

## CHAPTER 6

## HOTELS, MOTELS, AND DORMITORIES

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**H**OTELS, motels, and dormitories may be single-room or multiroom, long- or short-term dwelling (or residence) units; they may be stacked sideways and/or vertically. Information in the first three sections of the chapter applies generally; the last three sections are devoted to the individual types of facilities. High energy costs and consequent environmental damage require that these type of facilities be energy efficient and sustainable. Occupants need assurance that they can afford the fuel bills and that their lifestyle is not damaging to the planet. This chapter provides advice on sustainable practices to achieve these aims.

### 1. LOAD CHARACTERISTICS

- Ideally, each room served by an HVAC unit should be able to be ventilated, cooled, heated, or dehumidified independently of any other room. If not, air conditioning for each room will be compromised, and personal comfort will not be possible.
- Typically, the space is not occupied at all times. For adequate flexibility, each unit's ventilation and cooling should be able to be shut off (except when humidity control is required), and its heating to be shut off or turned down. This can be achieved by occupant detection, use of door key fobs, or simple-to-use manual controls such as thermostatic radiator valves (TRVs) on radiators.
- Concentrations of lighting and occupancy are variable, ranging from low for those who work during the day to high and continuous for family homes and residential elderly accommodation; activity is generally sedentary or light.
- Kitchens have the potential for high appliance loads and odor and steam generation, and have large exhaust requirements, with control from low to high, to boost air extraction to suit cooking.
- Rooms generally have an exterior exposure with good daylight levels and a view to green features; however, kitchens, toilets, and dressing rooms are normally internal and require extract ventilation. The building as a whole usually has multiple exposures, as may many individual dwelling units. Design must optimize passive solar gains while avoiding overheating and glare.
- Toilet, washing, and bathing facilities are almost always incorporated in the dwelling units, and the modern trend is to provide en-suite bathrooms in every bedroom. Exhaust air is usually incorporated in each toilet and bathroom area.
- The building has a relatively high hot-water demand, generally for periods of an hour or two, several times a day. This demand can vary from a fairly moderate and consistent daily load profile in a senior citizens building to sharp, unusually high peaks at about 6:00 PM in dormitories. [Chapter 50](#) includes details on service water heating.
- Load characteristics of rooms, dwelling units, and buildings can be well defined with little need to anticipate future changes to

design loads, other than adding a service such as cooling that may not have been incorporated originally.

- The prevalence of shifting, transient interior loads and exterior exposures with glass results in high diversity factors; the long hours of use result in fairly high load factors.

### 2. DESIGN CONCEPTS AND CRITERIA

Wide load swings and diversity within and between rooms require a flexible system design for 24 h comfort. Besides opening windows, the only way to provide flexible temperature control is having individual room components under individual room control that can cool, heat, and ventilate independently of equipment in other rooms.

In some climates, summer humidity becomes objectionable because of the low internal sensible loads that result when cooling is on/off controlled. Modulated cooling and/or reheat may be required to achieve comfort. Reheat should be avoided unless some sort of heat recovery is involved.

Dehumidification can be achieved by lowering cooling coil temperatures and reducing airflow or by using desiccant dehumidifiers.

Some people have a noise threshold low enough that certain types of equipment disturb their sleep. Higher noise levels may be acceptable in areas where there is little need for air conditioning. Medium- and better-quality equipment is available with noise criteria (NC) 35 levels at 3 to 4 m in medium to soft rooms and little sound change when the compressor cycles.

Perimeter fan coils are usually quieter than unitary systems, but unitary systems provide more redundancy in case of failure.

### 3. SYSTEMS

#### Energy-Efficient Systems

There is increased impetus to select energy-efficient systems for dwellings to limit potential climate impact, conserve fossil fuel reserves, and avoid fuel poverty. In Europe, the Energy Performance Directive sets out a strategy for each European country to achieve targets toward this objective; in the United Kingdom, for example, all new dwellings should be zero-carbon by 2016, which means a sliding scale from the current allowable values to zero between 2011 to 2016. Other countries have similar schemes. In North America, *ASHRAE Standard 90.1* is setting progressive reductions also aimed zero net energy.

Where natural gas is available, gas-fired condensing boilers are used, with modulating controls linked to load monitoring such as an outdoor temperature detector.

Heating and cooling applications generally include water-source and air-source heat pumps. In areas with ample solar radiation, water-source heat pumps may be solar assisted, and/or solar thermal collectors can be used. Energy-efficient equipment generally has the lowest operating cost and should be kept simple, an important factor where skilled operating personnel are unlikely to be available. Most

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systems allow individual operation and thermostatic control. The typical system allows individual metering so that most, if not all, of the cooling and heating costs can be metered directly to the occupant (McClelland 1983). Existing buildings can be retrofitted with heat flow meters and timers on fan motors for individual metering, and there is a drive toward provision of better real-time energy use to allow occupants to make changes that reduce their costs at the right time.

The water-loop heat pump has a lower operating cost than air-cooled unitary equipment and allows a degree of heat recovery because the condenser water loop acts to balance energy use when possible. The lower installed cost encourages its use in mid- and high-rise buildings where individual dwelling units have floor areas of 75 m<sup>2</sup> or larger. Some systems incorporate sprinkler piping as the water loop.

The system has a central plant consisting of circulating pumps, heat rejection when there is surplus heat capacity in the building, and supplementary gas-fired boiler heat input when there is an overall deficit of heat. The water-loop heat pump is predominantly decentralized; individual metering allows most of the operating cost to be paid by the occupant. Its life should be longer than for other unitary systems because most of the mechanical equipment is in the building and not exposed to outdoor conditions. Also, load on the refrigeration circuit is not as severe because water temperature is controlled for optimum operation. Operating costs are low because of the system's inherent energy conservation. Excess heat may be stored during the day for the following night, and heat may be transferred from one part of the building to another.

Although heating is required in many areas during cool weather, cooling could be needed in rooms having high solar loads. This should be avoided by effective solar shading design. On a mild day, surplus heat throughout the building is frequently transferred into the hot-water loop by water-cooled condensers on cooling cycle, so that water temperature rises. The heat remains stored in the water and can be extracted at night; a water heater is therefore avoided. This heat storage is improved by the presence of a greater mass of water in the pipe loop; some systems include a storage tank for this reason, or water tank with phase-change material (PCM) thermal storage. Because the system is designed to operate during the heating season with water supplied at a temperature as low as 15°C, the water-loop heat pump lends itself to solar assist; relatively high solar collector efficiencies result from the low water temperature.

The installed cost of the water-loop heat pump is higher in very small buildings. In severe cold climates with prolonged heating seasons, even where natural gas or fossil fuels are available at reasonable cost, the operating cost advantages of this system may diminish unless heat can be recovered from some another source, such as solar collectors, geothermal, or internal heat from a commercial area served by the same system.

### Energy-Neutral Systems

To qualify as energy-neutral, a system must have controls that prevent simultaneous operation of the cooling and heating cycles. Some examples are (1) packaged terminal air conditioners (PTACs) (through-the-wall units), (2) window units or radiant ceiling panels for cooling combined with finned or baseboard radiation for heating, (3) unitary air conditioners with an integrated heating system, (4) fan coils with remote condensing units, and (5) variable-air-volume (VAV) systems with either perimeter radiant panel heating or baseboard heating. For unitary equipment, control may be as simple as a heat/cool switch. For other types, dead-band thermostatic control may be required.

PTACs are frequently installed to serve one or two rooms in buildings with mostly small, individual units. In a common two-room arrangement, a supply plenum diverts some of the conditioned air serving one room into the second, usually smaller, room.

Multiple PTAC units allow additional zoning in dwellings with more rooms. Additional radiation heat is sometimes needed around the perimeter in cold climates.

Heat for a PTAC may be supplied either by electric resistance heaters or by hot-water or steam heating coils. Initial costs are lower for a decentralized system using electric resistance heat. Operating costs are lower for coils heated by combustion fuels. Despite its relatively inefficient refrigeration circuits, a PTAC's operating cost is quite reasonable, mostly because of individual thermostatic control over each machine, which eliminates the use of reheat while preventing the space from being overheated or overcooled. Also, because equipment is located in the space being served, little power is devoted to circulating the room air. Servicing is simple: a defective machine is replaced by a spare chassis and forwarded to a service organization for repair. Thus, building maintenance can be done by relatively unskilled personnel.

Noise levels are generally no higher than NC 40, but some units are noisier than others. Installations near a seacoast should be specially constructed (usually with stainless steel or special coatings) to avoid accelerated corrosion of aluminum and steel components caused by salt. In high-rise buildings of more than 12 stories, special care is required, both in design and construction of outdoor partitions and in installation of air conditioners, to avoid operating problems associated with leakage (caused by stack effect) around and through the machines.

Frequently, the least expensive installation is finned or baseboard radiation for heating and window-type room air conditioners for cooling. The window units are often purchased individually by the building occupants. This choice offers a reasonable operating cost and is relatively simple to maintain. However, window units have the shortest equipment life, highest operating noise level, and poorest distribution of conditioned air of any systems discussed in this section.

Fan-coils with remote condensing units are used in smaller buildings. Fan-coil units are located in closets, and the ductwork distributes air to the rooms in the dwelling. Condensing units may be located on roofs, at ground level, or on balconies.

Low-capacity residential warm-air furnaces may be used for heating, but with gas- or oil-fired units, combustion products must be vented. In a one- or two-story structure, it is possible to use individual chimneys or flue pipes, but a high-rise structure requires a multiple-vent chimney or a manifold vent. Local codes should be consulted.

Sealed combustion furnaces draw all combustion air from, and discharge flue products through a windproof vent to, the outdoors. The unit must be located near an outer wall, and exhaust gases must be directed away from windows and intakes. In one- or two-story structures, outdoor units mounted on the roof or on a pad at ground level may also be used. All of these heating units can be obtained with cooling coils, either built-in or add-on. Evaporative-type cooling units are popular in motels, low-rise apartments, and residences in mild climates.

Desiccant dehumidification should be considered when independent control of temperature and humidity is required to avoid reheat.

### Energy-Inefficient Systems

Energy-inefficient systems allow simultaneous cooling and heating. Examples include two-, three-, and four-pipe fan coil units, terminal reheat systems, and induction systems. Some units, such as the four-pipe fan coil, can be controlled so that they are energy-neutral by ensuring that the two circuits do not simultaneously serve the PTAC. They are primarily used for humidity control.

Four-pipe systems and two-pipe systems with electric heaters can be designed for complete temperature and humidity flexibility during summer and intermediate season weather, although none provides winter humidity control. Both systems provide full dehumidification and cooling with chilled water, reserving the other two pipes or an

electric coil for space heating or reheat. The equipment and necessary controls are expensive, and only the four-pipe system, if equipped with an internal-source heat-recovery design for the warm coil energy, can operate at low cost. When year-round comfort is essential, four-pipe systems or two-pipe systems with electric heat should be considered.

### Total Energy Systems

A total energy system is an option for any multiple or large housing facility with large year-round service water heating requirements. Total energy systems are a form of cogeneration in which all or most electrical and thermal energy needs are met by on-site systems as described in Chapter 7 of the 2012 *ASHRAE Handbook—HVAC Systems and Equipment*. A detailed load profile must be analyzed to determine the merits of using a total energy system. The reliability and safety of the heat-recovery system must also be considered.

Any of the previously described systems can perform the HVAC function of a total energy system. The major considerations as they apply to total energy in choosing an HVAC system are as follows:

- Optimum use must be made of thermal energy recoverable from the prime mover during all or most operating modes, not just during conditions of peak HVAC demand.
- Heat recoverable through the heat pump may become less useful because the heat required during many of its potential operating hours will be recovered from the prime mover. The additional investment for heat pump or heat recovery cycles may be more difficult to justify because operating savings are lower.
- The best application for recovered waste heat is for those services that use only heat (i.e., service hot water, laundry facilities, and space heating).

### Special Considerations

Local building codes govern ventilation air quantities for most buildings. Where they do not, ASHRAE *Standard* 62.1 should be followed. The quantity of outdoor air introduced into rooms or corridors is usually slightly in excess of the exhaust quantities to pressurize the building. To avoid adding load to individual systems, outdoor air should be treated to conform to indoor air temperature and humidity conditions. In humid climates, special attention must be given to controlling humidity from outdoor air. Otherwise, the outdoor air may reach corridor temperature while still retaining a significant amount of moisture.

In buildings having a centrally controlled exhaust and supply, the system is regulated by a time clock or a central management system for certain periods of the day. In other cases, the outdoor air may be reduced or shut off during extremely cold periods, although this practice is not recommended and may be prohibited by local codes. These factors should be considered when estimating heating load.

For buildings using exhaust and supply air on a 24-hour basis, air-to-air heat recovery devices may be merited (see Chapter 26 of the 2012 *ASHRAE Handbook—HVAC Systems and Equipment*). These devices can reduce energy consumption by capturing 60 to 80% of the sensible and latent heat extracted from the air source.

Infiltration loads in high-rise buildings without ventilation openings for perimeter units are not controllable year-round by general building pressurization. When outer walls are pierced to supply outdoor air to unitary or fan-coil equipment, combined wind and thermal stack-effect forces create equipment operating problems. These factors must be considered for high-rise buildings (see Chapter 16 of the 2013 *ASHRAE Handbook—Fundamentals*).

Interior public corridors should have tempered supply air with transfer into individual area units, if necessary, to provide kitchen and toilet makeup air requirements. Transfer louvers need to be acoustically lined. Corridors, stairwells, and elevators should be pressurized for fire and smoke control (see Chapter 53).

Kitchen air can be recirculated through hoods with activated charcoal filters rather than exhausted. Toilet exhaust can be VAV with a damper operated by the light switch. A controlled source of supplementary heat in each bathroom is recommended to ensure comfort while bathing.

Air-conditioning equipment must be isolated to reduce noise generation or transmission. The cooling tower or condensing unit must be designed and located to avoid disturbing occupants of the building or of adjacent buildings.

An important but frequently overlooked load is the heat gain from piping for hot-water services. Insulation thickness should conform to the latest local energy codes and standards at a minimum. In large, luxury-type buildings, a central energy or building management system allows supervision of individual air-conditioning units for operation and maintenance.

Some facilities conserve energy by reducing indoor temperature during the heating season. Such a strategy should be pursued with caution because it could affect occupant comfort, and, for example, the competitiveness of a hotel/motel.

## 4. HOTELS AND MOTELS

Hotel and motel accommodations are usually single guest rooms with a toilet and bath adjacent to a corridor, and flanked on both sides by other guest rooms. The building may be single-story, low-rise, or high-rise. Multipurpose subsidiary facilities range from stores and offices to ballrooms, dining rooms, kitchens, lounges, auditoriums, and meeting halls. Luxury motels may be built with similar facilities. Occasional variations are seen, such as kitchenettes, multiroom suites, and outer doors to patios and balconies. Hotel classes range from the deluxe hotel to the economy hotel/motel as outlined in Table 1.

Table 1 Hotel Classes

Type of Facility	Typical Occupancy, Persons per Room	Characteristics
Deluxe hotel	1.2	Large rooms, suites, specialty restaurants
Luxury/first class, full-service hotel	1.2 to 1.3	Large rooms, large public areas, business center, pool and health club, several restaurants
Mid-scale, full-service hotel	1.2 to 1.3	Large public areas, business center, several restaurants
Convention hotel	1.4 to 1.6	Large number of rooms, very large public areas, extensive special areas, rapid shifting of peak loads
Limited-service hotel	1.1	Limited public areas, few restaurants, may have no laundry
Upscale, all-suites hotel	2.0	Rooms are two construction bays, in-room pantries, limited public areas, few restaurants
Economy, all-suites hotel	2.0 to 2.2	Smaller suites, limited public areas and restaurants
Resort hotel	1.9 to 2.4	Extensive public areas, numerous special and sport areas, several restaurants
Conference center	1.3 to 1.4	Numerous special meeting spaces, limited dining options
Casino hotel	1.5 to 1.6	Larger rooms, large gaming spaces, extensive entertainment facilities, numerous restaurants
Economy hotel/motel	1.6 to 1.8	No public areas, little or no dining, usually no laundry

Table 2 Hotel Design Criteria<sup>a,b</sup>

Category	Indoor Design Conditions				Ventilation <sup>d</sup>	Exhaust <sup>e</sup>	Filter Efficiency <sup>f</sup>	Noise, RC Level
	Winter		Summer					
	Temperature	Relative Humidity <sup>c</sup>	Temperature	Relative Humidity				
Guest rooms	23 to 24°C	30 to 35%	23 to 26°C	50 to 60%	15 to 30 L/s per room	10 to 25 L/s per room	6 to 8 MERV	25 to 35
Lobbies	20 to 23°C	30 to 35%	23 to 26°C	40 to 60%	8 L/s per person	—	8 MERV or better	35 to 45
Conference/ meeting rooms	20 to 23°C	30 to 35%	23 to 26°C	40 to 60%	10 L/s per person	—	8 MERV or better	25 to 35
Assembly rooms	20 to 23°C	30 to 35%	23 to 26°C	40 to 60%	8 L/s per person	—	8 MERV or better	25 to 35

<sup>a</sup> This table should not be the only source for design criteria. Data contained here can be determined from volumes of the *ASHRAE Handbook*, standards, and governing local codes.

<sup>b</sup> Design criteria for stores, restaurants, and swimming pools are in [Chapters 2, 3, and 5](#), respectively.

<sup>c</sup> Minimum recommended humidity.

<sup>d</sup> Per *ASHRAE Standard 62.1*.

<sup>e</sup> Air exhaust from bath and toilet area.

<sup>f</sup> Per *ASHRAE Standard 52.2* (MERV = minimum efficiency reporting values).

A hotel can be divided into three main areas:

1. Guest rooms
2. Public areas
  - Lobby, atrium, and lounges
  - Ballrooms
  - Meeting rooms
  - Restaurants and dining rooms
  - Stores
  - Swimming pools
  - Health clubs
3. Back-of-the-house (BOTH) areas
  - Kitchens
  - Storage areas
  - Laundry
  - Offices
  - Service areas and equipment rooms

The two main areas of use are the guest rooms and the public areas. Maximum comfort in these areas is critical to success of any hotel. Normally the BOTH spaces are less critical than the remainder of the hotel with the exception of a few spaces where a controlled environment is required or recommended.

### Guest Rooms

Air conditioning in hotel rooms should be quiet, easily adjustable, and draft free. It must also provide ample outdoor air. Because the hotel business is so competitive and space is at a premium, systems that require little space and have low total owning and operating costs should be selected.

**Design Concepts and Criteria.** Table 2 lists design criteria for hotel guest rooms. In addition, the design criteria for hotel room HVAC services must consider the following factors:

- Individual and quickly responding temperature control
- Draft-free air distribution
- Toilet room exhaust
- Ventilation (makeup) air supply
- Humidity control
- Acceptable noise level
- Simple controls
- Reliability
- Ease of maintenance
- Operating efficiency
- Use of space

**Load Characteristics.** The great diversity in the design, purpose, and use of hotels and motels makes analysis and load studies very important. Load diversification is possible because of guest rooms' transient occupancy and the diversity associated with support facility operation.

The envelope cooling and heating load is dominant because the guest rooms normally have exterior exposures. Other load sources such as people, lights, appliances, etc. are a relatively small part of the space sensible and latent loads. The ventilation load can represent up to 15% of the total cooling load.

Because of the nature of the changing envelope sensible load and the transient occupancy of the guest room, large fluctuations in the space sensible load in a one-day cycle are common. The ventilation sensible cooling load can vary from 0 to 100% in a single day, whereas the ventilation latent load can remain almost constant for the entire day. A low sensible heat ratio is common in moderate to very humid climates. Usually, the HVAC equipment must only handle part or low loads and peak loads rarely occur. For example, in humid climates, introducing untreated outdoor air directly into the guest room or into the return air plenum of the HVAC unit operating at part or low load creates a severe high-humidity problem, which is one of the causes of mold and mildew. The situation is further aggravated when the HVAC unit operates in on/off cycle during part- or low-load conditions.

**Applicable Systems.** Most hotels use all-water or unitary refrigerant-based equipment for guest rooms. All-water systems include

- Two-pipe fan-coils
- Two-pipe fan-coil with electric heat
- Four-pipe fan-coils

Unitary refrigerant-based systems include

- Packaged terminal air conditioner or packaged terminal heat pump (with electric heat)
- Air-to-air heat pump (ductless, split)
- Water-source heat pump

Except for the two-pipe fan-coil, all these systems cool, heat, or dehumidify independently of any other room and regardless of the season. A two-pipe fan-coil system should be selected only when economics and design objectives dictate a compromise to performance. Selection of a particular system should be based on

- First cost
- Economical operation, especially at part load
- Maintainability

Compared to unitary refrigerant-based units, all-water systems offer the following advantages:

- Reduced total installed cooling capacity due to load diversity
- Lower operating cost due to a more efficient central cooling plant
- Lower noise level (compared to PTAC and water-source heat pump)
- Longer service life
- Less equipment to be maintained in the occupied space
- Less water in circulation (compared to water-source heat pump)
- Smaller pipes and pumps (compared to water-source heat pump)

Unitary refrigerant-based systems offer the following advantages:

- Lower first cost
- Immediate all year availability of heating and cooling
- No seasonal changeover required
- Cooling available without operating a central refrigeration plant
- Can transfer energy from spaces being cooled to spaces being heated (with water-source heat pump)
- Range of circulated water temperature requires no pipe insulation (for water-source heat pump)
- Less dependence on a central plant for heating and cooling
- Simplicity, which results in lower operating and maintenance staff costs

The type of facility, sophistication, and quality desired by the owner/operator, as well as possible code requirements typically influence the selection. An economic analysis (life-cycle cost) is particularly important when selecting the most cost-effective system. Chapter 37 has further information on economic analysis techniques. Computer software like the NIST Building Life-Cycle Cost Program (BLCC) performs life-cycle cost analyses quickly and accurately (NIST 2006).

Chapters 2, 5, 13 and 49 of the 2012 *ASHRAE Handbook—HVAC Systems and Equipment* provide additional information about all-water systems and unitary refrigerant-based systems.

Room fan-coils and room unitary refrigerant-based units are available in many configurations, including horizontal, vertical, exposed, and concealed. The unit should be located in the guest room so that it provides excellent air diffusion without creating unpleasant drafts. Air should not discharge directly over the head of the bed, to keep cold air away from a sleeping guest. The fan-coil/heat pump unit is most commonly located

- Above the ceiling in the guest room entry corridor or above the bathroom ceiling (horizontal air discharge),
- On the room's perimeter wall (vertical air discharge), or
- In a floor-to-ceiling enclosed chase (horizontal air discharge).

Locating the unit above the entry corridor is preferred because air can flow directly along the ceiling and the unit is relatively accessible for maintenance (see Figures 1 and 2).

Most units are designed for free-air discharge. The supply air grille should be selected according to the manufacturer's recommendations for noise and air diffusion. Also, airflow should not interfere with the room drapes or other wall treatment.

Other factors that should be considered include

- Sound levels at all operating modes, particularly with units that cycle on and off
- Adequately sized return air grille
- Access for maintenance, repair, and filter replacement

Ventilation (makeup) supply and exhaust rates must meet local code requirements. Ventilation rates vary and the load imposed by ventilation must be considered.

Providing conditioned ventilation air directly to the guest room is the preferred approach. Normally, outdoor air is conditioned in a primary makeup air unit and distributed by a primary air duct to every guest room. This approach controls the supply air conditions, ensures satisfactory room conditions and room air balance (room pressurization) even during part- or no-load conditions, and controls mold and mildew.

Other ventilation techniques are to

- Transfer conditioned ventilation air from the corridor to each guest room. This approach controls ventilation air conditions better; however, the air balance (makeup versus exhaust) in the guest room may be compromised. This approach is prohibited under many code jurisdictions.

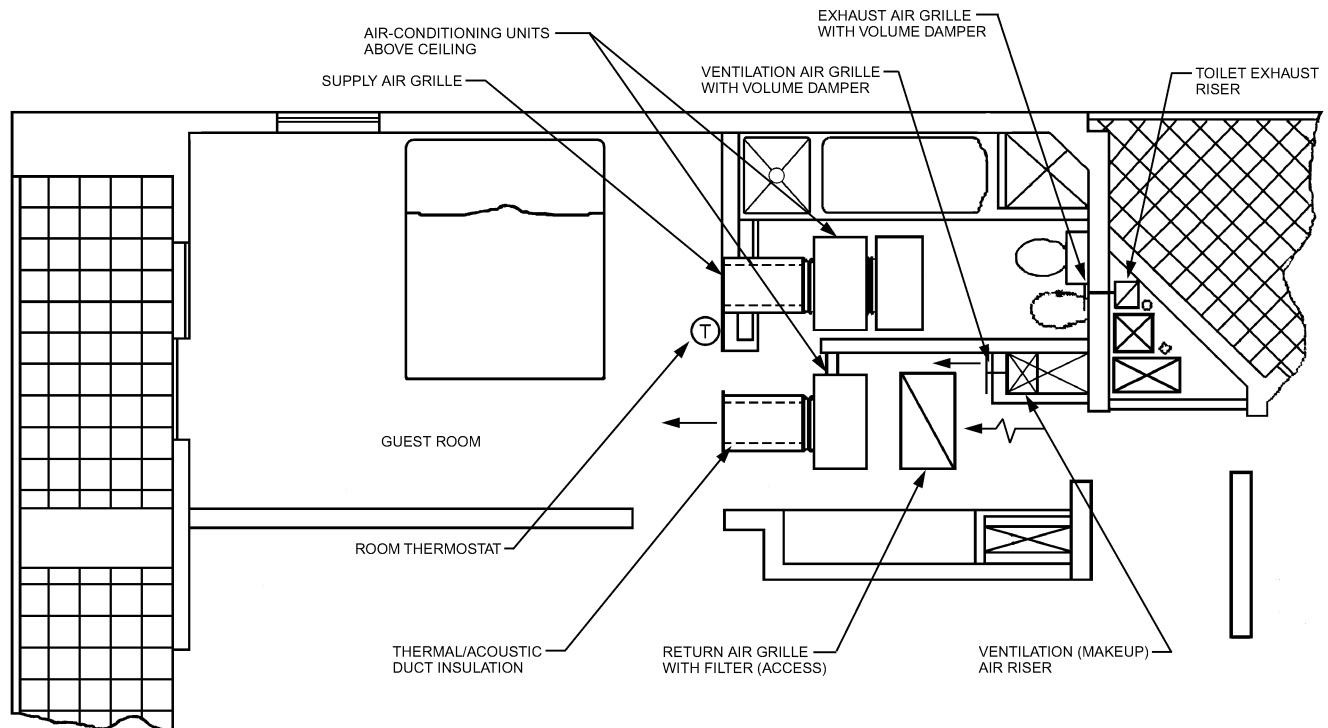
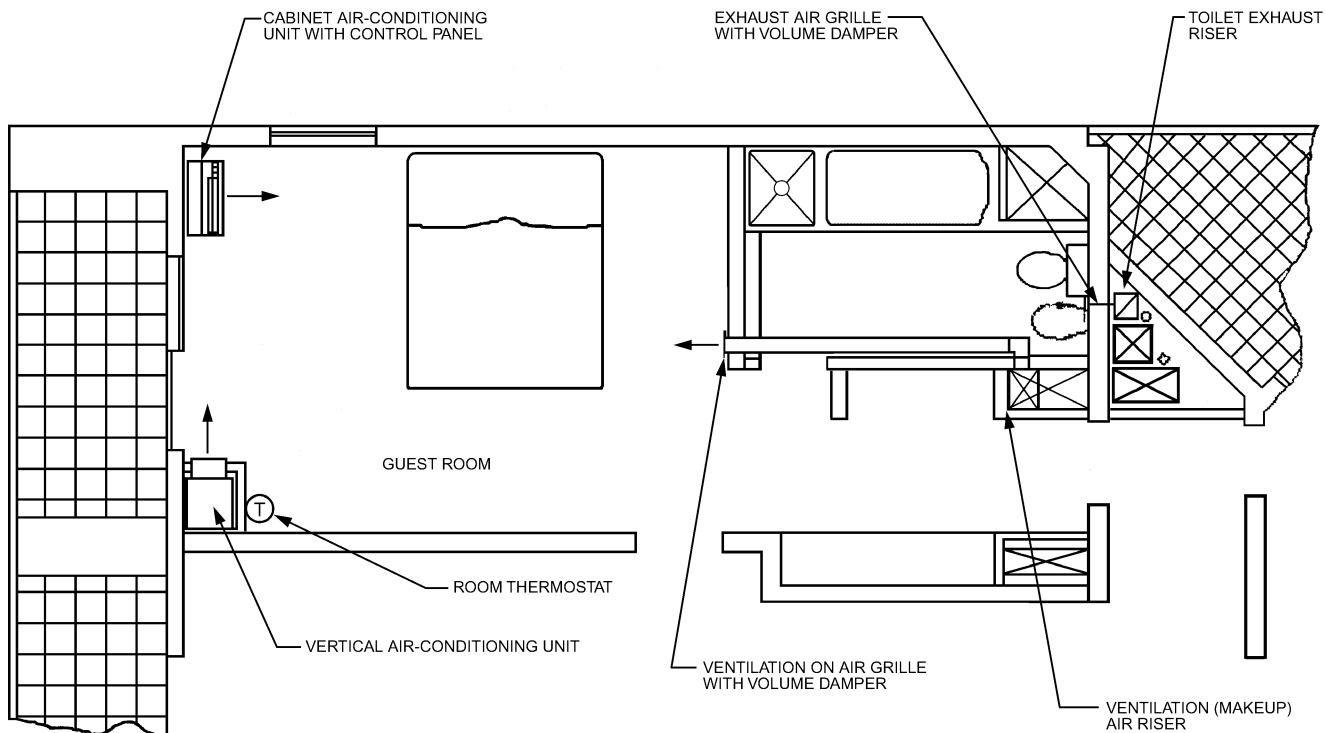


Fig. 1 Alternative Location for Hotel Guest Room Air-Conditioning Unit above Hung Ceiling



**Fig. 2 Alternative Location for Hotel Guest Room Air-Conditioning Unit on Room Perimeter and Chase-Enclosed**

- Introduce unconditioned outdoor air directly to the air-conditioning unit's return air plenum (perimeter wall installations). This approach can cause mold and mildew and should be avoided. During periods of part or low load, which occur during most of the cooling season, the thermostatically controlled air conditioner does not adequately condition the constant flow of outdoor air because the cooling coil valve closes and/or the compressor cycles off. As a result, humidity in the room increases. Also, when the air conditioner's fan is off, outdoor air infiltrates through the ventilation opening and again elevates the room's humidity level.

Guest-room HVAC units are normally controlled by a room thermostat. Thermostats for fan-coils normally control valves in two-pipe, four-pipe, and two-pipe chilled-water/electric heat systems. Control should include dead-band operation to separate the heating and cooling set points. Two-pipe system control valves are normally equipped with automatic changeover, which senses the water temperature and changes operation from heating to cooling. The thermostat may provide modulation or two-position control of the water control valve. The fan can be adjusted to high, medium, or low speed on most units.

Typical unitary refrigerant-based units have a push button off/fan/heat/cool selector switch, adjustable thermostat, and fan cycle switch. Heat pumps include a defrost cycle to remove ice from the outdoor coil. [Chapter 47](#) has more information on control for fan coils.

### Public Areas

Public areas are generally the showcase of a hotel. Special attention must be paid to incorporating a satisfactory system into the interior design. Locations of supply diffusers, grilles, air outlets, etc. must be coordinated to satisfy the architect. The HVAC designer must pay attention to access doors for servicing fire dampers, volume dampers, valves, and variable-air-volume (VAV) terminals.

**Design Concepts and Criteria.** Design criteria for public areas are given in [Table 2](#). In addition, the following design criteria must be considered:

- Year-round availability of heating and cooling
- Independent unit for each main public area
- Economical and satisfactory operation at part- and low-load conditions
- Coordination with adjacent back-of-the-house (BOTH) areas to ensure proper air pressurization (e.g., restaurants, kitchens)

**Load Characteristics.** The hours each public area is used vary widely. In many cases, the load is from internal sources from people, lights, and equipment. The main lobby normally is operational 24 hours per day. Areas like restaurants, meeting rooms, and retail areas have intermittent use, so the load changes frequently. HVAC systems that respond effectively and economically must be selected for these areas.

**Applicable Systems.** All-air systems, single-duct constant-volume, and VAV are most frequently used for public areas. [Chapter 4](#) of the 2012 *ASHRAE Handbook—HVAC Systems and Equipment* has more information on these systems, and [Chapter 47](#) in this volume covers control for all-air VAV systems.

### Back-of-the-House (BOTH) Areas

The BOTH area is normally considered a service or support area. Climatic conditions in these areas are typically less critical than in the remainder of the hotel. However, a few spaces require special attention.

**Design Concepts and Criteria.** Recommended design criteria for several areas in the BOTH are shown in [Table 3](#).

### Special Concerns

**Humidity, Mildew, Moisture Control, and IAQ.** Humidity control is critical to ensure satisfactory air quality and to minimize

costly mold and mildew problem in hotels. Moisture can be introduced and infiltrate into the guest rooms in the following ways:

- Unconditioned ventilation air is delivered directly into the guest room through the HVAC unit. At part or low sensible loads or in situations where the unit cycles on and off, the air-conditioning unit will not dehumidify the air adequately to remove the excess moisture.
- Outdoor humid air infiltrates through openings, cracks, gaps, shafts, etc. because of insufficient space pressurization.
- Moisture migrates through external walls and building elements because of a vapor pressure differential.
- An internal latent load or moisture is generated.

Removing water vapor from the air is the most feasible way to control mold and mildew, particularly when the problem spreads to walls and carpeting. Good moisture control can be achieved by applying the following techniques:

- Introduce adequately dried ventilation (makeup) air [i.e., with a dew point of 11°C (8.2 g/kg of dry air) or less] directly to the guest room.
- Maintain slightly positive pressure in the guest room to minimize infiltration of hot and humid air into the room. Before a new HVAC system is accepted by the owner, a certified air balance contractor should be engaged to demonstrate that the volume of dry makeup air exceeds the volume of exhaust air. As the building ages, it is important to maintain this slight positive pressure; otherwise, humid air that infiltrates into the building cavities will be absorbed regardless of how dry the room is maintained (Banks 1992).
- Provide additional dehumidification capability to the ventilation (makeup air) by dehumidifying the air to a lower level than the desired space humidity ratio. For example, introducing 30 L/s of makeup air at 8 g/kg can provide approximately 120 W of internal latent cooling (assuming 9.5 g/kg is a desirable space humidity ratio).
- Allow air conditioning to operate in unoccupied rooms instead of turning the units off, especially in humid areas.
- Improve the room envelope by increasing its vapor and infiltration resistance.

The third method allows ventilation air to handle part of the internal latent load (people, internal moisture generation, and moisture migration from external walls and building elements). In addition, this method can separate the internal sensible cooling, in-

**Table 3 Design Criteria for Hotel Back-of-the-House Areas<sup>a</sup>**

Category	Indoor Design Conditions	Comments
Kitchen, general <sup>b</sup>	28°C	Provide spot cooling
pastry <sup>b</sup>	24°C	
chef's office <sup>b</sup>	23 to 26°C 50 to 60% rh (summer) 30 to 35% rh (winter)	Fully air conditioned
Housekeeper's office	23 to 26°C 50 to 60% rh (summer) 30 to 35% rh (winter)	Fully air conditioned
Telephone equipment room	Per equipment criteria	Stand-alone air conditioner; air conditioned all year
Wine storage	Per food and beverage manager criteria	Air conditioned all year
Laundry		Spot cooling as required at workstations

<sup>a</sup> Governing local codes must be followed for design of the HVAC.

<sup>b</sup> Consult [Chapter 33](#) for details on kitchen ventilation.

ternal latent cooling, and ventilation loads. Independent ventilation/dehumidification allows room pressurization and space humidity control regardless of the mode of operation or magnitude of the air-conditioning load. Desiccant dehumidifiers can be retrofitted to solve existing moisture problems.

**Dedicated Outdoor Air Systems (DOAS).** DOAS air units are designed to condition ventilation air introduced into a space and to replace air exhausted from the building. The geographic location and class of the hotel dictate the functions of the makeup air units, which may filter, heat, cool, humidify, and/or dehumidify the ventilation air. Makeup air may be treated directly or by air-to-air heat recovery (sensible or combined sensible and latent) and other heat recovery techniques. Equipment to condition the air by air-to-air heat recovery and final heating, cooling, humidification, and/or dehumidification is also available.

Chapter 14 of the 2013 *ASHRAE Handbook—Fundamentals* provides design weather data for ventilation. Analyzing and selecting the proper makeup unit for the full range of entering conditions are critical for efficient and sufficient all-year operation. Air-to-air heat recovery helps stabilize entering conditions, which helps provide efficient and stable operation. However, heat recovery may not always be feasible. Often, exhaust air comes from many individual stacks. In this case, the cost of combining many exhausts for heat recovery may not be warranted.

Typical design criteria for ventilation (makeup) air units are listed in [Table 4](#).

Makeup air units can be stand alone packaged (unitary) or integrated in an air handler. A typical makeup air unit usually has the following features:

- Heating, cooling, and dehumidification
  - Chilled/hot water or steam coils in the air handling unit
  - Unitary refrigerant-based unit (direct-expansion cooling and gas furnace or electric heat)
  - Air-to-air energy recovery combined with mechanical cooling (DX or chilled water) and heating
  - Desiccant-based dehumidifier combined with air-to-air energy recovery, indirect/direct evaporative cooling and supplementary mechanical cooling and heating
- Heating only
  - Hot water or steam coils in the air handling unit
  - Stand alone gas-fired or electric makeup units
  - Air-to-air energy recovery with supplement heat

Humidification should be considered for all cold climates. The HVAC designer must also consider avoiding coil freeze up in water based systems. Chapters 26 and 28 of the 2012 *ASHRAE Handbook—HVAC Systems and Equipment* provide information about air-to-air energy recovery and makeup air units, respectively.

Hotel location, environmental quality desired by the owner, and design sophistication determines the system selected. For example, in locations with cool summers, dehumidification with mechanical cooling only is satisfactory. For humid locations or where enhanced

**Table 4 Design Criteria for Hotel Guest Room DOAS**

Supply Air Conditions				Filter Efficiency (ASHRAE Standard 52.2)
Winter		Summer		
Temperature	Relative Humidity	Temperature	Relative Humidity	
20 to 24°C	30 to 45%	23 to 26°C	40 to 50%	6 to 8 MERV

Notes:

1. Follow local codes when applicable.

2. Building location may dictate optimum supply condition in recommended range.

3. MERV = minimum efficiency rating values.

dehumidification is required, a desiccant-based unit can provide lower supply air humidity, to help prevent mold and mildew and provide internal latent cooling.

**Central Mechanical Plant.** Designing a reliable and energy-efficient mechanical plant is essential to ensuring a profitable hotel. The chiller plant must operate efficiently at part-load conditions. Some redundancy should be considered in case of equipment failure. Designs often include spare critical equipment where spare parts and qualified service are not readily available. Chillers with multistage compressors should be considered because they provide partial cooling during failures and enhance part-load operation. When using two chillers, each should provide at least 60% of the total load. Combinations of three chillers providing 40% each or four chillers providing 30% each are better for tracking part-load conditions. Cooling towers, pumps, etc., can be sized in a similar manner.

The heating plant should be designed to accommodate the winter heating load and could provide domestic hot water, swimming pool heating, and service to kitchens and laundries as well. The type of fuel used depends on location, availability, use, and cost.

Multipurpose boiler design for the kitchen and laundry should offer redundancy, effective part-load handling, and efficient operation during summer, when the HVAC heating load does not exist.

In areas with mild winters, a two-pipe system or an air-to-water heat pump chiller/heater can be considered. In any event, the HVAC designer must understand the need for all-year cooling and heating availability in the public areas. In this case, a combination of air-to-water heat pump, chiller/heater for the guest rooms, and independent heat pumps for public areas can be installed.

**Acoustics and Noise Control.** The sound level in guest room and public areas is a major design element. Both the level and constancy of noise generated by the HVAC unit are of concern. Normally, packaged terminal air conditioners/heat pumps and water-source heat pumps are noisier because of the compressor. Some equipment, however, has extra sound insulation, which reduces the noise significantly.

Lowering fan speed, which is usually acceptable, can reduce fan noise levels. On/off cycling of the fan and compressor can be objectionable, even if the generated noise is low. Temperature control by cycling the fan only (no flow control valve) should not be used.

Another source of noise is sound that transfers between guest rooms through the toilet exhaust duct. Internal duct lining and sound attenuators are commonly used to minimize this problem.

Noise from equipment located on the roof or in a mechanical room located next to a guest room should be avoided. Proper selection of vibration isolators should prevent vibration transmission. In critical cases, an acoustician must be consulted.

**New Technology in Hotels.** Modern hotels are implementing techniques to enhance comfort and convenience. For example, the telephone, radio, TV, communications, lighting, and air-conditioning unit can be integrated into one control system. Occupancy sensors conserve energy by resetting the temperature control when the room is occupied or when guests leave. As soon as a new guest checks in at the front desk, the room temperature is automatically reset. But even with this improved technology, it is important to remember that temperature reset may create humidity problems.

## 5. DORMITORIES

Dormitory buildings frequently have large commercial dining and kitchen facilities, laundering facilities, and common areas for indoor recreation and bathing. These ancillary loads may make heat pump or total energy systems appropriate, economical alternatives, especially on campuses with year-round activity.

When dormitories are shut down during cold weather, the heating system must supply enough heat to prevent freezing. If the

dormitory contains non-dwelling areas such as administrative offices or eating facilities, these facilities should be designed as a separate zone or with a separate system for flexibility, economy, and odor control.

Subsidiary facilities should be controlled separately for flexibility and shutoff capability, but they may share common refrigeration and heating plants. With internal-source heat pumps, this interdependence of unitary systems allows reclamation of all internal heat usable for building heating, domestic water preheating, and snow melting. It is easier and less expensive to place heat reclaim coils in the building's exhaust than to use air-to-air heat recovery devices. Heat reclaim can easily be sequence controlled to add heat to the building's chilled-water system when required.

## 6. MULTIPLE-USE COMPLEXES

Multiple-use complexes combine retail, office, hotel, residential, and/or other commercial spaces into a single site. Peak HVAC demands of the various facilities may occur at different times of the day and year. Loads should be determined independently for each occupancy. Where a central plant is considered, a block load should also be determined.

Separate air handling and distribution should serve separate facilities. However, heating and cooling units can be combined economically into a central plant. A central plant provides good opportunities for heat recovery, thermal storage, and other techniques that may not be economical in a single-use facility. A multiple-use complex is a good candidate for central fire and smoke control, security, remote monitoring, billing for central facility use, maintenance control, building operations control, and energy management.

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