as a master designer rather than an amateur. The tasks in this domain will test your ability to develop concepts, identify room requirements, and create logical equipment and distribution layouts.

# Domain 1: Tasks A-F Self-Assessment

### Size Supply, Return, and Exhaust Ducts

Determine appropriate duct dimensions based on airflow requirements and space constraints

### Differentiate HVAC System Types

Select appropriate systems like VAV, VRF, radiant, or thermal storage

### Prepare HVAC Zoning Plans

Create zoning layouts and sensor locations according to building design needs

### Prepare Control Sequences

Develop control sequences and schematics for system operation

### Design Ductwork and Piping

Plan shaft and ceiling space requirements for distribution systems

For each task, assess your confidence level and consult the recommended resources. For Task A, review the 2017 Fundamentals Handbook, Chapter 21. For Task B, focus on the 2019 Applications Handbook, Chapter 48. Task C requires understanding of control sequences found in the 2019 Applications Handbook, Chapter 43.

# Domain 1: Tasks G-L Overview

### Minimize Pressure Loss

Design duct and fluid systems to reduce power requirements

### Select HVAC Equipment

Choose appropriate AHUs, fans, pumps, chillers based on calculations

### Design Air Diffusion

Select proper air devices following codes and standards

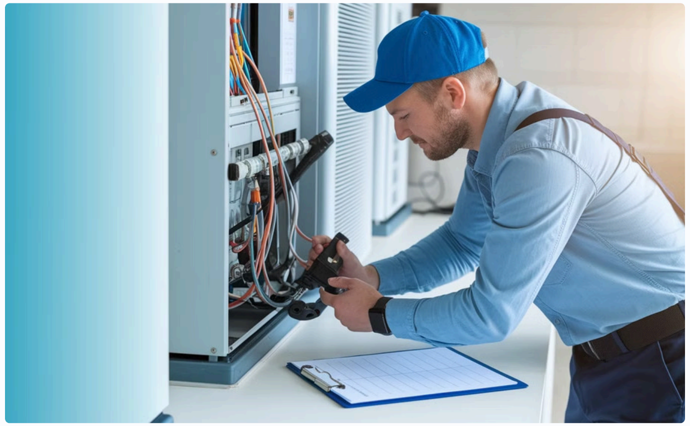
Tasks G-L build upon the work done in Tasks A-F, narrowing in on the details that were left out earlier. These tasks are critical to carry your design forward and ensure it meets the design intent. You'll refine duct and piping paths to minimize pressure loss, select appropriate air distribution devices, and prepare detailed design documentation.

Your competency in these tasks will ensure you can properly communicate your design, which is paramount to ensuring that whoever carries your design from paper to the real world will achieve the goals you set from the beginning.

# Domain 1: Tasks M-R Overview

## Renovation Challenges

Renovations are often more complicated than new construction projects. Designers frequently operate with poor as-built documentation and limited access to existing distribution systems.



## System Evaluation

Your ability to investigate and audit existing system designs, evaluate equipment, and determine capacities using supporting documentation is crucial for project success.


## Technology Integration

Recommending integration of new technologies to increase efficiency and effectiveness of HVAC systems requires understanding both existing conditions and current innovations.

Tasks M-R evaluate your understanding of design functionality and designs affecting existing buildings. Due to the nature of renovations, an HVAC designer relies heavily on effective coordination and communication. Proper focus on these skills will pay dividends throughout the project lifecycle.

# Domain 1: Tasks S-Z Overview

## Design for System Balancing

Create systems with appropriate balancing dampers, valves, and self-balancing control valves to ensure proper distribution of air and water throughout the building.

## Prepare Flow Diagrams

Develop ductwork and piping flow diagrams that clearly convey design intent, including primary/secondary systems, pumping arrangements, and distribution networks.

## Select Major Components

Size and select expansion tanks, heat exchangers, air handlers, boiler plants, pumps, valves, fans, and other critical system components based on calculated requirements.

## Design Safety Systems

Incorporate leak detection systems and other safety features to protect equipment, building occupants, and the environment.

Tasks S-Z round out the rest of the design by providing needed detail. At this point, you incorporate calculations and integrate them into your design. These final touches complete your design's journey from abstract intent to a tangible, workable product.

# Domain 1: Practice Exam Sample Questions

1. Which design method should be used to size ducts downstream of terminal boxes, toilet exhaust ducts, and other low-pressure systems?

A. Equal friction method
B. Static friction method
C. Static regain method

2. For duct sizing, the static regain method should be avoided for:

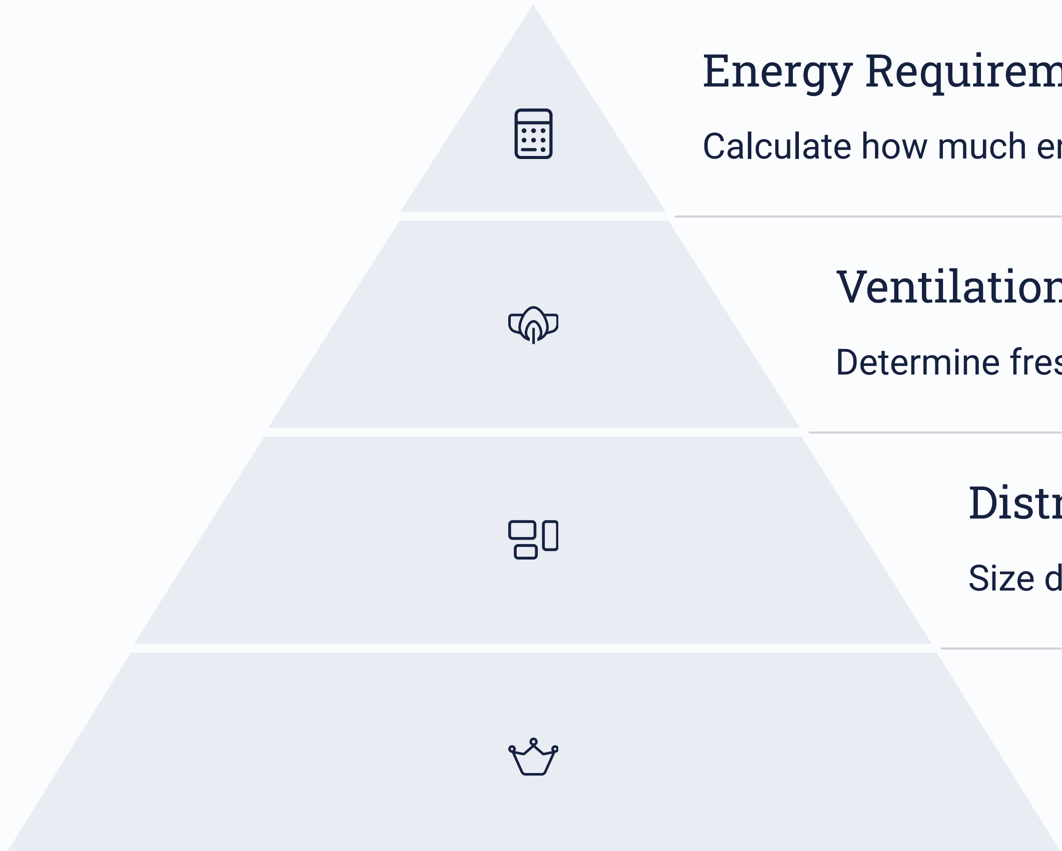
A. Positive-pressure duct systems
B. Negative-pressure systems
C. Low-pressure duct systems

3. Which statement is MOST accurate regarding the task of sequencing heating and cooling?

A. Central fan systems should not use cool outdoor air in sequence between heating and cooling
B. Heating and cooling should be supplied simultaneously for humidity control
C. Zoning and system selection should eliminate, or at least minimize, simultaneous heating and cooling

The practice exam questions test your knowledge of key concepts in system design. For example, question 1 tests your understanding of duct sizing methods, where the equal friction method (answer A) is typically used for low-pressure systems. Question 3 addresses the important principle of minimizing simultaneous heating and cooling (answer C) to improve energy efficiency.

# Domain 2: Design Calculations Overview



### Energy Requirements

Calculate how much energy to add or remove from spaces

### Ventilation Needs

Determine fresh air and exhaust requirements

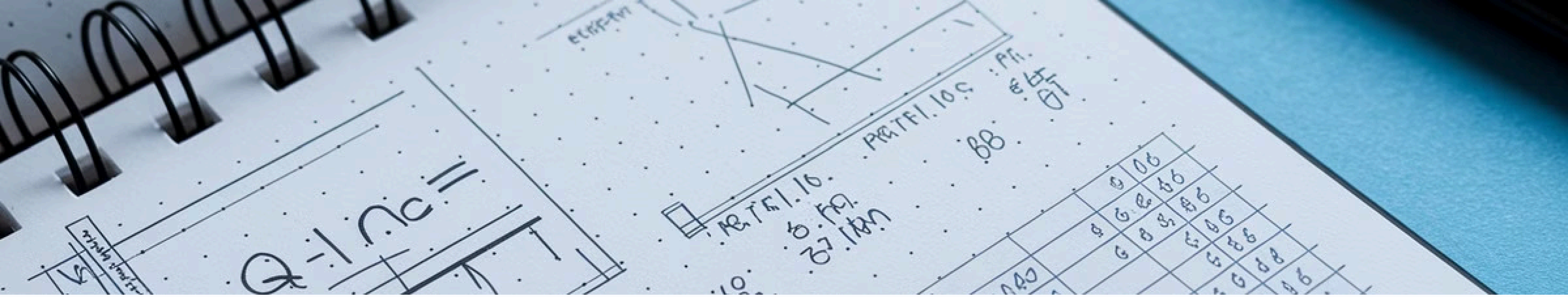
### Distribution Sizing

Size ducts and pipes to carry heating and cooling mediums

### Component Selection

Choose system components to suit unique demands

If Domain 1 is the art of HVAC, then Domain 2 is certainly the science. The skills tested under this domain ensure that your design achieves its goals through accurate calculations. While Domain 1 builds a solid foundation for your design, those efforts are wasted if your calculations are inaccurate or based on incorrect assumptions.



# Domain 2: Design Calculations Self-Assessment

**10**

### Key Tasks

Total number of tasks to master in Domain 2

**25%**

### Exam Weight

Approximate percentage of exam questions from this domain

**3**

### Critical Formulas

Essential calculation types: load, flow, and pressure

**5**

### Key Resources

Primary handbook chapters needed for study

For each task in Domain 2, assess your confidence level and consult the recommended resources. Task A requires understanding of HVAC system requirements found in the 2017 Fundamentals Handbook, Chapters 21 and 22. Task F focuses on heat load calculations for individual spaces, covered in Chapters 17 and 18 of the same handbook.

# Domain 2: Calculation Types and Methods

## Load Calculations

Heat gain and loss calculations determine the amount of heating or cooling required for each space. These calculations account for:

- Conduction through building envelope
- Solar radiation through glazing
- Internal heat gains from people, lights, and equipment
- Ventilation and infiltration loads
- Heat storage effects in building mass

## Flow and Pressure Calculations

Distribution system calculations determine the size of ducts and pipes and the capacity of fans and pumps:

- Duct sizing using equal friction, static regain, or velocity methods
- Pipe sizing based on flow rates and allowable pressure drop
- Fan and pump head calculations
- System effect factors and component pressure losses
- Critical path analysis for complex systems

Accurate calculations are the foundation of successful HVAC design. The formulas and methods used must account for all factors affecting system performance, from building orientation and construction to occupancy patterns and equipment selection. Understanding the relationships between these variables is essential for creating efficient, effective systems.

# Domain 2: Practice Exam Sample Questions

1. A louver is rated to resist water penetration for velocities up to 1000 fpm (5.1 m/s) and has 70% free area. What is the maximum airflow that can flow through a louver with an overall area of 12 $ft^2$ (1.11 $m^2$)?

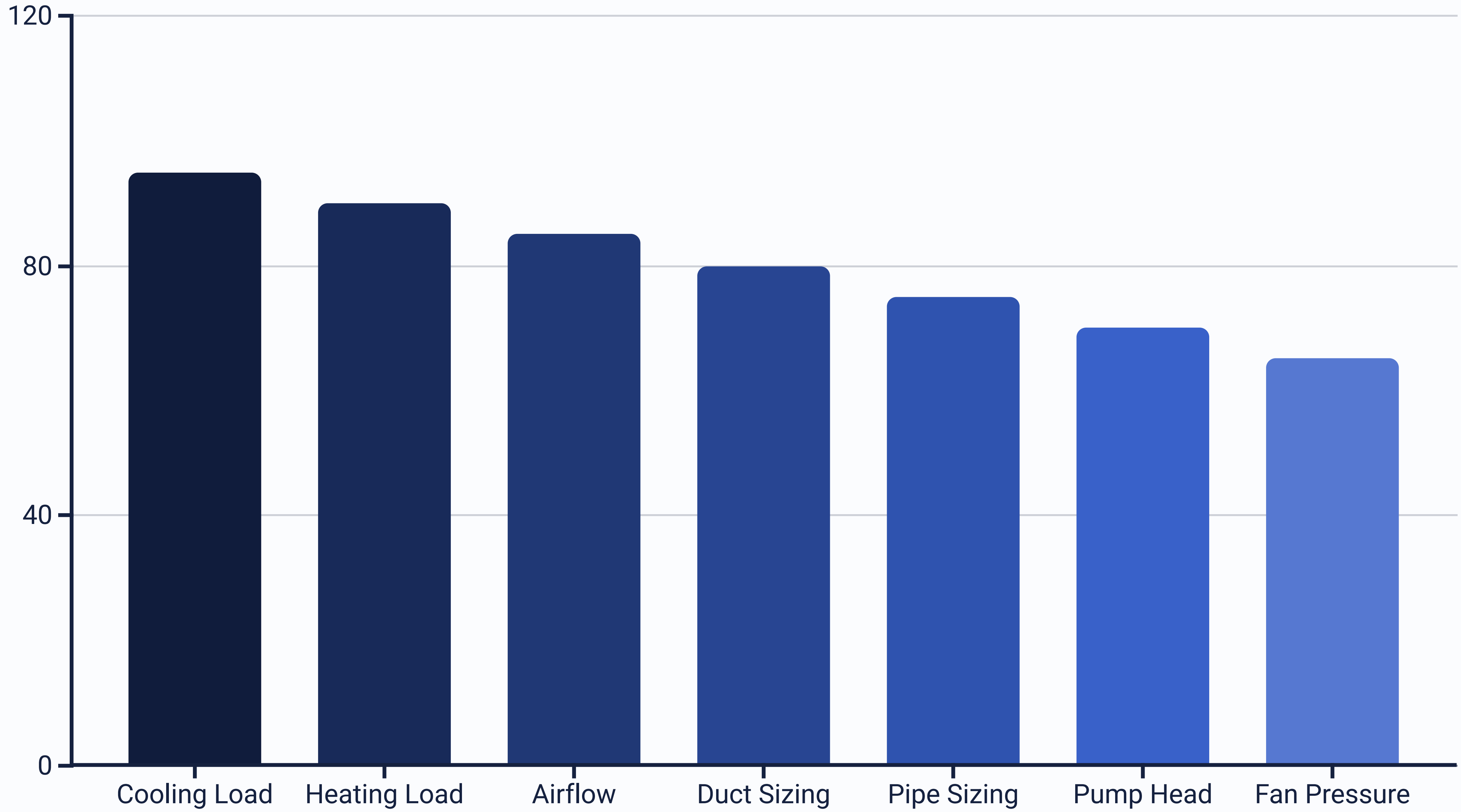
A. 3600 cfm (102 $m^3$/min)
B. 8400 cfm (238 $m^3$/min)
C. 12,000 cfm (340 $m^3$/min)

2. An existing building is served by a chiller plant operating at delta T 10F (5.56 C) with total chilled water flow 700 U.S. gpm (44.16 L/s). The building owner decides to replace the chiller plant with a new high-performance chiller plant, while maintaining the same total cooling capacity. The new chiller plant will operate at delta T 14F (7.78 C). What is the TOTAL chilled water flow of the new pump(s)?

A. 500 U.S. gpm (31.55 L/s)
B. 700 U.S. gpm (61.83 L/s)
C. 980 U.S. gpm (44.16 L/s)

The practice exam questions test your ability to perform calculations essential to HVAC design. Question 1 requires calculating the maximum airflow through a louver based on its free area and velocity rating. Question 2 tests your understanding of the relationship between flow rate and temperature difference in a chilled water system when maintaining the same cooling capacity.

# Domain 2: Common HVAC Design Formulas




Key formulas you should know include:

Sensible Heat: Hs = 1.085 × CFM × ΔT (I-P) or Hs = cp ρ q ΔT (SI)

Latent Heat: HL = 0.68 × CFM × ΔWGR (I-P) or HL = c1 ρ q ΔW (SI)

Water Flow: GPM = (H × 24)/ΔT (I-P) or q = H/(ρ × cp × ΔT) (SI)

Air Change Rate: ACH = (CFM × 60)/V (I-P) or ACH = (q × 3600)/V (SI)

Velocity: V = Q/A (both I-P and SI)

These formulas form the foundation of HVAC calculations and are essential for accurate system design.

# Domain 3: Procedural Overview

## Code Compliance

Analyze buildings, designs, and HVAC plans for compliance with applicable codes, standards, and regulations to ensure safety and performance.

## Documentation Review

Review shop drawings and equipment submittals to verify compliance with contract documents and design intent before installation begins.

## Field Verification

Perform field investigations to verify as-built conditions, create punch lists, and document quality control measures throughout construction.

## Consultant-Contractor Interaction

Review and respond to requests for information (RFIs) and coordinate with authorities having jurisdiction for permit applications.

Domain 3 focuses on the procedures that HVAC designers execute to take their designs from paper to reality. The procedural work in this domain is paramount to achieving the goals set out in Domains 1 and 2. Carefully following proper procedures ensures your design will be built to your specifications.

# Domain 3: Procedural Self-Assessment

## Code Compliance Tasks

- Analyze buildings for compliance with codes and standards
- Apply Building Information Modeling (BIM) standards
- Review and comply with HVAC codes and standards

## Documentation Tasks

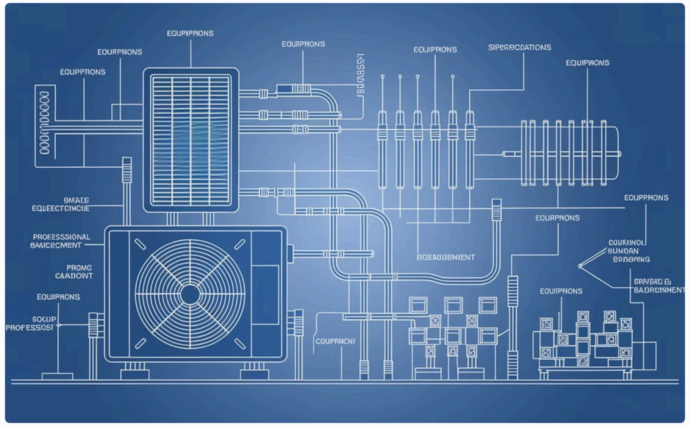
- Review shop drawings and equipment submittals
- Interpret design documents during bidding/tender
- Prepare HVAC documentation for building permits
- Incorporate field "as-built" documents into final documents

## Field Verification Tasks

- Verify and document as-built field conditions
- Perform periodic field investigations
- Review and respond to Requests for Information (RFI)

For each task in Domain 3, assess your confidence level and consult the recommended resources. Task A requires understanding of code compliance found in the 2017 Fundamentals Handbook, Chapter 40. Tasks C through K focus on construction phase activities covered in the 2019 Applications Handbook, Chapter 44.

# Domain 3: Construction Documentation

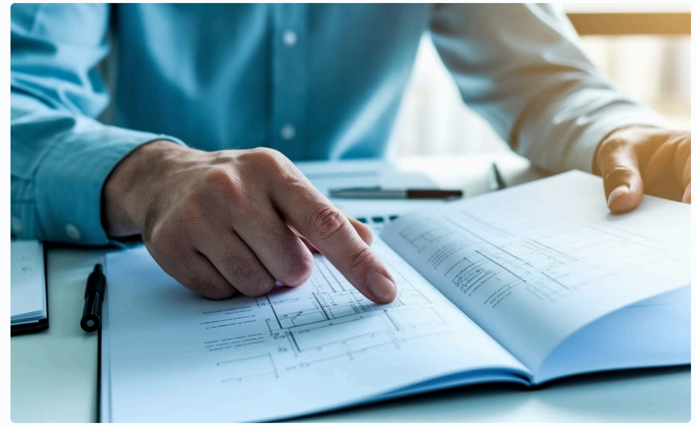


## Shop Drawings

Shop drawings provide detailed information about equipment and systems to be installed. They translate design intent into specific installation details and must be carefully reviewed for compliance with specifications and coordination with other trades.

## As-Built Documentation

As-built drawings document the actual installation, including any field modifications from the original design. These records are essential for future maintenance, troubleshooting, and renovations.



## RFI Process

Requests for Information provide a formal process for contractors to seek clarification on design documents. Timely and accurate responses to RFIs help prevent construction delays and ensure proper system installation.

Proper documentation throughout the construction process is essential for successful project completion. The HVAC designer plays a critical role in reviewing submittals, responding to field questions, and ensuring that the installed systems match the design intent.

# Domain 3: Practice Exam Sample Questions

1. Which of the following is developed with the help of users, occupants, and owners?

A. Basis of design (BOD)
B. Current facility requirements (CFR)
C. Existing building commissioning (EBCx) process

2. What is the building design and documentation methodology that relies on the creation and collection of interrelated, computable information about a building project that is a reliable, coordinated, and internally consistent digital representation of the building?

A. Building information management (BIM)
B. Building information modeling (BIM)
C. Computer-aided design (CAD) systems

3. In a situation of disputes or ambiguities, the highest priority document to refer to is which of the following?

A. Contract
B. Project manual
C. Drawings

The practice exam questions test your understanding of procedural aspects of HVAC design. Question 1 addresses the development of facility requirements documents. Question 2 tests your knowledge of Building Information Modeling (BIM). Question 3 examines your understanding of contract document hierarchy in resolving disputes.

# Domain 4: Coordination Overview

### Design Team Coordination

Collaborate with architects, structural designers, plumbing designers, and electrical designers throughout all design phases

### Structural Coordination

Coordinate with structural engineers for equipment support, duct and pipe runs, anchorage, and seismic requirements

### Electrical Coordination

Work with electrical designers on power requirements, controls, and space needs for mechanical equipment

### Plumbing Coordination

Coordinate domestic water and waste requirements with plumbing designers

### Acoustical Coordination

Work with acoustical engineers on equipment selection and distribution design to meet sound requirements

An HVAC designer does not exist in a vacuum. Your work affects, and is affected by, every system and assembly in the building. Domain 4 measures your ability to coordinate with other individuals or teams and ensure your design meets the conditions presented.

# Domain 4: Coordination Tasks A-J

## Design Development Tasks

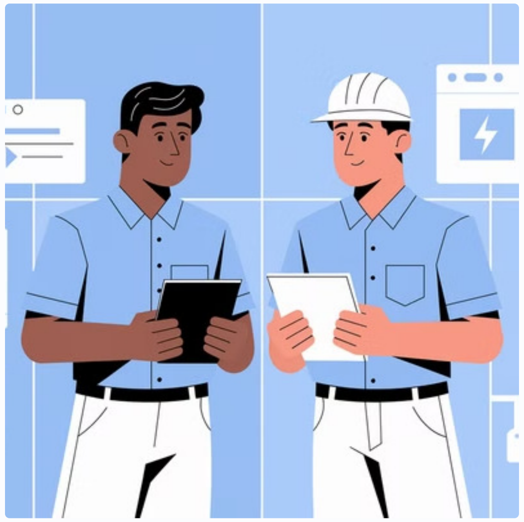
- Assist in the development of the basis of design (BOD)
- Review HVAC drawings with Commissioning Authority (CxA)
- Coordinate space requirements for HVAC equipment
- Modify HVAC design documents based on team reviews
- Coordinate systems expansion compensation design with structural engineer

## Architectural Coordination Tasks

- Analyze architectural plans, sections, and elevations for HVAC design
- Comply with client specifications and performance requirements
- Collaborate in the development of HVAC systems and design parameters
- Review architectural life safety plan relative to mechanical plan
- Coordinate with life safety engineer for smoke management systems

For each task in Domain 4, assess your confidence level and consult the recommended resources. Task A requires understanding of basis of design development found in the 2019 Applications Handbook, Chapters 44 and 60. Tasks I and J focus on life safety coordination covered in Chapters 44 and 54 of the same handbook.

# Domain 4: Coordination Tasks K-U



Tasks K-U focus on coordination with specific disciplines and stakeholders. These tasks include coordinating with electrical designers on power requirements, structural engineers on support and seismic needs, plumbing designers on water and waste requirements, acoustical engineers on sound control, and energy modelers on system performance.

Additional tasks involve coordinating with civil engineers on site utilities, vendors on equipment schedules, and reviewing drawings to identify potential obstructions that may impact the HVAC system installation.

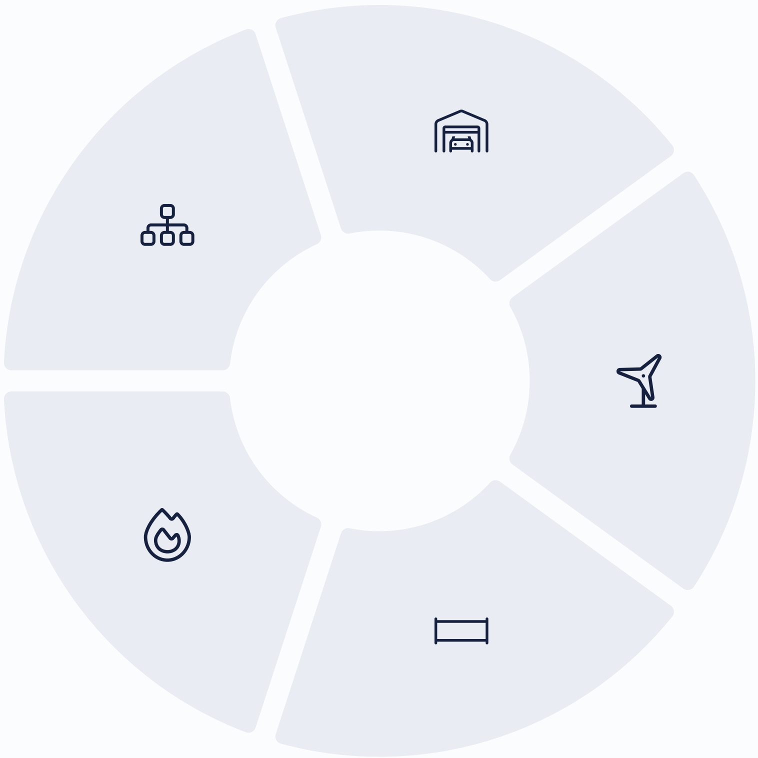
# Domain 4: Interdisciplinary Coordination

## Structural

Coordinate equipment weights, support requirements, penetrations, and seismic restraints

## Architectural

Coordinate ceiling heights, equipment locations, shaft spaces, and aesthetic concerns



## Electrical

Coordinate power requirements, control systems, lighting integration, and emergency power

## Fire Protection

Coordinate smoke control, fire dampers, and equipment shutdown sequences

## Plumbing

Coordinate water supply, drainage, and space requirements for mechanical equipment

Effective coordination requires understanding the needs and constraints of each discipline. The HVAC designer must be able to communicate technical requirements clearly and work collaboratively to resolve conflicts. Building Information Modeling (BIM) has become an essential tool for identifying and resolving interdisciplinary clashes before construction begins.

# Domain 4: Practice Exam Sample Questions

1. What is the document that records the concepts, calculations, decisions, and product selections used to meet the owner's project requirements (OPR)?

A. Basis of design (BOD)
B. Current facility requirements (CFR)
C. Systems manual

2. When is the MOST appropriate time to begin the commissioning process on a project?

A. Commissioning is unnecessary if the designer has completed their work properly
B. During the predesign phase, when the scope and intent have been established
C. When the project is completed and performance needs to be verified

3. When coordinating with architectural members of the design team, what relevant information should the HVAC designer provide as it relates to HVAC equipment placement?

A. Equipment tonnage
B. Power and voltage requirements
C. Service clearances and clearance to combustibles

The practice exam questions test your understanding of coordination aspects of HVAC design. Question 1 addresses documentation of design decisions. Question 2 examines the timing of commissioning activities. Question 3 tests your knowledge of critical information needed for equipment placement coordination with architects.

# Creating Your CHD Certification Study Map

### Self-Assessment

Complete the self-assessments for all domains to identify your strengths and weaknesses

### Prioritize Topics

Focus on areas where you have the least confidence and highest exam weight

### Create Schedule

Develop a 6-week study plan with specific domains and tasks for each week

### Practice Questions

Test your knowledge with practice questions after studying each domain

After completing your self-assessments for all domains, use the Task Notes section to record which topics need the most attention. Then create a weekly study schedule leading up to your exam date. The suggested 6-week schedule can be adjusted based on your timeline and needs.

Remember to balance your study time according to the exam weight of each domain: Domain 1 (40%), Domain 2 (25%), Domain 3 (15%), and Domain 4 (20%).

# Common HVAC Design Formulas

## Cooling & Heating Equations (SI)

Sensible Heat: $H_s = c_p \rho q \Delta T$

Latent Heat: $H_L = c_1 \rho q \Delta W$

Total Heat: $H_T = \rho q \Delta h$

Sensible Heat Ratio: $SHR = H_s / H_T$

Where:

$H_s$ = Sensible Heat (kW)

$H_L$ = Latent Heat (kW)

$H_T$ = Total Heat (kW)

$\Delta T$ = Temperature Difference (°K)

$q$ = Air Volume Flow ($m^3/s$)

$\rho$ = Density of Air (1.202 $kg/m^3$)

$c_p$ = Specific Heat of Air (1.0 kJ/kg·K)

$c_1$ = Air Latent Factor (typically 3010)

$\Delta W$ = Humidity Ratio Difference (kg water/kg dry air)

$\Delta h$ = Enthalpy Difference (kJ/kg)

## Cooling & Heating Equations (I-P)

Sensible Heat: $H_s = 1.085 \times CFM \times \Delta T$

Latent Heat: $H_L = 0.68 \times CFM \times \Delta W_{GR} = 4840 \times CFM \times \Delta W_{LB}$

Total Heat: $H_T = 4.5 \times CFM \times \Delta h$

Sensible Heat Ratio: $SHR = H_s / H_T$

Where:

$H_s$ = Sensible Heat (Btu/hr)

$H_L$ = Latent Heat (Btu/hr)

$H_T$ = Total Heat (Btu/hr)

$\Delta T$ = Temperature Difference (°F)

$\Delta W_{GR}$ = Humidity Ratio Difference (Gr.H2O/Lb.DA)

$\Delta W_{LB}$ = Humidity Ratio Difference (Lb.H2O/Lb.DA)

$\Delta h$ = Enthalpy Difference (Btu/Lb.DA)

CFM = Air Flow Rate (Cubic Feet per Minute)

# Thermal Resistance and Water System Equations

## Thermal Resistance Values

Thermal Value (R-Value): $R = t / k$

Thermal Transmittance (U-Value): $U = 1 / \Sigma R$

Where:

For SI:

$k$ = Thermal Conductivity ($W/(m \cdot K)$)

$R$ = Thermal Resistance ($(m^2 \cdot K)/W$)

$U$ = Thermal Transmittance ($W/(m^2 \cdot K)$)

$t$ = Thickness (m)

$\Sigma R$ = Sum of Individual R-Values

For I-P:

$k$ = Thermal Conductivity ($Btu/hr \cdot ft \cdot °F$)

$R$ = Thermal Resistance ($hr \cdot ft^2 \cdot °F/Btu$)

$U$ = Thermal Transmittance ($Btu/hr \cdot ft^2 \cdot °F$)

$t$ = Thickness (ft)

## Water System Equations

For SI:

$H = \rho \cdot q \cdot cp \cdot \Delta T$

$q \text{ (Evap)} = H / (\rho \cdot cp \cdot \Delta T)$

Where:

$H$ = Total Heat (kW)

$q$ = Water Flow Rate ($m^3/s$)

$\rho$ = Density of Water (997 $kg/m^3$)

$cp$ = Specific Heat of Water (4.187 $kJ/kg \cdot K$)

$\Delta T$ = Temperature Difference (°K)

For I-P:

$H = (GPM \cdot \Delta T) / 24$

$GPM \text{ (Evap)} = (H \cdot 24) / \Delta T$

$GPM \text{ (Cond)} = (H \cdot 30) / \Delta T$

Where:

$H$ = Total Heat (Tons of Refrigerant)

$\Delta T$ = Temperature Difference (°F)

$GPM$ = Water Flow Rate (Gallons per Minute)

# Air Change Rate and Mixed Air Temperature

## Air Change Rate Equations

For SI:

$ACH = (q \cdot 3600) / V$

Where:

ACH = Air Change Rate per Hour

q = Air Volume Flow ($m^3/s$)

V = Space Volume ($m^3$)

For I-P:

$ACH = (CFM \cdot 60) / V$

Where:

ACH = Air Change Rate per Hour

CFM = Air Volume Flow (cubic feet per minute)

V = Space Volume ($ft^3$)

## Mixed Air Temperature

$TMA = (TRA \cdot (QRA/QSA)) + TOA \cdot (QOA/QSA)$

Where:

For SI:

QSA = Supply Air (L/s)

QRA = Return Air (L/s)

QOA = Outside Air (L/s)

TMA = Mixed Air Temperature (°C)

TRA = Return Air Temperature (°C)

TOA = Outside Air Temperature (°C)

For I-P:

QSA = Supply Air (CFM)

QRA = Return Air (CFM)

QOA = Outside Air (CFM)

TMA = Mixed Air Temperature (°F)

TRA = Return Air Temperature (°F)

TOA = Outside Air Temperature (°F)

# Ductwork and Fan Equations

## Ductwork Equations

Total Pressure: $p_t = p_s + p_v$

Where:

$p_t$ = Total Pressure (Pa)

$p_s$ = Static Pressure (Pa)

$p_v$ = Velocity Pressure (Pa)

Velocity: $v = Q / A$

Where:

For SI:

v = Fluid Mean Velocity (m/s)

Q = Volumetric Flow Rate ($m^3/s$)

A = Cross-Sectional Area of Duct ($m^2$)

For I-P:

v = Fluid Mean Velocity (FPM)

Q = Volumetric Flow Rate (CFM)

A = Cross-Sectional Area of Duct ($ft^2$)

## Fan Affinity Laws

Flow Rate: $Q1 = Q2 \cdot (N1/N2)$

Static Pressure: $P1 = P2 \cdot (N1/N2)^2$

Electrical Power: $W1 = W2 \cdot (N1/N2)^3$

Where:

For SI:

Q = Volumetric Flow Rate ($m^3/s$)

N = Rotational Speed, RPM

P = Static Pressure (Pa)

W = Electrical Power (W)

For I-P:

Q = Volumetric Flow Rate (CFM)

N = Rotational Speed, RPM

P = Static Pressure (in.wg)

W = Electrical Power (W)

# Pump Equations and NPSH Calculations

## Pump Affinity Laws

Flow Rate: $Q1 = Q2 \cdot (N1/N2)$

Pump Head: $P1 = P2 \cdot (N1/N2)^2$

Electrical Power: $W1 = W2 \cdot (N1/N2)^3$

Where:

For SI:

Q = Volumetric Flow Rate ($m^3/s$)

N = Rotational Speed, RPM

P = Pump Head (bar)

W = Electrical Power (W)

For I-P:

Q = Volumetric Flow Rate (GPM)

N = Rotational Speed, RPM

P = Static Pressure (ft.wg)

W = Electrical Power (W)

## Pump Net Positive Suction Head (NPSH)

NPSHAVAIL = HA ± HS - HF - HVP

Where:

For SI:

NPSHAVAIL = Net Positive Suction Available (m)

NPSHREQ'D = Net Positive Suction Required (m)

HA = Pressure at Liquid Surface (m)

HS = Height of Liquid Surface Above/Below Pump (m)

HF = Friction Loss between Pump and Source (m)

HVP = Absolute Pressure of Water Vapor (m)

For I-P:

NPSHAVAIL = Net Positive Suction Available (ft)

NPSHREQ'D = Net Positive Suction Required (ft)

HA = Pressure at Liquid Surface (ft)

HS = Height of Liquid Surface Above/Below Pump (ft)

HF = Friction Loss between Pump and Source (ft)

HVP = Absolute Pressure of Water Vapor (ft)

NPSHAVAIL > NPSHREQ'D

# Cooling Tower and Efficiency Equations

## Cooling Tower Equations

Cycles of Concentration: $C = (E + D + B) / (D + B)$

Blowdown: $B = (E - ((C - 1) \cdot D)) / (C - 1)$

For SI:

Evaporation: $E = 0.00153 \cdot R \cdot m$

Drift: $D = 0.0002 \cdot m$

For I-P:

Evaporation: $E = GPM\ (Cond) \cdot R \cdot 0.00085$

Drift: $D = 0.0002 \cdot GPM\ (Cond)$

Range: $R = EWT - LWT$

Where:

m = Circulating Cooling Water ($m^3$/hr)

B = Blowdown ($m^3$/hr or GPM)

C = Cycles of Concentration

D = Drift ($m^3$/hr or GPM)

E = Evaporation ($m^3$/hr or GPM)

EWT = Entering Water Temperature (°C or °F)

LWT = Leaving Water Temperature (°C or °F)

R = Range (°C or °F)

## Efficiency Equations

For SI:

Coefficient of Performance (COP):

COP = Total Cooling Capacity (W) / (Compressor Input Power (W) + Condenser Fan Input Power (W))

Energy Efficiency Ratio (EER):

EER = Net Cooling Capacity (W) · 3.413 / Total Input Power (W)

For I-P:

Coefficient of Performance (COP):

COP = Total Cooling Capacity (BTU/h) / ((Compressor (W) + Condenser Fan (W)) · 3.413)

Energy Efficiency Ratio (EER):

EER = Net Cooling Capacity (BTU/h) / Total Input Power (W)

Cooling Towers and Heat Exchangers:

APPROACH (COOLING TOWER) = LWT - AWB

APPROACH (HEAT EXCHANGER) = EWTHS - LWTCS

RANGE = EWT - LWT

# Key HVAC Terminology: A-C

| | |
|---|---|
| **Acceptable indoor air quality** | Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction. |
| **Air changes** | Expression of the amount of air movement or air leakage into or out of a building in terms of the number of building volumes or room volumes exchanged. |
| **Air conditioning** | The process of treating air to meet the requirements of a conditioned space by controlling its temperature, humidity, cleanliness, and distribution. |
| **Air economizer** | A duct and damper arrangement and automatic control system that together allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather. |
| **Approach** | In a water cooling tower, the difference between the average temperature of the circulating water leaving the device and the average wet-bulb temperature of the entering air. In heat exchangers, the temperature difference between the leaving fluids. |
| **Basis of design (BOD)** | A document that records the concepts, calculations, decisions, and product selections used to meet the owner's project requirements and to satisfy applicable regulatory requirements, standards, and guidelines. |

# Key HVAC Terminology: B-C

| | |
|---|---|
| **Blowdown** | Discharge of water from a steam boiler or open recirculating system that contains high total dissolved solids; the addition of makeup water will reduce the concentration of dissolved solids to minimize their precipitation. |
| **Breathing zone** | The region within an occupied space between planes 3 and 72 in. (75 and 1800 mm) above the floor and more than 2 ft (600 mm) from the walls or fixed air-conditioning equipment. |
| **Bypass factor** | The percentage of the air that does not come into contact with the coil; the remaining air is assumed to exit the coil at the average coil temperature. |
| **Capacity** | Measure of the maximum amount of energy or material that may be stored in a given system. The rate of heat removal by the refrigerant used in the compressor or condensing unit in a refrigerating system. |
| **Cavitation** | Formation by mechanical forces of vapor in liquids; specifically, the formation of vapor cavities in the interior or on the solid boundaries of liquids in motion, where the pressure is reduced to a critical value without a change in ambient temperature. |
| **Coefficient of performance (COP)** | Ratio of the rate of net heat output to the total energy input expressed in consistent units and under designated rating conditions. Ratio of the refrigerating capacity to the work absorbed by the compressor per unit time. |

# Key HVAC Terminology: C-D

| | |
|---|---|
| **Compression tank** | Pneumatic cushioning device, operating at system pressure, that absorbs fluid expansion as a result of temperature change and prevents unnecessary periodic operation of the relief valve. |
| **Cooling design temperature** | The outdoor dry-bulb temperature equal to the temperature that is exceeded by 1% of the number of hours during a typical weather year. |
| **Cooling design wet bulb temperature** | The outdoor wet-bulb temperature equal to the temperature that exceeds a stated number of hours during a typical weather year. The value is normally stated as a percent. |
| **Daily range** | Difference between high and low temperatures for a typical day. Used in HVAC load calculations. |
| **Degree day (Kelvin-day)** | The difference in temperature between the outdoor mean temperature over a 24-hour period and a given base temperature, used in estimating heating and cooling energy use. |
| **Dew-point temperature** | Temperature of moist air saturated at pressure p, with the same humidity ratio W as that of the given sample of moist air. |

# Key HVAC Terminology: D-E

| | |
|---|---|
| **Direct digital control (DDC)** | A type of control where controlled and monitored analog or binary data are converted to digital format for manipulation and calculations by a digital computer or microprocessor, then converted back to analog or binary form to control physical devices. |
| **Direct expansion (DX) refrigeration systems** | System in which the cooling effect is obtained directly from the expansion of the liquid refrigerant into a vapor. Common term applied to an air-conditioning or refrigeration system that utilizes the vapor-compression refrigeration cycle. |
| **Displacement ventilation system** | A type of air-distribution system, used only for cooling purposes, in which air at a temperature below room temperature is supplied to the floor level at a low discharge velocity and is returned near ceiling level. |
| **Distribution system** | Conveying means, such as ducts, pipes, and wires, to bring substances or energy from a source to the point of use. The distribution system includes auxiliary equipment such as fans, pumps, and transformers. |
| **District cooling** | Concept of providing and distributing, from a central plant, cooling energy to a surrounding area (district) of tenants or clients (residences, commercial businesses, or institutional sites). |
| **Diversity factor** | Ratio, or percentage, obtained when the total output capacity of a system is divided by the total output capacity of all the terminal devices connected to the systems. |

# Key HVAC Terminology: D-E

| | |
|---|---|
| **Draft** | Current of air, when referring to pressure difference that causes a current of air or gases to flow through a flue, chimney, heater, or space. Also, the unwanted local cooling of the body caused by air movement. |
| **Drawdown** | Difference between the static water level and the active-pumping water level. |
| **Dry-bulb temperature (DBT)** | Temperature of air indicated by an ordinary thermometer shielded from solar and long wave radiation. In general, any thermometer that indicates the temperature of air (or other fluids); distinguished from a wet-bulb thermometer. |
| **Energy efficiency ratio (EER)** | Ratio of net cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions. Ratio of the net total cooling capacity to the effective power input at any given set of rating conditions, in watts per watt. |
| **Energy storage system** | System that has to be operated during on-peak as well as off-peak periods. System wherein the load demand is met by a combination of stored thermal energy and an energy conversion device. |
| **Enthalpy** | Thermodynamic quantity equal to the sum of the internal energy of a system plus the product of the pressure volume work done on the system. $H = E + pv$, where $H$ = enthalpy or total heat content, $E$ = internal energy of the system, $p$ = pressure, and $v$ = volume. |

# Key HVAC Terminology: E-F

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|---|---|
| **Equilibrium** | The steady-state condition during which the fluctuations of variables being measured remain within stated limits. |
| **Eutectic** | Mixture of substances whose solid and liquid phases in equilibrium have identical composition. Such a mixture has a minimum freezing point. |
| **Exfiltration** | Leakage of indoor air out of a building through similar types of openings. Like natural ventilation, it is driven by natural and/or artificial pressure differences. |
| **Exhaust air** | Air that must be removed from a space due to contaminants, regardless of pressurization. |
| **Expansion tank** | Partially filled tank for the accommodation of volume expansion of a fluid, typically water. |
| **Face velocity** | The rate of air movement at the face of the device (airflow rate divided by face area), expressed in m/s (fpm) to three significant figures. |

# Key HVAC Terminology: F-H

| | |
|---|---|
| **Failsafe** | Position or mode of operation a controlled device takes on removal of the control signal and/or power. To return to a position that, on loss of control system power, allows the controlled system to go to a safe mode. |
| **Fan total efficiency** | The ratio of fan power output to fan power input. |
| **Fenestration** | Commonly used to refer to any opening, usually glazed, in a building envelope; windows. Examples include windows, plastic panels, clerestories, skylights, glass doors that are more than one-half glass, and glass block walls. |
| **Free area** | Actual open area between the fins of a grille or register. Total area through which air can pass in a grille, face, or register. |
| **Friction loss** | Pressure loss due to friction between a flowing fluid and its contact surface. |
| **Global warming potential (GWP)** | An index developed to provide a simplified means of describing the relative ability of a chemical compound to affect radiative forcing, if emitted to the atmosphere, over its lifetime in the atmosphere, and thereby to affect the global climate. |

# Key HVAC Terminology: G-H

| | |
|---|---|
| **Gross floor area** | The sum of the floor areas of all the spaces within the building with no deductions for floor penetrations other than atria. Measured from the exterior faces of exterior walls or from the centerline of walls separating buildings. |
| **Heat capacity** | The amount of heat necessary to raise the temperature of a given mass one degree; numerically, the mass multiplied by the specific heat. The capacity of a body to store heat. |
| **Heat gain (heat uptake)** | Quantity of heat absorbed by an enclosed space or system. |
| **Heat index** | An index that combines air temperature and relative humidity in an attempt to determine the human-perceived equivalent temperature (how hot it feels, also termed the felt air temperature). |
| **Heat loss** | Energy required to warm outdoor air leaking in through cracks and crevices around doors and windows, through open doors and windows, and through porous building materials. Heat transferred through confining walls, glass, ceilings, floors, or other surfaces. |
| **Heat pump** | Thermodynamic heating/refrigerating system to transfer heat. The condenser and evaporator may change roles to transfer heat in either direction. By receiving the flow of air or other fluid, a heat pump is used to cool or heat. |

# Key HVAC Terminology: H-I

| | |
|---|---|
| **Humidifying effect** | Product of the mass of water evaporated times the latent heat at the evaporating temperature. |
| **Hydraulic diameter** | For a fully filled duct or pipe whose cross section is a regular polygon, the hydraulic diameter is equivalent to the diameter of a circle inscribed within the wetted perimeter. A commonly used approximation is to take four times the flow area divided by the perimeter of the solid boundary in contact with the fluid. |
| **HVAC zone** | A space or group of spaces within a building with heating and cooling requirements that are sufficiently similar so that desired conditions (e.g., temperature) can be maintained throughout using a single sensor (e.g., thermostat or temperature sensor). |
| **Indoor air** | Air inside the building envelope. |
| **Indoor air quality (IAQ)** | Attributes of the respirable air inside a building (indoor climate), including gaseous composition, humidity, temperature, and contaminants. |
| **Indoor environment quality (IEQ)** | A perceived indoor experience of the building indoor environment that includes aspects of design, analysis, and operation of energy efficient, healthy, and comfortable buildings. |

# Key HVAC Terminology: I-L

| | |
|---|---|
| **Infiltration** | Uncontrolled inward air leakage to conditioned spaces through unintentional openings in ceilings, floors, and walls from unconditioned spaces or the outdoors, caused by the same pressure differences that induce exfiltration. |
| **Inhibitor** | Chemical substance that reduces the rate of corrosion, scale formation, fouling, or slime production. |
| **Jacket** | Integral covering, sometimes fabric reinforced, that is applied over insulation. Also, the core, shield, or armor of a cable to provide mechanical or environmental protection. |
| **Jet** | Concentrated airstream formed as primary air leaves the diffuser. |
| **K-factor (thermal conductivity)** | Time rate of steady-state heat flow through a unit area of a homogeneous material, induced by a unit temperature gradient in a direction perpendicular to that unit area. |
| **Latent heat** | The change in enthalpy associated with a change in humidity ratio, caused by the addition or removal of moisture. |

# Key HVAC Terminology: L-M

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|---|---|
| **Latent heat of fusion** | Quantity of heat required to change a unit mass of ice to water at 32°F (0°C) temperature, measured in Btu/lbm (J/kg). |
| **Life-cycle cost** | Cost of equipment over its entire life including operating, maintenance, and repair/replacement cost. May also include decommissioning cost. |
| **Lift** | Vertical distance that fluid must be pumped to reach a specified height. |
| **Load profile** | Summary of thermal or other energy loads in a system over a period of time. Note: for example, a common load profile on a peak design day for thermal storage designs would show hourly system load requirements for 24 hours. |
| **Makeup air (dedicated replacement air)** | Air brought into a building from the outdoors to replace air that is exhausted. Makeup air may or may not be conditioned. |
| **Mean radiant temperature** | Theoretical uniform surface temperature of an enclosure in which an occupant would exchange the same amount of radiant heat as in the actual nonuniform enclosure. |

# Key HVAC Terminology: M-O

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|---|---|
| **Mean temperature** | Can be calculated as the average of temperature readings over a period of time or the average of the high and low temperatures over a given time. |
| **Mechanical cooling** | Reducing the temperature of a fluid by using vapor compression, absorption, desiccant dehumidification combined with evaporative cooling, or other energy-driven thermodynamic means. |
| **Mechanical heating** | Raising the temperature or change of phase of a solid or fluid by use of fossil-fuel burners, electric resistance heaters, heat pumps, or other systems that require energy to operate. |
| **Mechanical ventilation** | The active process of supplying or removing air to or from an indoor space by powered equipment such as motor-driven fans and blowers but not by devices such as wind-driven turbine ventilators and mechanically operated windows. |
| **Metabolic rate** | Rate of energy production of the body. The rate varies with the type of activity. The rate of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism, usually expressed in terms of unit area of the total body surface. |
| **Minimum efficiency reporting values (MERV)** | Scaled rating of the effectiveness of air filters. The scale is designed to represent the worst-case performance of a filter when dealing with particles in the range of 0.3 to 10 micrometers. |

# Key HVAC Terminology: M-O

| | |
|---|---|
| **Miscibility** | Ability of a liquid or gas to dissolve uniformly in another liquid or gas. |
| **Moisture carryover** | Retention and transport of water droplets in a gas stream (usually air) (e.g., water droplets formed by bridging fins of a coil and transported by the airstream). |
| **Natural ventilation** | Movement of air into and out of a space primarily through intentionally provided openings (such as windows and doors), through nonpowered ventilators, or by infiltration. |
| **Net positive suction head (NPSH)** | Minimum head at the pump inlet to prevent the liquid being pumped from flashing into a vapor at that temperature and pressure and potentially causing the pump to cavitate. |
| **Nominal capacity** | The capacity recorded and reported by a given test. The capacity reported by the manufacturer for a specified device. |
| **Nonstandard part-load value (NPLV)** | A single-number part-load efficiency figure of merit calculated and referenced to conditions other than IPLV conditions for units that are not designed to operate at ARI standard rating conditions. |

# Key HVAC Terminology: N-P

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|---|---|
| **Net occupiable area** | The floor area of an occupiable space defined by the inside surfaces of its walls but excluding shafts, column enclosures, and other permanently enclosed, inaccessible, and unoccupiable areas. |
| **Occupiable space** | Any enclosed space inside the pressure boundary (including, but not limited to, all habitable spaces, toilets, closets, halls, storage and utility areas, and laundry areas) and intended for human activities. |
| **Occupied zone** | The portion of the space that is normally occupied. The occupied zone is typically defined as encompassing all space from the floor level, excluding the space from the floor to 0.25 ft (0.076 m) above the floor, to 6 ft (1.83 m) above the floor and excluding the space from the wall to 2 ft (0.61 m) away from any wall. |
| **Operating differential** | Difference between the cut-out and cut-in at the sensing element. |
| **Operative temperature** | The uniform temperature of an enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual nonuniform environment. |
| **Optimization** | Collection of data in a control system in order to produce the best possible output, usually in accordance with what is most economical. |

# Key HVAC Terminology: O-P

| | |
|---|---|
| **Outdoor air** | Air outside a building or taken from the external atmosphere and, therefore, not previously circulated through the system. Ambient air that enters a building through a mechanical ventilation system, through intentional openings for natural ventilation, or by infiltration. |
| **Outlet velocity** | Average velocity of fluid emerging from an outlet measured in the plane of the outlet. |
| **Outside air** | Air external to a defined zone (e.g., corridors). |
| **Overall heat transfer coefficient** | Heat flow per area for a given construction and for an overall temperature difference of one degree. |
| **Overall thermal transfer value (OTTV)** | Quantity of heat transferred per unit of temperature difference into a building through its walls or roof, due to solar heat gain and outdoor/indoor temperature difference. |
| **Packaged terminal air conditioner (PTAC)** | A factory selected wall sleeve and separate unencased combination of heating and cooling components, assemblies, or sections. It may include heating capability by hot water, steam, or electricity and is intended for mounting through the wall to serve a single room or zone. |

# Key HVAC Terminology: P-R

| | |
|---|---|
| **Part-load value** | Single number figure of merit expressing part-load efficiency for equipment on the basis of weighted operation at various partial load capacities for the equipment; expressed in kilowatts per ton of refrigeration. |
| **Performance factor** | The ratio of capacity to power input at specified operating conditions. Using consistent units, the performance factor may be expressed in dimensionless form as a coefficient of performance (COP) or as the energy efficiency ratio (EER). |
| **Plane radiant temperature** | Uniform temperature of an enclosure where the radiance on one side of a small plane element is the same as in the nonuniform actual environment. |
| **Plenum** | A compartment or chamber, to which one or more ducts are connected, that forms a part of the air-distribution system and that is not used for occupancy or storage. A plenum often is formed in part or in total by portions of the building. |
| **Predicted mean vote (PMV)** | Index that predicts the mean value of thermal sensation votes of a large group of persons, expressed on a seven-point scale. |
| **Predicted percentage dissatisfied (PPD)** | Index that predicts the percentage of a large group of people who are likely to feel thermally dissatisfied for the body as a whole (i.e., feel either too warm or too cold). |

# Key HVAC Terminology: P-R

| | |
|---|---|
| **Pressure dependent (PD)** | The flow rate through a flow control device varies in response to changes in system pressure. |
| **Pressure head** | Hydrostatic height of fluid, equal to the fluid pressure divided by the density times the gravitational acceleration. |
| **Pressure independent** | The flow rate through a flow control device is not affected by changes in system pressure. |
| **Pressure limiting device** | A pressure-responsive electronic or mechanical control designed to automatically stop the operation of the pressure-imposing element at a predetermined pressure. |
| **Pressure sustaining valve** | Valve providing maintenance of designated pressure level within a system. |
| **Primary air** | Any air that is mixed with fuel at or in a burner prior to burning. In a clean room, air that recirculates through the work space. Treated supply air that enters the space through any supply air device, such as air outlet or through any air supply terminal, such as a VAV unit or fan terminal unit. |

# Key HVAC Terminology: P-S

| | |
|---|---|
| **Pump down** | Of refrigerant, withdrawal of all refrigerant from the low side of a system by pumping it to either the condenser or the liquid receiver. |
| **Range** | Difference between the highest and the lowest operational values, such as pressure, temperature, rate of flow, or computer values. Region between limits within which a quantity is measured, transmitted, or received, expressed by stating the lower and upper range values. |
| **Recirculated air** | Air taken from a space and returned to that space, usually after being passed through a conditioning system. The part of the return air that is reused. Air removed from a space and reused as supply air. |
| **Recirculating system** | A domestic or service hot-water distribution system that includes a closed-circulation circuit designed to maintain usage temperatures in hot-water pipes near terminal devices (e.g., lavatory faucets, shower heads) in order to reduce the time required to obtain hot water when the terminal device valve is opened. |
| **Refrigerating effect** | In a refrigeration system, the rate of heat removal. |
| **Return air** | Air removed from a space to be recirculated or exhausted. Air extracted from a space and totally or partially returned to an air conditioner, furnace, or other heating, cooling, or ventilating system. |

# Key HVAC Terminology: S

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|---|---|
| **Seasonal energy efficiency ratio – cooling only (SEER)** | For the cooling season, the ratio of the total heat removed from the conditioned space to the total electrical energy input if the combined appliance operated exclusively in a space-cooling-only (COOL) mode. The quantity is expressed in units of Btu/Wh. |
| **Sensible cooling panel** | A panel designed for sensible cooling of an indoor space through heat transfer to the thermally effective panel surfaces from the occupants and/or indoor space by thermal radiation and natural convection. |
| **Sensible heat** | The energy exchanged by a thermodynamic system that relates to a change of temperature. |
| **Sensible heat ratio (SHR)** | The ratio of sensible heat transfer to total (sensible + latent) heat transfer for a process. Also see sensible heat and latent heat. |
| **Setback** | Reduction of heating (by reducing the setpoint) or cooling (by increasing the setpoint) during hours when a building is unoccupied or during periods when lesser demand is acceptable. |
| **Setpoint** | Point at which the desired temperature (°F [°C]) of the heated or cooled space is set. |

# Preparing for Your CHD Certification Exam

### Review All Four Domains

Ensure you've studied all aspects of System Design, Design Calculations, Procedural tasks, and Coordination requirements.

### Take Practice Exams

Complete the CHD Practice Exam available from ASHRAE to familiarize yourself with the question format and timing.

### Memorize Key Formulas

Be comfortable with the common HVAC design formulas and know when to apply them to solve problems.

### Know the Standards

Be familiar with key ASHRAE standards referenced in the exam, particularly Standards 55, 62.1, and 90.1.

The CHD certification validates your competency as an HVAC designer and demonstrates your commitment to professional excellence. By thoroughly preparing with this study guide and the recommended resources, you'll be well-positioned to succeed on the exam and advance your career in HVAC design.

Good luck with your certification journey!