

## CHAPTER 5

# 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.

### LOAD CHARACTERISTICS

1. 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.
2. 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.
3. Concentrations of lighting and occupancy are typically low; activity is generally sedentary or light. Occupancy is transient in nature, with greater use of bedrooms at night.
4. Kitchens, whether integrated with or separate from residential quarters, have the potential for high appliance loads, odor generation, and large exhaust requirements.
5. Rooms generally have an exterior exposure, kitchens, toilets, and dressing rooms may not. The building as a whole usually has multiple exposures, as may many individual dwelling units.
6. Toilet, washing, and bathing facilities are almost always incorporated in the dwelling units. Exhaust air is usually incorporated in each toilet area.
7. 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 P.M. in dormitories. [Chapter 49](#) includes details on service water heating.
8. Load characteristics of rooms, dwelling units, and buildings can be well defined with little need to anticipate future changes to the design loads, other than the addition of a service such as cooling that may not have been incorporated originally.
9. The prevalence of shifting, transient interior loads and exterior exposures with glass results in high diversity factors; the long-hour usage results in fairly high load factors.

### DESIGN CONCEPTS AND CRITERIA

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

The preparation of this chapter is assigned to TC 9.8, Large Building Air-Conditioning Applications.

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. Another means of dehumidification is 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.

### SYSTEMS

#### Energy-Efficient Systems

The most efficient systems generally include water-source and air-source heat pumps. In areas with ample solar radiation, water-source heat pumps may be solar assisted. Energy-efficient equipment generally has the lowest operating cost and is relatively simple, an important factor where skilled operating personnel are unlikely to be available. Most 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.

The water-loop heat pump has a lower operating cost than air-cooled unitary equipment, especially where electric heat is used. 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.

Except for the central circulating pump, heat rejector fans, and supplementary heater, 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, the load on the refrigeration circuit is not as severe because the water temperature is controlled for optimum operation. Operating costs are low due to the energy conservation inherent in the system. 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.

While heating is required in many areas during cool weather, cooling may be needed in rooms having high solar or internal loads. 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 water from which it can be extracted at night; a water heater is not needed. 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. 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

Energy-neutral systems do not allow simultaneous cooling and heating. 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. To qualify as energy-neutral, a system must have controls that prevent simultaneous operation of the cooling and heating cycles. 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 a portion of the conditioned air serving one room into the second, usually smaller, room. Multiple PTAC units allow additional zoning in dwellings having 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 having relatively inefficient refrigeration circuits, the operating cost of a PTAC is quite reasonable, mostly because individual thermostatic control each machine, which eliminates the use of reheat while preventing the space from being overheated or overcooled. Also, because the 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 requires 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 the accelerated corrosion to aluminum and steel components caused by salt. In high-rise buildings of more than 12 stories, special care is required, both in the design and construction of outside partitions and in the 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, the highest operating noise level, and the poorest distribution of conditioned air of any of the 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, the products of combustion must be vented. In a one- or two-story structure, it is possible to use individual chimneys or flue pipes, but in a high-rise structure requires a multiple-vent chimney or a manifold vent. Local codes should be consulted.

Sealed combustion furnaces draw all the combustion air from outside and discharge the flue products through a windproof vent to the outdoors. The unit must be located near an outside 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. 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 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 a HVAC system are as follows:

- Optimum use must be made of the thermal energy recoverable from the prime mover during all or most operating modes, not just during conditions of peak HVAC demand.
- Heat recoverable via 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 should be followed. The quantity of outdoor air introduced into the rooms or corridors is usually slightly in excess of the exhaust quantities to pressurize the building. To avoid adding any load to the 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 the 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 outside 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 44 of the ASHRAE Handbook—HVAC Systems and Equipment](#)). Such recovery 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 26 of the 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. The transfer louvers need to be acoustically lined. Corridors, stairwells, and elevators should be pressurized for fire and smoke control (see [Chapter 52](#)).

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 achieve energy conservation by reducing the indoor temperature during the heating season. Such a strategy should be pursued with caution because it could affect the competitiveness of the hotel/motel, for example.

### 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 outside doors to patios and balconies. Hotel classes range from the deluxe hotel to the economy hotel/motel as outlined in [Table 1](#).

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 the 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 outside 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:

**Table 1 Hotel Classes**

| Type of Facility                       | Typical Occupancy,<br>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                  | Inside 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 | 10 to 15%                      | 25 to 35        |
| Lobbies                   | 20 to 23°C               | 30 to 35%                      | 23 to 26°C  | 40 to 60%         | 8 L/s per person         | —                     | 35% 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        | —                     | 35% 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         | —                     | 35% or better                  | 25 to 35        |

<sup>a</sup> This table should not be used as the only source for design criteria. The data contained here can be determined from ASHRAE handbooks, standards, and governing local codes.

<sup>b</sup> Design criteria for stores, restaurants, and swimming pools are in [Chapters 2, 3, and 4](#), respectively.

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

<sup>d</sup> Per ASHRAE *Standard* 62.

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

<sup>f</sup> Per ASHRAE *Standard* 52.1.

- Individual and quick 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. The fact that guest rooms have a transient occupancy and the diversity associated with the operation of the support facilities provides an opportunity to take advantage of load diversification.

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 portion 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 outside 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

With the exception of the two-pipe fan coil, all of 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)

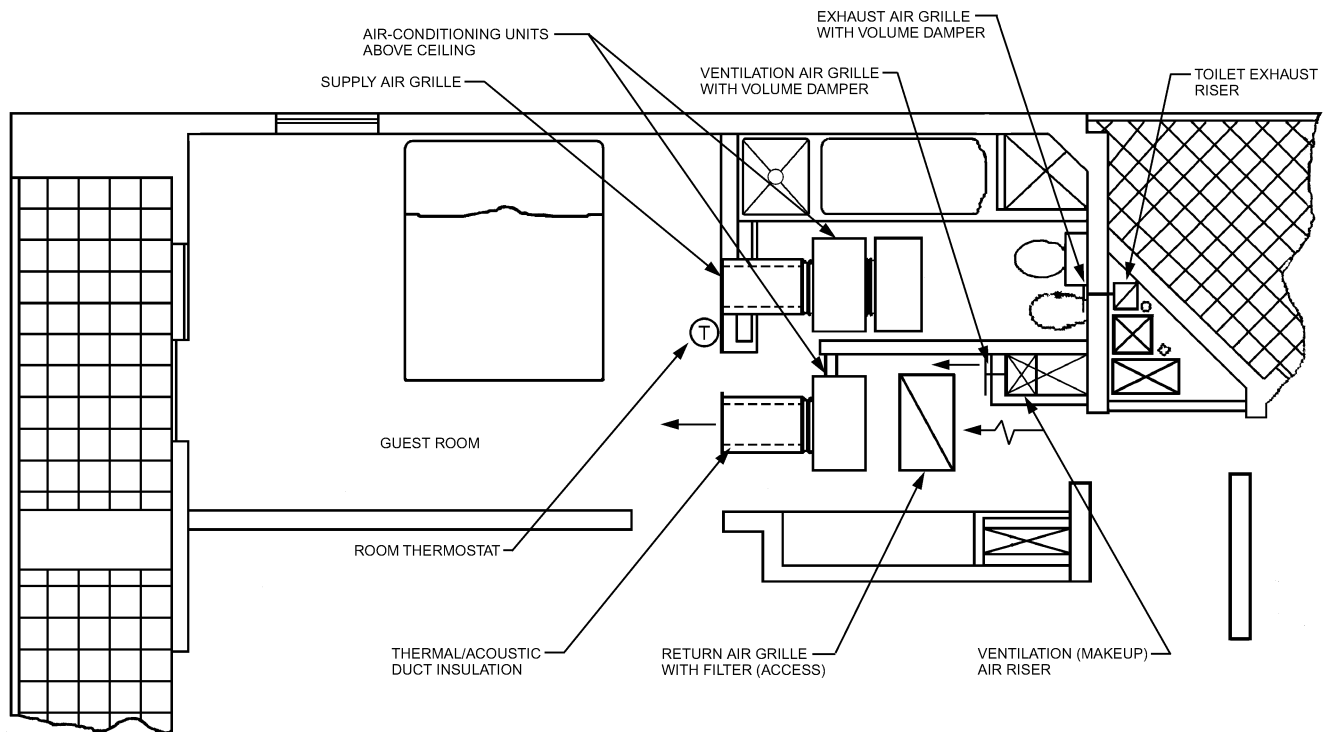
The unitary refrigerant-based system on the other hand offer the following advantages:

- 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

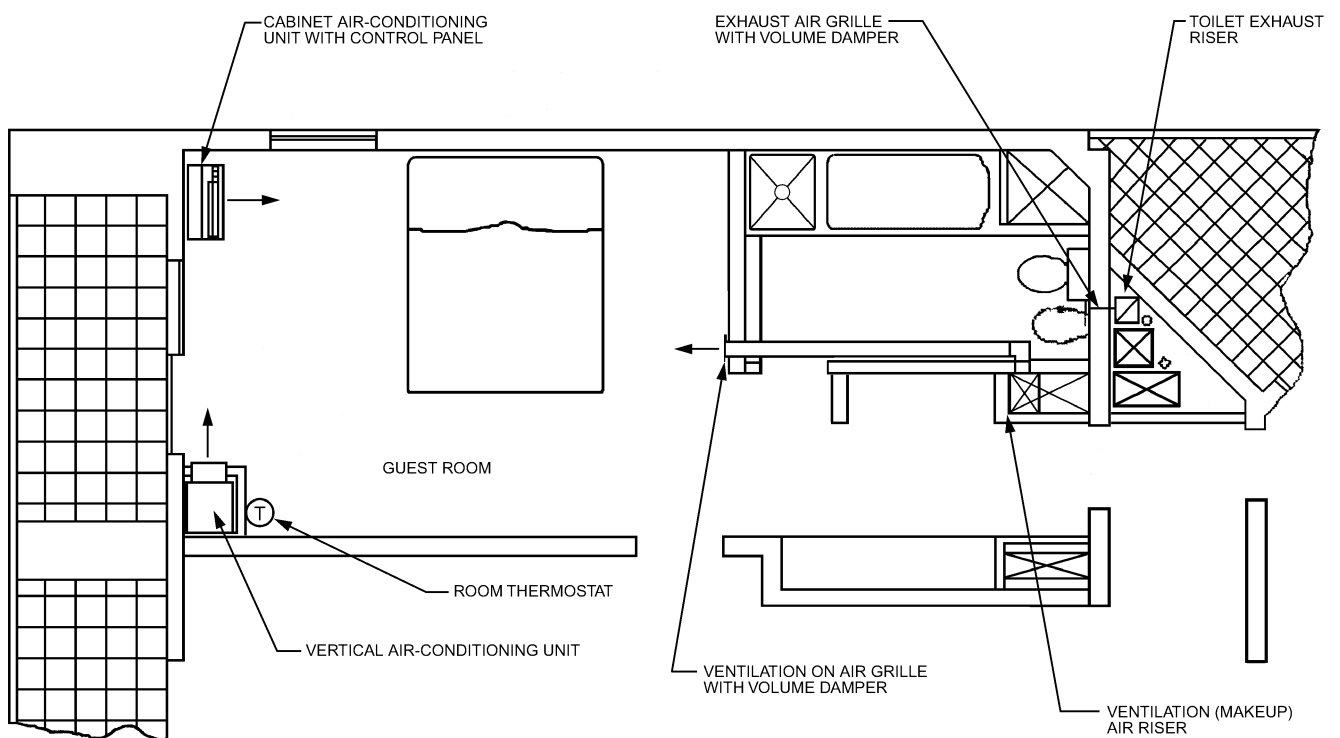
The type of facility, sophistication, and quality desired by the owner/operator, as well as possible code requirements typically influence the selection. An economic analysis (life-cycle cost) is particularly important when selecting the most cost-effective system. [Chapter 36](#) has further information on economic analysis techniques. Computer software like the NIST Building Life-Cycle Cost Program (BLCC) performs life-cycle cost analyses quickly and accurately (NIST 1994).

[Chapter 3](#) and [Chapter 5 of the 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



**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**

the bed in order 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 in a relatively accessible location for maintenance (see [Figure 1](#) and [Figure 2](#)).

Most units are designed for free-air discharge. The supply air grille should be selected according to the manufacturer recommendations for noise and air diffusion. Also, the 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 outside air is conditioned in a primary makeup air unit and distributed via 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.
- Introduce unconditioned outside 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 outside air because the cooling coil valve closes and/or the compressor cycles off. As a result the humidity level in the room increases. Also, when the air conditioner's fan is off, outside air infiltrates through the ventilation opening and again elevates the room 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 with electric heat systems. The 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 the mode of 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 46](#) has more information on control for fan coils.

## Public Areas

The public areas are generally the showcase of a hotel. Special attention must be paid to incorporating a satisfactory system into the

interior design. The location 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 is 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-load and low-load conditions
- Coordination with adjacent back-of-the-house (BOTH) areas to ensure proper air pressurization (i.e., restaurants and kitchens)

**Load Characteristics.** The hours each public area is used varies widely. In many cases the load is due to 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 2 of the ASHRAE Handbook—HVAC Systems and Equipment](#) has more information on these systems while [Chapter 46](#) 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. The 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:

1. 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

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

| Category                             | Inside Design Conditions                                     | Comments                                              |
|--------------------------------------|--------------------------------------------------------------|-------------------------------------------------------|
| Kitchen (general) <sup>b</sup>       | 28°C                                                         | Provide spot cooling                                  |
| Kitchen (pastry) <sup>b</sup>        | 24°C                                                         |                                                       |
| Kitchen (chef's office) <sup>b</sup> | 23 to 26°C<br>50 to 60% rh (summer)<br>30 to 35% rh (winter) | Fully air conditioned                                 |
| Housekeeper's office                 | 23 to 26°C<br>50 to 60% rh (summer)<br>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 31](#) for details on kitchen ventilation.

unit will not dehumidify the air adequately to remove the excess moisture.

2. Outdoor humid air infiltrates through openings, cracks, gaps, shafts, etc. due to insufficient space pressurization.
3. Moisture migrates through external walls and building elements due to a vapor pressure differential.
4. 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:

1. 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.
2. 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).
3. 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).
4. Allow air conditioning to operate in unoccupied rooms instead of turning the units off, especially in humid areas.
5. Improve the room envelope by increasing its vapor and infiltration resistance.

Method 3 allows the 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, internal 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.

**Ventilation (Makeup) Air Units.** Makeup 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 27 of the 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 an efficient and sufficient all-year operation. Air-to-air heat recovery helps stabilize the entering conditions, which helps provide an 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](#).

**Table 4 Design Criteria for Hotel Guest Room Makeup Air Units**

| Supply Air Conditions |                   |             |                   | Filter Efficiency<br>(ASHRAE<br>Standard<br>52.1) |
|-----------------------|-------------------|-------------|-------------------|---------------------------------------------------|
| Winter                |                   | Summer      |                   |                                                   |
| Temperature           | Relative Humidity | Temperature | Relative Humidity |                                                   |
| 20 to 24°C            | 30 to 45%         | 23 to 26°C  | 40 to 50%         |                                                   |
|                       |                   |             |                   | 30%                                               |

Notes:

1. Follow local codes when applicable.
2. The building location may dictate the optimum supply condition in the recommended range.

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. [Chapter 31](#) and [Chapter 44 of the ASHRAE Handbook—HVAC Systems and Equipment](#) provide information about makeup air units and air-to-air energy recovery, 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 dehumidification is required, a desiccant-based unit can provide lower supply air humidity. Such a unit can help prevent mold and mildew and provide internal latent cooling.

**Central Mechanical Plant.** Designing a reliable and energy efficient mechanical plant is essential element toward 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 heating load during the winter end 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 the 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 the 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 the noise generated by the HVAC unit are of concern. Normally, packaged-terminal air conditioners/heat pumps and water-source heat pumps are noisier due to the compressor. Some equipment, however, has extra sound insulation, which reduces the noise significantly.

Lowering the fan speed, which is usually acceptable, can reduce fan noise levels. On/off cycling of the fan and the 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 new techniques to enhance comfort and convenience. For example, the telephone, radio, TV, communications, lighting, and air-conditioning unit are being integrated into one control system. Occupancy sensors are being used to conserve energy by resetting the temperature control when the room is occupied or when the 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.

## DORMITORIES

Dormitory buildings frequently have large commercial dining and kitchen facilities, laundering facilities, and common areas for indoor recreation and bathing. Such 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 sufficient heat to prevent freeze-up. 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 permits the reclamation of all internal heat usable for building heating, domestic water preheat-

ing, 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.

## MULTIPLE-USE COMPLEXES

Multiple-use complexes combine retail facilities, office space, hotel space, residential space, and/or other commercial space into a single site. The 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 the 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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