NCARB

ARE 4.0

EXAM GUIDE

Building Systems

This document, effective August 2015, supersedes all previous editions of the ARE® 4.0 Exam Guide: Building Systems. Please check NCARB's web site, www.ncarb.org, regularly for updates to the ARE 4.0 Exam Guides and for the most current information regarding the ARE.

BUILDING SYSTEMS

OVERVIEW

DIVISION STATEMENT

The evaluation, selection, and integration of mechanical, electrical, and specialty systems in building design and construction.

Content Areas

1. CODES & REGULATIONS
   (6-9 percent of scored items)
2. ENVIRONMENTAL ISSUES
   (9-11 percent of scored items)
3. PLUMBING
   (10-15 percent of scored items)
4. HVAC
   (18-23 percent of scored items)
5. ELECTRICAL
   (10-15 percent of scored items)
6. LIGHTING
   (15-20 percent of scored items)
7. SPECIALTIES
   (18-23 percent of scored items)

Vignettes

MECHANICAL & ELECTRICAL PLAN

Develop a reflected ceiling plan that integrates ceiling, lighting, mechanical, and structural systems and incorporates life safety considerations.

BUILDING SYSTEMS

KNOWLEDGE / SKILLS

The division has been broken down into a listing of knowledge and skills directly related to each major content area.

1. CODES & REGULATIONS
(6-9 percent of scored items)

A. Incorporate building codes, specialty codes, and other regulatory requirements in the design of mechanical, electrical, plumbing, conveying, and other specialty systems.

1. **Government and Regulatory Requirements and Permit Processes**
   Interpret codes, protocols, and procedures of government regulations to determine their impact on building design, and construction.

2. ENVIRONMENTAL ISSUES
(9-11 percent of scored items)

A. Apply sustainable design principles to the selection, design, and construction of building systems.

1. **Building Design**
   Utilize sustainable and environmental principles in building design as it relates to basic engineering systems.
2. **Building Systems and their Integration**
   Analyze and evaluate the implications of sustainable design decisions in relation to project goals.
3. **Implications of Design Decisions**
   Evaluate and determine environmental and sustainability parameters most appropriate for building design.
4. **Construction Details**
   Utilize sustainable and environmental design details and recognize their effect on constructability, aesthetics, and technical properties.
5. **Sustainable Design**
   Utilize sustainable design principles in building design as it relates to basic engineering systems.
6. **Alternative Energy Systems and New Technologies**
   Evaluate sustainable strategies to utilize alternative energy systems and evolving technologies in building design.
7. **Adaptive Reuse of Buildings and/or Materials**
   Evaluate sustainable strategies for adaptive reuse of components, systems and/or materials in building design.

3. PLUMBING
(10-15 percent of scored items)

A. PRINCIPLES
Analyze and design plumbing systems.

1. **Building Design**
   Apply basic engineering principles and technologies for plumbing systems in building design.
2. **Implications of Design Decisions**
   Analyze and evaluate the implications of plumbing system design decisions in relation project goals, cost, schedule, and quality.

BUILDING SYSTEMS

KNOWLEDGE / SKILLS

B. MATERIALS & TECHNOLOGY
Evaluate and select materials and construction details related to plumbing systems.

1. **Building Systems and their Integration**
   Evaluate and determine plumbing system parameters most appropriate for building design.

2. **Construction Details and Constructability**
   Utilize plumbing system details and recognize their effect on constructability, aesthetics, and technical properties.

4. HVAC
(18-23 percent of scored items)

A. PRINCIPLES
Analyze and design heating, ventilating, and air conditioning systems.

1. **Building Design**
   Apply basic engineering principles and technologies for HVAC systems in building design.

2. **Implications of Design Decisions**
   Analyze and evaluate the implications of HVAC system design decisions in relation to project goals, cost, schedule, and quality.

3. **Indoor Air Quality**
   Analyze and evaluate the implications of HVAC system design decisions in relation to indoor air quality.

B. MATERIALS & TECHNOLOGY
Evaluate and select materials and construction details related to heating, ventilating, and air conditioning systems.

1. **Building Systems and their Integration**
   Evaluate and determine HVAC system parameters most appropriate for building design.

2. **Construction Details and Constructability**
   Utilize HVAC system details and recognize their effect on constructability, aesthetics, and technical properties.

3. **Thermal and Moisture Protection**
   Analyze and evaluate the implications of thermal and moisture protection principles in relation to HVAC system design.

5. ELECTRICAL
(10-15 percent of scored items)

A. PRINCIPLES
Analyze and design electrical systems.

1. **Building Design**
   Apply basic engineering principles and technologies for electrical systems in building design.

2. **Implications of Design Decisions**
   Analyze and evaluate the implications of electrical system design decisions in relation to project goals, cost, schedule, and quality.

B. MATERIALS & TECHNOLOGY
Evaluate and select materials and construction details related to electrical systems.

1. **Building Systems and their Integration**
   Evaluate and determine electrical system parameters most appropriate for building design.

2. **Construction Details and Constructability**
   Evaluate and determine electrical system parameters most appropriate for building design.

BUILDING SYSTEMS

KNOWLEDGE / SKILLS

6. LIGHTING
(15-20 percent of scored items)

A. PRINCIPLES
Analyze and design natural and artificial lighting systems.

1. **Building Design**
   Apply basic engineering principles and technologies for lighting systems in building design.
2. **Implications of Design Decisions**
   Analyze and evaluate the implications of lighting system design decisions in relation to project goals, cost, schedule, and quality.
3. **Natural and Artificial Lighting**
   Evaluate and determine design principles and theories related to sustainable strategies, daylighting, solar control, energy consumption, and artificial lighting.

B. MATERIALS & TECHNOLOGY
Evaluate and select materials and construction details related to natural and artificial lighting systems.

1. **Building Systems and their Integration**
   Evaluate and determine lighting system parameters most appropriate for building design.
2. **Construction Details and Constructability**
   Utilize lighting system details and recognize their effect on constructability, aesthetics, and technical properties.
3. **Natural and Artificial Lighting**
   Utilize lighting components and details to recognize their effect on constructability, aesthetics, and technical properties.

7. SPECIALTIES
(18-23 percent of scored items)

A. ACOUSTICS
Evaluate, select, and design acoustical systems.

1. **Building Design**
   Apply basic engineering principles and technologies for acoustic systems in building design.
2. **Building Systems and their Integration**
   Evaluate and determine acoustic system parameters most appropriate for building design.
3. **Implications of Design Decisions**
   Analyze and evaluate the implications of acoustic system design decisions in relation to project goals.
4. **Construction Details and Constructability**
   Utilize acoustical components and details to recognize their effect on constructability, aesthetics, and technical properties.

B. COMMUNICATIONS & SECURITY
Evaluate, select, and design communications and security systems.

1. **Building Design**
   Apply basic engineering principles and technologies for communications and security systems in building design.
2. **Building Systems and their Integration**
   Evaluate and determine communications and security systems parameters most appropriate for building design.
3. **Implications of Design Decisions**
   Analyze and evaluate the implications of communication and security system design decisions in relation to project goals.

BUILDING SYSTEMS

KNOWLEDGE / SKILLS

4. **Construction Details and Constructability**
   Utilize communications and security system details and recognize their effect on constructability, aesthetics, and technical properties.

C. CONVEYING SYSTEMS

Evaluate, select, and design elevators, escalators, moving walkways, and other conveying systems.

1. **Building Design**
   Apply basic engineering principles and technologies for conveying systems in building design.
2. **Building Systems and their Integration**
   Evaluate and determine conveying system parameters most appropriate for building design.
3. **Implications of Design Decisions**
   Analyze and evaluate the implications of conveying system design decisions in relation to project goals.
4. **Construction Details and Constructability**
   Utilize conveying system details and recognize their effect on constructability, aesthetics, and technical properties.

D. FIRE DETECTION AND SUPPRESSION

Evaluate, select, and design fire detection and suppression systems.

1. **Building Design**
   Apply basic engineering principles and technologies for fire detection and suppression systems in building design.
2. **Building Systems and their Integration**
   Evaluate and determine fire detection and suppression system parameters most appropriate for building design.
3. **Implications of Design Decisions**
   Analyze and evaluate the implications of fire detection and suppression system design decisions in relation to project goals.
4. **Construction Details and Constructability**
   Utilize fire detection and suppression system details and recognize their effect on constructability, aesthetics, and technical properties.

BUILDING SYSTEMS

SAMPLE MULTIPLE-CHOICE QUESTIONS

Go to page 17 for answers.

1. An office area has an average continuous lighting load of 1,000 watts. What is the energy cost of providing lighting to this area for a 12-hour day, based on a unit cost of 8 cents per kilowatt-hour?

   _____ dollars

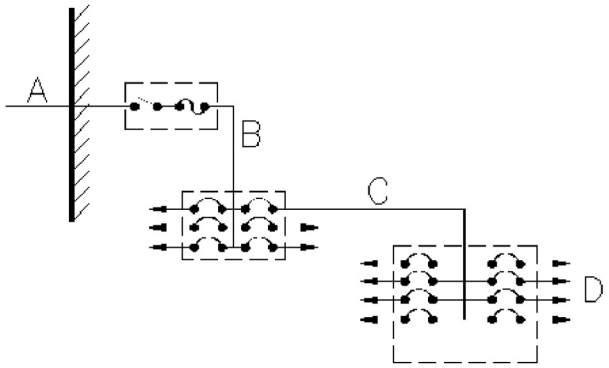
2. If the unit price of a central air-conditioning system is $1,000 per ton, what would be the total cost of a system able to provide cooling (refrigeration) for 96,000 Btu/h?

   _____ dollars

3. A waste line on a sloping lot must be run a horizontal distance of 75 feet. The vertical rise has been calculated to be 9.75 feet. What will be the percent grade of the waste line?

   _____ percent

4. In the single-line diagram of a typical electrical distribution system (below), which is the branch circuit?
   - ☐ A
   - ☐ B
   - ☐ C
   - ☐ D



5. Which of the following terms is defined as "water tested to be suitable for bathing, cooking, and consumption by humans"?
   - ☐ Well water
   - ☐ Groundwater
   - ☐ Potable water
   - ☐ Grey water

6. Which of the following is a requirement of electrical receptacles to be installed in a residential bathroom?
   - ☐ Locate adjacent to the light switch
   - ☐ Install below the level of toilet or lavatory fixtures
   - ☐ Include ground-fault circuit-interrupter protection
   - ☐ Locate a minimum of 6 ft from a tub or shower

BUILDING SYSTEMS

SAMPLE MULTIPLE-CHOICE QUESTIONS

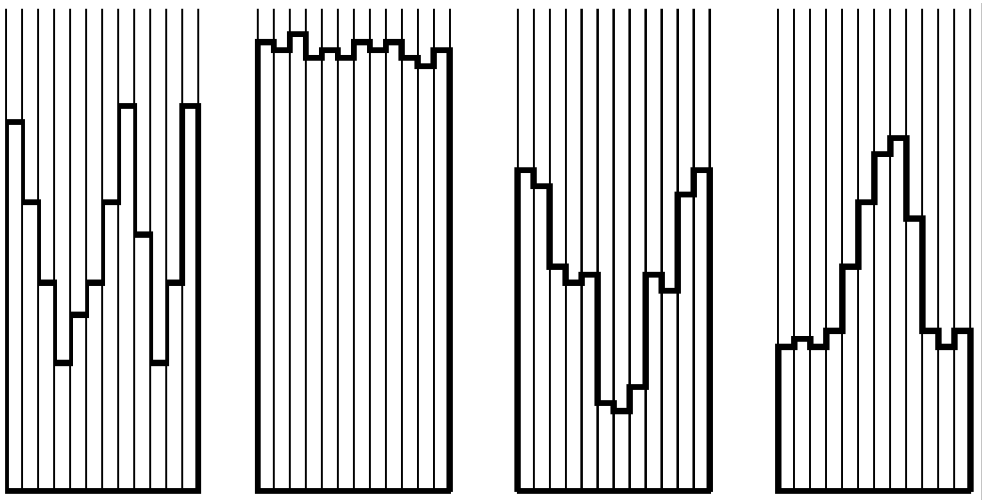
Go to page 17 for answers.

7. Which of the following can be used most effectively to limit low-frequency sounds in an HVAC system?
   - ☐ Turning vanes
   - ☐ Duct lining
   - ☐ Mufflers
   - ☐ Dampers

8. Which of the following plumbing fixture types is permitted to connect to a waste stack vent?
   Check the four that apply.
   - ☐ A. Bidet
   - ☐ B. Utility sink
   - ☐ C. Lavatory
   - ☐ D. Water closet
   - ☐ E. Bathtub
   - ☐ F. Standpipe

9. The flush control for a handicapped accessible urinal is a maximum of how many inches above the floor?
   - ☐ 36 in
   - ☐ 40 in
   - ☐ 44 in
   - ☐ 48 in

10. The following graphs show monthly energy consumption in kWh for four "all-electric" buildings located at 36° north latitude. If all four buildings have the same floor area, which graph shows the building that will probably benefit most from an energy-conserving retrofit that emphasizes reduction of lighting energy?



☐ ☐ ☐ ☐

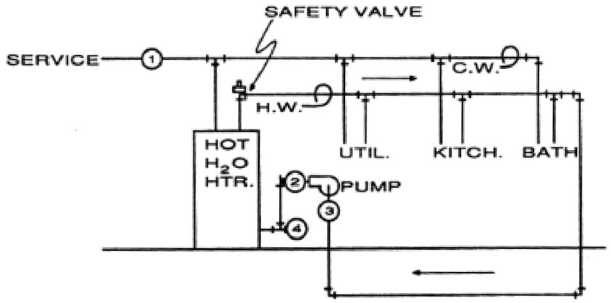
11. Which piping material has the highest coefficient of thermal expansion?
   - ☐ Plastic
   - ☐ Steel
   - ☐ Cast iron
   - ☐ Glass

BUILDING SYSTEMS

SAMPLE MULTIPLE-CHOICE QUESTIONS

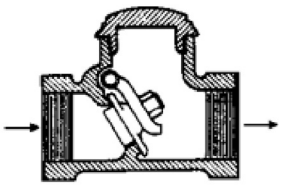
Go to page 17 for answers.

12. When found in a building's indoor air, carbon monoxide, radon, formaldehyde, and nicotine are all classified as
    - ☐ ventilation components
    - ☐ hydrocarbon-fuel emissions
    - ☐ building-materials emissions
    - ☐ indoor-air contaminants

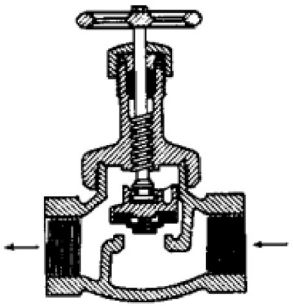


13. In the diagram above, which valve type should be used at position 3?

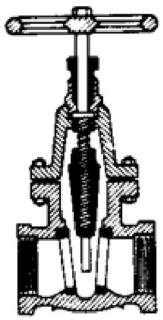
☐ CHECK



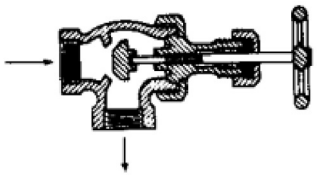
☐ GLOBE



☐ GATE



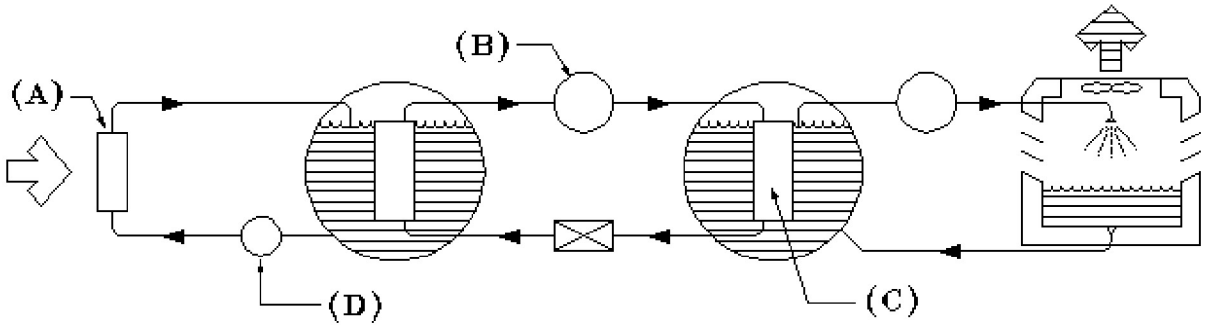
☐ ANGLE



BUILDING SYSTEMS

SAMPLE MULTIPLE-CHOICE QUESTIONS

Go to page 17 for answers.



14. The diagram above schematically illustrates a typical chiller and cooling tower cycle. At which point is the compressor located?

- ☐ A
- ☐ B
- ☐ C
- ☐ D

15. Resistance allowances for which of the following factors are included in the calculation of the U-value of a wall assembly? **Check the four that apply.**

- ☐ A. Unvented air spaces
- ☐ B. Orientation
- ☐ C. Building components
- ☐ D. Interior air film
- ☐ E. Exterior air film
- ☐ F. Building type

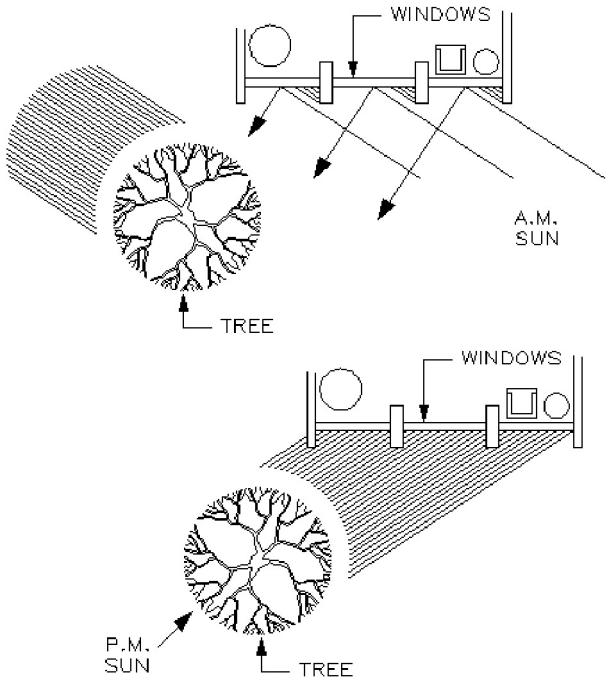
16. A developer wants to construct a 15-story office building with approximately 10,000 square feet of gross floor area per floor. Which of the following electrical distribution systems would best meet the developer's requirement and be most economical in terms of initial cost as well as later operational costs?

- ☐ 120/208-volt, three-phase, 4-wire
- ☐ 120/240-volt, single-phase, 3-wire
- ☐ 120/240-volt, three-phase, 3-wire
- ☐ 277/480 -volt, three-phase, 4-wire

BUILDING SYSTEMS

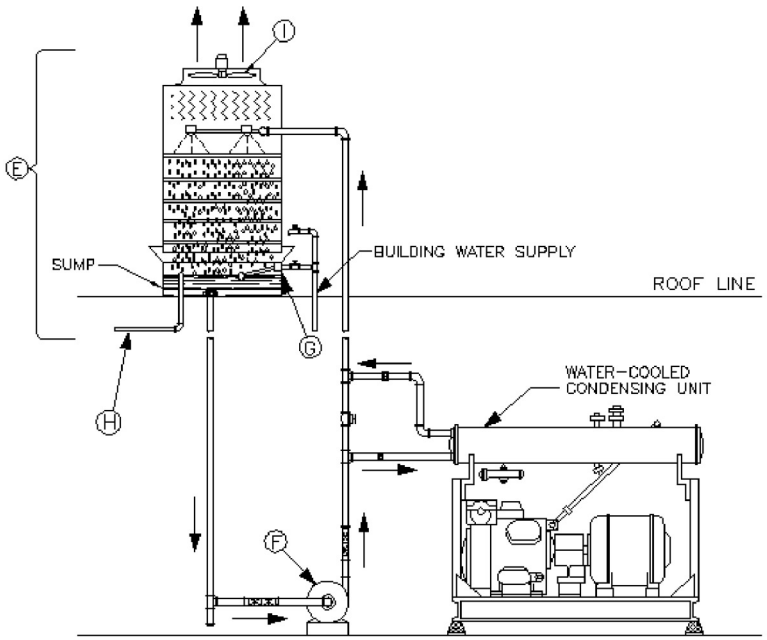
SAMPLE MULTIPLE-CHOICE QUESTIONS

Go to page 17 for answers.



17. In the diagram above of a house in the Northern Hemisphere, the windows are positioned to achieve the best solar gain as well as sun protection. In what direction are the windows facing?
    - ☐ North
    - ☐ South
    - ☐ East
    - ☐ West

18. Which of the following is the term for the persistence of sound reflected from surfaces of enclosed spaces?
    - ☐ Creep
    - ☐ Dampening
    - ☐ Frequency
    - ☐ Reverberation



19. In the drawing above of a refrigeration system for a large building, what is the term for E ?
    - ☐ Cooling coil
    - ☐ Cooling tower
    - ☐ Dehumidifier
    - ☐ Heat pump

BUILDING SYSTEMS

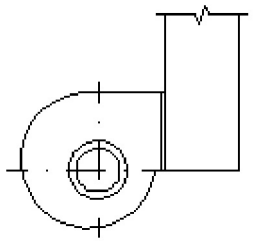
SAMPLE MULTIPLE-CHOICE QUESTIONS

Go to page 17 for answers.

20. When a jurisdiction is governed by national, state, and local building codes, and provisions in at least two of these codes conflict, which code takes precedence?
    - ☐ The local code
    - ☐ The state code
    - ☐ The national code
    - ☐ The most stringent or restrictive code

21. The diagrams below represent outlet connections from blowers to ductwork in a forced-air system. Which one illustrates the connection with the least discharge resistance?

☐



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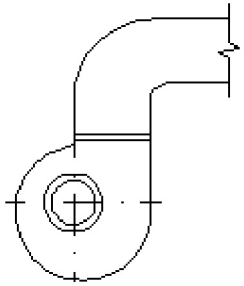

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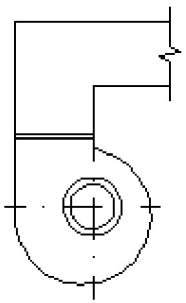

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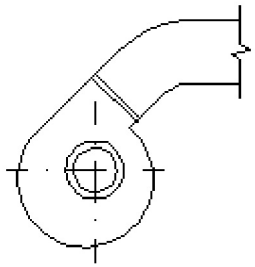


22. Which of the following HVAC systems would have the highest operating cost for a large office building?
    - ☐ Single-zone, constant volume
    - ☐ Variable air volume
    - ☐ Double-duct, constant volume
    - ☐ Constant volume reheat

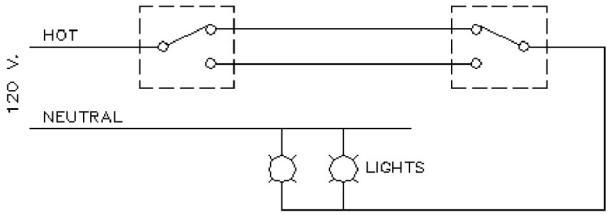
23. In calculations of lighting levels, the coefficient of utilization is defined as the percentage of total lamp lumens that
    - ☐ leave the luminaire
    - ☐ reach the work plane
    - ☐ are lost because of lamp age
    - ☐ are lost because of environmental dust

24. Single-duct, variable air volume systems are more energy-efficient than constant air volume systems because in variable air volume systems
    - ☐ the use of variable-pitch blades or variable-speed fans allows air volume to be modulated from zero to the required demand
    - ☐ fans run at their most efficient speed at all times and air volume is controlled by manual dampers
    - ☐ duct sizes can be reduced, thus saving initial and finance costs
    - ☐ lower-voltage equipment is needed

BUILDING SYSTEMS

SAMPLE MULTIPLE-CHOICE QUESTIONS

Go to page 17 for answers.



25. The diagram above indicates the use of which of the following devices to control lighting from two locations?
- ☐ Two single-pole, single-throw switches
- ☐ Two single-pole, double-throw switches
- ☐ Two double-pole, double-throw switches
- ☐ Two three-pole, double-throw switches

26. Noise generated within a space can be most effectively controlled by
- ☐ absorption
- ☐ reflection
- ☐ focusing
- ☐ diffusion

27. Given an existing building, which of the following factors are relevant to life-cycle costing?
Check the four that apply.
- ☐ A. Maintenance costs
- ☐ B. Land costs
- ☐ C. Salvage value
- ☐ D. Estimated lifespan
- ☐ E. Initial installation cost
- ☐ F. Repair costs

28. Which of the following items are required for plumbing waste-drainage systems? **Check the three that apply.**
- ☐ A. Trap
- ☐ B. Vacuum breaker
- ☐ C. Vent
- ☐ D. Meter
- ☐ E. Cleanout
- ☐ F. Pump

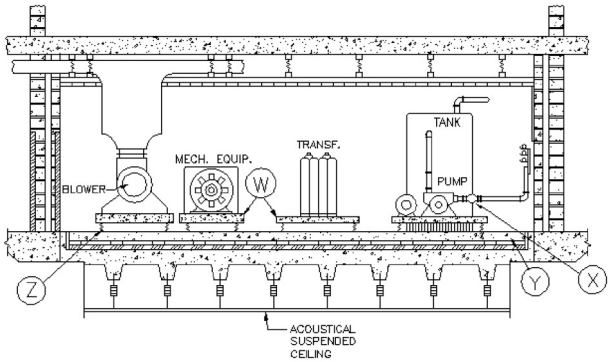
29. Which of the following may be a source of a building's heat loss?
- ☐ Air infiltration
- ☐ Occupants
- ☐ Insolation
- ☐ Electric lighting

BUILDING SYSTEMS

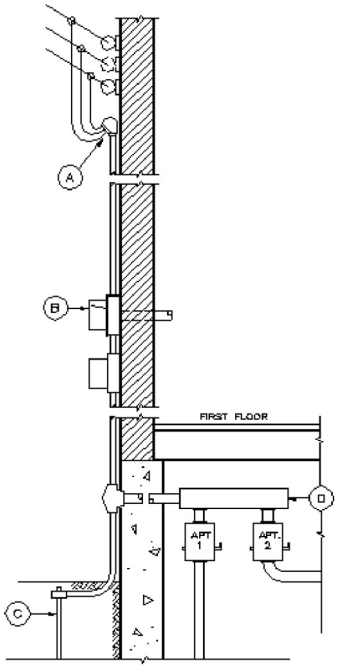
SAMPLE MULTIPLE-CHOICE QUESTIONS

Go to page 17 for answers.

30. The sun is lowest in the sky in the northern hemisphere on the day of the
    - ☐ vernal equinox
    - ☐ summer solstice
    - ☐ autumnal equinox
    - ☐ winter solstice



31. What is the term for Z in the drawing above?
    - ☐ Resilient hanger
    - ☐ Flexible coupling
    - ☐ Paver pedestal
    - ☐ Vibration isolator

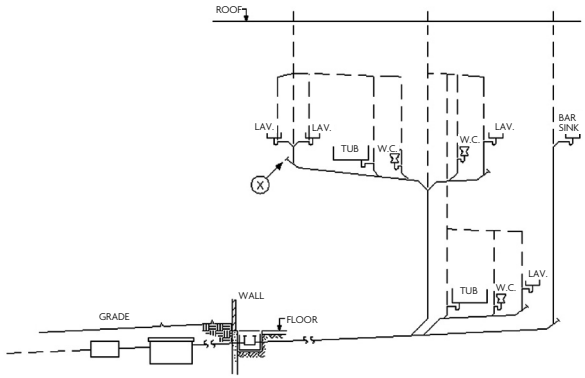


32. The diagram above shows a typical overhead electric service to a multiple residence. What is the name of item C?
    - ☐ Ground rod
    - ☐ Breaker
    - ☐ Disconnect switch
    - ☐ Switch box

BUILDING SYSTEMS

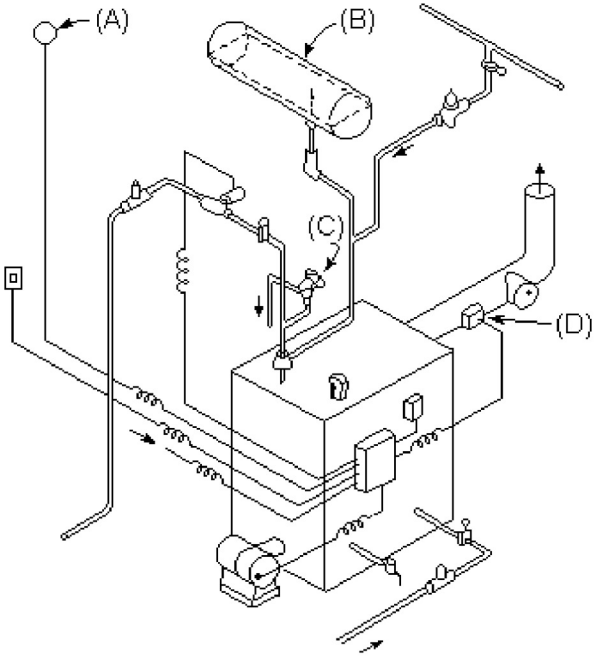
SAMPLE MULTIPLE-CHOICE QUESTIONS

Go to page 17 for answers.



33. What is the name for X in the riser diagram above?
- ☐ Cleanout
- ☐ Vent
- ☐ Drain
- ☐ Trap

34. A four-pipe fan-coil system functions as which of the following?
- ☐ A heating and cooling system
- ☐ An evaporative cooling system
- ☐ A domestic hot-water recirculation system
- ☐ A high-rise fire-safety system



35. Which component in the diagram above represents the pressure relief valve?
- ☐ A
- ☐ B
- ☐ C
- ☐ D

36. In contrast to wet-pipe sprinkler systems, dry-pipe sprinkler systems are used because they
- ☐ are lighter and less expensive to install
- ☐ have fewer valves and fittings to maintain
- ☐ will not freeze in unheated spaces
- ☐ contain water and will not corrode as fast

BUILDING SYSTEMS

SAMPLE MULTIPLE-CHOICE QUESTIONS

Go to page 17 for answers.

37. The psychrometric chart plots which of the following factors? **Check the two that apply.**
    - ☐ A. Relative humidity
    - ☐ B. Air motion
    - ☐ C. Mean radiant temperature
    - ☐ D. Air temperature
    - ☐ E. Convection current
    - ☐ F. Surface temperature

38. The equation (U) x (area) x (temperature difference) = heat gain often underestimates summer heat gain through a building roof because heat flow through the roof is also affected by **(Check the three that apply)**:
    - ☐ A. Entropy
    - ☐ B. Roof color
    - ☐ C. Roof mass
    - ☐ D. Roof texture
    - ☐ E. Time of day
    - ☐ F. Relative humidity

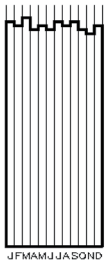
39. Which of the following fixtures or types of equipment must have their waste outlets equipped with air gaps adequate to prevent contamination due to any possible backup of sewage through the waste piping? **Check the two that apply.**
    - ☐ A. Refrigerators
    - ☐ B. Heat recovery units
    - ☐ C. Water closets
    - ☐ D. Bathtubs
    - ☐ E. Sterilizers
    - ☐ F. Waste interceptors

40. Which of the following terms are used in describing heat flow? **Check the four that apply.**
    - ☐ A. Convection
    - ☐ B. Conduction
    - ☐ C. Suction
    - ☐ D. Radiation
    - ☐ E. Enthalpy
    - ☐ F. Conveyance

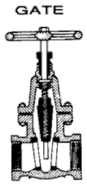
BUILDING SYSTEMS

SAMPLE MULTIPLE-CHOICE ANSWERS

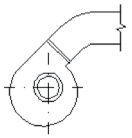
1. 0.96 dollars
2. 8,000 dollars
3. 13.00 percent
4. D
5. Potable water
6. Include ground-fault circuit-interrupter protection
7. Duct lining
8. A, B, C, E
9. 44 in
10.



11. Plastic
12. indoor-air contaminants
13.



14. B
15. A, C, D, E
16. 277/480 -volt, three-phase, 4-wire
17. South
18. Reverberation
19. Cooling tower
20. The most stringent or restrictive code
21.

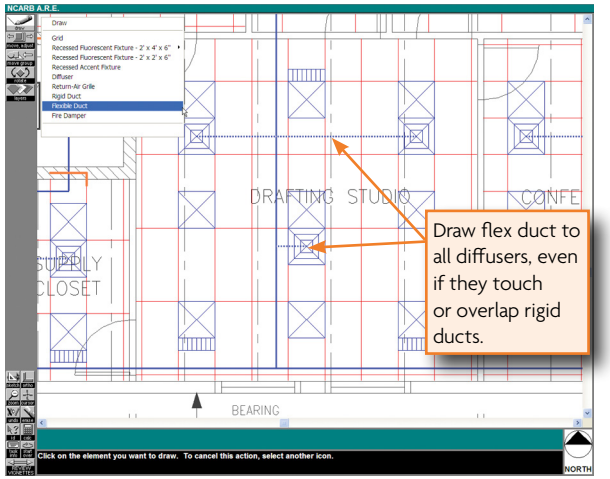


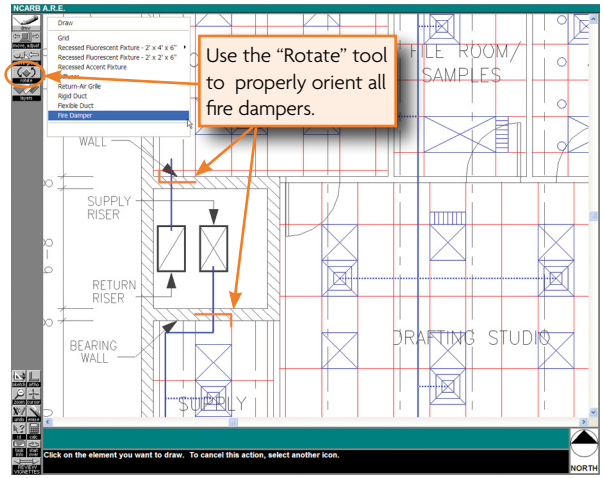
22. Constant volume reheat
23. reach the work plane
24. the use of variable-pitch blades or variable-speed fans allows air volume to be modulated from zero to the required demand
25. Two single-pole, double-throw switches
26. absorption
27. A, C, D, F
28. A, C, E
29. Air infiltration
30. winter solstice
31. Vibration isolator
32. Ground rod
33. Cleanout
34. A heating and cooling system
35. C
36. will not freeze in unheated spaces
37. A, D
38. B, C, E
39. A, E
40. A, B, D, E

BUILDING SYSTEMS

MECHANICAL & ELECTRICAL PLAN VIGNETTE

General Tips for Taking Mechanical & Electrical Plan





Directions

Complete the partially completed reflected ceiling plan on the work screen by (1) providing a grid for acoustical tile, (2) locating lighting fixtures to achieve specified light intensity, and (3) developing a schematic HVAC plan complete with fire dampers and air diffusers, ductwork, and return-air grilles to meet specified air distribution requirements. It is recommended that the ceiling layout be completed before ducts are added. Your solution must be contained within the perimeter walls of the overall space.

The completed plan should reflect effective coordination and integration of structural, mechanical, and electrical units within the ceiling grid and should provide for maximum flexibility for furniture layouts at the most economical cost.

Before beginning your solution, you should review the program information and lighting diagrams that can be accessed through the Vignette Index screen and familiarize yourself with the partially completed plan on the work screen.

Program

A reflected ceiling plan for an architect's office is to be prepared. The space is in a multistory building and is enclosed by leaseable office space on one side, a corridor on another, and two exterior walls. The client wants flexibility for furniture placement, efficient lighting levels, and a comfortable environment.

BUILDING SYSTEMS

MECHANICAL & ELECTRICAL PLAN VIGNETTE

Comply with the following requirements to develop the reflected ceiling plan:

Suspended Ceiling System

1. Provide a 2 ft X 4 ft grid with lay-in acoustical tiles in all spaces.

2. All ceiling heights are 9 ft above the finished floor.

3. Typical walls terminate 6 inches above the finished ceiling; bearing walls and fire-rated walls extend to the bottom of the floor deck above.

Lighting System

Lighting layouts should be efficient and should minimize overlighting and underlighting.

1. For all spaces, use only recessed fluorescent fixtures to provide uniform light distribution with a light level of approximately 50 footcandles measured at desk level (3 ft above the finished floor).

2. In addition to the fluorescent fixtures required above, provide recessed accent light fixtures.
   - ▶ Locate the accent light fixtures along the west wall of the Architect's Office so that the direct light level on the wall at a height of 5 ft above the floor is 80 footcandles.
   - ▶ Space the accent light fixtures so that the light level between the fixtures at 5 ft above the floor is 80 footcandles.
   - ▶ The accent light fixtures should not be considered in determining the uniform light distribution levels.
   - ▶ The recessed fluorescent fixtures should not be considered in determining the accent light levels.

HVAC System

The space is served by the supply and return risers within the shaft indicated on the floor plan. The HVAC system should provide for uniform air distribution with an economical duct layout conforming to the following restrictions:

1. Provide a minimum of one supply diffuser and one return-air grille in each space. An acceptable air distribution pattern includes one supply diffuser and one return-air grille for every 144 ft² of floor area (or portion thereof) in each space.

2. Connect each supply diffuser to the rigid supply duct system with flexible duct.
   - ▶ Do not exceed 10 ft for flexible duct lengths.

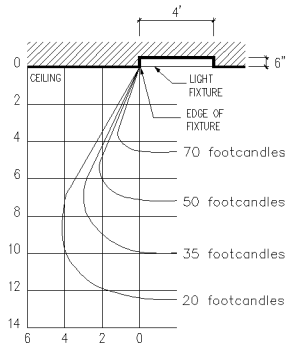
3. Return-air grilles are open to the ceiling space, which serves as a return-air plenum.
   - ▶ Connect the plenum to the return riser with rigid duct.

4. Protect duct openings in fire-rated walls with fire dampers.

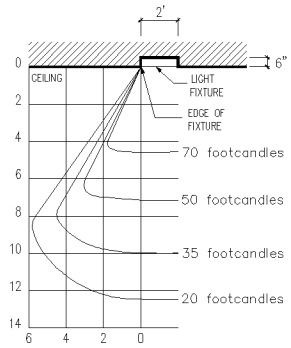
5. Flexible ducts fit through joist webs.

6. Rigid ducts fit under beams, in spaces between joists, and in a zone that extends 2 ft on either side of beams and bearing walls in plan view.
   - ▶ Rigid ducts do not fit through joists or between the bottom of joists and the ceiling.

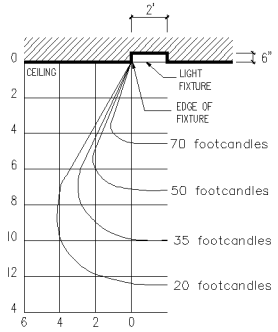
LIGHTING DIAGRAMS



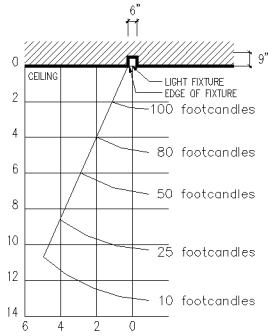
RECESSED FLUORESCENT FIXTURE (2'X4') END
(Grid Units in Feet)



RECESSED FLUORESCENT FIXTURE (2'X4') SIDE
(Grid Units in Feet)



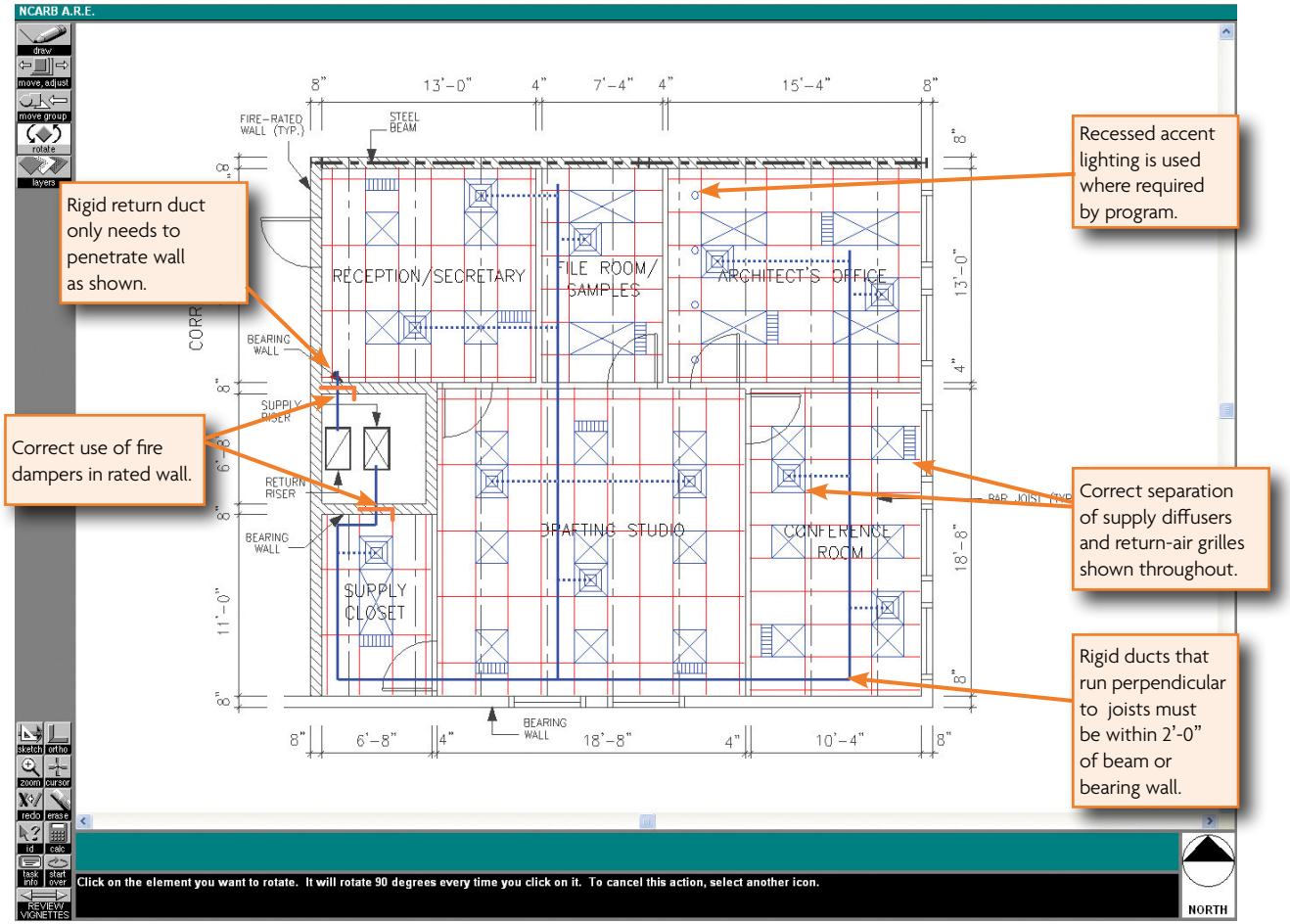
RECESSED FLUORESCENT FIXTURE (2'X2')
(Grid Units in Feet)
Distribution is the same for sides and ends of fixture



RECESSED ACCENT FIXTURE
(Grid Units in Feet)
Distribution is the same all around fixture

BUILDING SYSTEMS

MECHANICAL & ELECTRICAL PLAN VIGNETTE - Sample Passing Solution



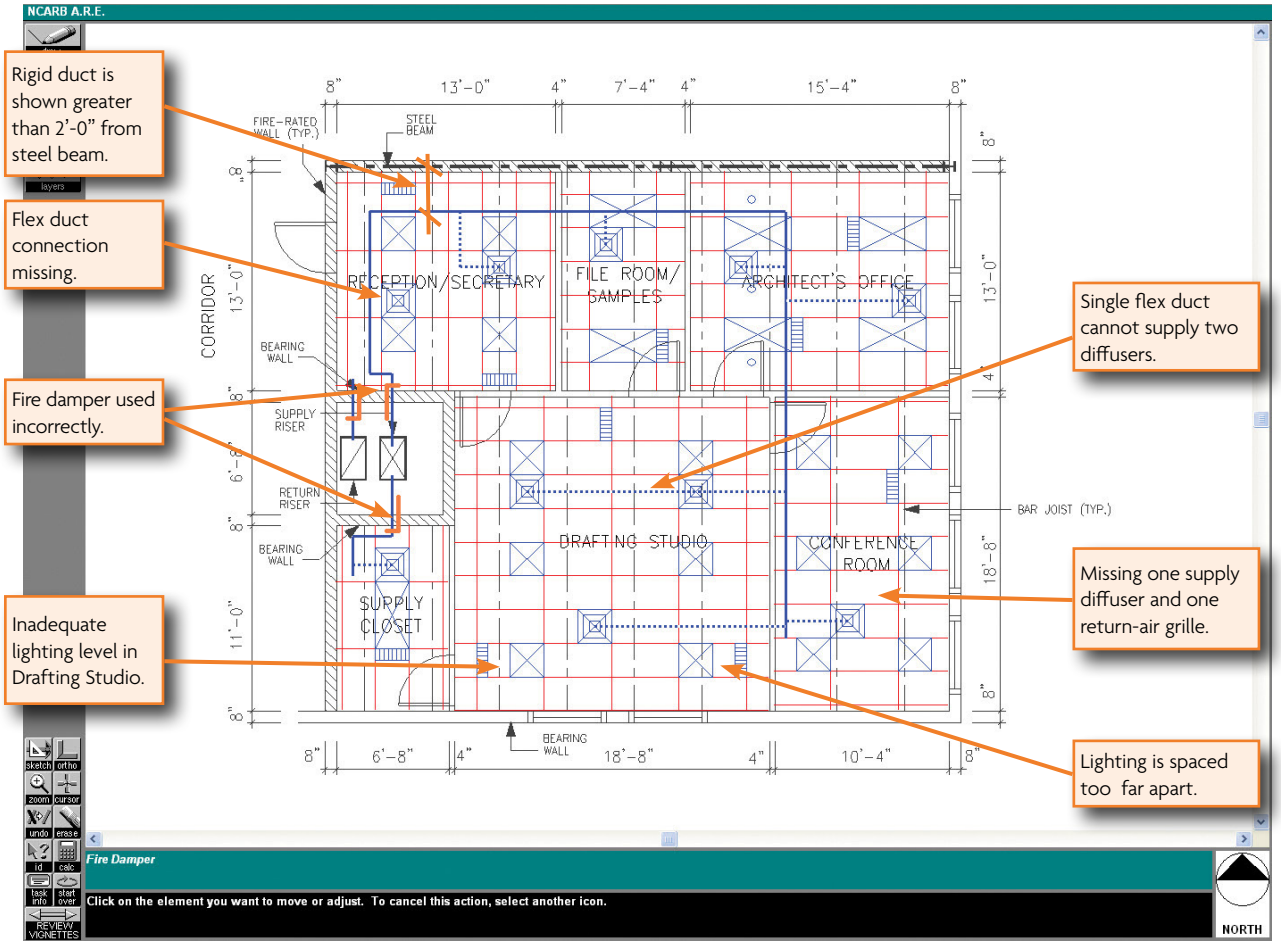
The best way to solve this vignette is to start with the ceiling grid, keeping the possible light spacing in mind. This solution has the correct number of supply diffusers and return-air grilles in each room and the lighting is spaced correctly throughout. All supply diffusers are connected to the rigid supply duct with flexible duct. All flexible duct runs are shorter than the 10-foot maximum allowed and serve a single diffuser. While the rigid ducts may run anywhere parallel (and between) the joists, they may not run perpendicular to the joists except within two feet of bearing walls or beams. This solution resolves that correctly. Fire dampers provided at the chase penetrations are oriented correctly, and the return duct properly extends into the plenum area.

Procedural Tips

- Familiarize yourself with the contents of each layer by turning the **layers** on and off.
- There are three ways to realign a ceiling grid.
  - Use the **move,adjust** tool and click anywhere within the grid to shift the cells within the perimeter of the grid rectangle.
  - Use the **move,adjust** tool and click on an edge of the grid rectangle to increase or decrease the length or width of the entire grid rectangle.
  - Use the **move group** tool and click on any part of the grid to move the entire grid rectangle elsewhere.
- The rotate tool in this vignette works without the wand. To rotate an element:
  - Click on the **rotate** icon.
  - Click on the element you want to rotate. If it is rotatable, it will rotate 90 degrees every time you click on it.
- The **rotate** tool will change the orientation of the ceiling grid.
- When elements overlap, you may have trouble selecting a particular element. If this happens, keep clicking (without moving the mouse) until the desired element highlights.

BUILDING SYSTEMS

MECHANICAL & ELECTRICAL PLAN VIGNETTE - Sample Failing Solution



The rigid duct runs perpendicular to the joists farther than two feet from the beam along the north wall. The Conference Room only has one supply diffuser and one return-air grille when two of each are required by the area calculation given in the program. The one supply diffuser provided in the Reception/Secretary area sits directly under the rigid duct but is not connected by flex duct as required. In the Drafting Studio, the flex duct is also used to connect two supply diffusers in a series which is prohibited by the program. The lights are spaced too far apart in some locations to achieve the required lighting levels.

Tools You Might Find Useful

- **Zoom** to help you lay out the ceiling grid
- **Full-screen cursor** to help you line up elements

BUILDING SYSTEMS

REFERENCES

The following references are presented to assist candidates in preparation for the examination. This list represents texts that have content covered in this division of the examination. This is not intended to be an exhaustive list of all possible reference materials for the subject area. NCARB makes no guarantee that the various references are currently in print.

Architectural Graphic Standards
The American Institute of Architects
John Wiley & Sons, latest edition

ASHRAE Fundamentals Handbook
www.ashrae.org
2009

Heating, Cooling, Lighting: Sustainable Design Methods for Architects
Norbert Lechner
John Wiley & Sons, latest edition

Mechanical & Electrical Equipment for Buildings
Walter T. Grondzik, Alison G. Kwok, Ben Stein, and John S. Reynolds, Editors
John Wiley & Sons, latest edition

Mechanical and Electrical Systems in Buildings
Richard R. Janis and William K. Y. Tao
Prentice Hall, latest edition