Lodging Industry Solutions

Heating and Cooling Space Conditioning Technology Guidebook

TR-111676-V1

Final Report, December 1998

EPRICSG Project Manager
A. Saleh

EPRICSG • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10414, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

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Energy International, Inc.

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CITATIONS

This report was prepared by

Energy International, Inc.
127 Bellevue Way, SE, Suite 200
Bellevue, Washington 98004

Principal Investigator
K. Smit

This report describes research sponsored by EPRICSG.

The report is a corporate document that should be cited in the literature in the following manner:

Lodging Industry Solutions: Heating and Cooling Space Conditioning Technology Guidebook, EPRICSG, Palo Alto, CA: 1998. TR-111676-V1.

REPORT SUMMARY

This guidebook provides utility representatives with a tool to help understand the lodging industry and its space conditioning needs and options. It also provides information to help build and maintain customer loyalty. The guidebook will enable utility personnel to provide additional services to their lodging clients by informing them of space conditioning choices and solutions for their facilities.

Background
The U.S. lodging industry has experienced growth and relative prosperity in recent years. The healthy economic situation presents property owners and managers with opportunities for investing in energy-efficient heating, ventilating, and air conditioning system improvements that can yield savings well into the future. Utilities can assist decision makers in selecting the best equipment for their needs; such valuable services are important for utilities in a deregulated environment to help them retain existing customers and win new ones.

Objectives
To develop a guidebook for utility staff to help their lodging industry customers understand space conditioning technology options for their facilities and to be of help when selecting equipment to optimize profitability.

Approach
Investigators used a variety of industry data sources to develop an overview of the lodging industry. Focused discussions were held with representatives from the lodging industry to help identify their needs and plans related to heating and cooling technology. Equipment manufacturers also were contacted to obtain information and insights about systems that best apply to the lodging industry.

Results
This guidebook provides utility representatives with an overview of the lodging industry, primarily hotels and motels. It provides technical and economic information regarding heating and cooling technologies for both individual guest rooms and central systems for non-guest room areas and entire facilities. It also provides information regarding the problem of moisture control and technological solutions for controlling

moisture in hotels and motels. Because guest comfort and health are important to the lodging industry, the report also covers the topic of indoor air quality.

EPRI Perspective

To attract and maintain customers, electric utilities in a deregulated environment need to provide services that are geared toward adding value to their product. The energy retailer, distribution company, and generation company each has a stake in servicing the lodging industry. This guidebook provides utilities with technical and economic information useful for helping lodging customers make important decisions regarding space conditioning systems as part of a proactive utility marketing strategy.

TR-111676-V1

Interest Categories

Commercial building systems
Commercial HVAC
Thermal storage
Refrigeration & dehumidification

Keywords

Air conditioning
Commercial buildings
Hotels and motels
Moisture control
Indoor air quality
Heat pumps

ACKNOWLEDGMENTS

Mr. Kevin Smit of Energy International, Inc. directed the development of this guidebook. Mr. Mark Parish and Dr. Juliet Mak conducted most of the research and prepared the guidebook content. Mr. Richard Tidball provided additional review. Desktop publishing services and graphics development were provided by Colleen Williams and Lorraine Day, both of Energy International.

Numerous contacts were made throughout the development of this project. We wish to thank the following hotel/motel chains for their input: Hyatt, Hilton, LaQuinta, Radisson, Best Western, Ramada, Extended Stay America, Westin, Sheraton, Travelodge, Super 8, Intercontinental, Four Seasons, Motel 6, Knights Inn, Holiday Inn, Bristol Hotels, and Wyndham. HVAC product vendors were also contacted, but are too numerous to mention by name.

Andrew J. Saleh, P.E. is the EPRI project manager and provided direction as well as final review.

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INTRODUCTION

The American lodging industry has experienced growth and relative prosperity in recent years. Profits have increased steadily since 1991 to record levels (AHMA 1998b), spurring property improvements and new construction—approximately 7% of lodging property floor space was constructed after 1990 (EIA 1998a) and more than 127,000 new rooms were added in 1997 alone (AHMA 1998a). This healthy economic situation presents property owners and managers with opportunities for investing in energy-efficient heating, ventilation, and air conditioning improvements that can yield substantial cost savings well into the future.

Operating costs and occupancy rates are critical to the economic success of any lodging establishment. Maintaining high occupancy requires providing guests with a comfortable environment while establishing a high profile through advertising, curbside appeal, and word of mouth. At the same time, operating costs of the establishment must be kept in check, presenting the manager with the challenge of maintaining a delicate balance between the two. This makes financial resource allocation in the lodging industry a critical issue and upgrading of existing equipment a lower priority. When funds are available, they oftentimes go toward special services and aesthetic improvements as opposed to equipment investments. However, recent financial gains in the lodging industry are making more funds available for heating and cooling system upgrades.

Among new equipment installations in the lodging industry (air handling equipment, water heaters, laundry and cooking equipment), about 70% is in new construction, remodeling, or expansion, 14% replaces non-functioning equipment, and the remainder is for miscellaneous purposes (AGA 1998). Lodging equipment purchasing decisions have historically been made without any organized approach, and most decision-makers have no formal guidelines for making equipment choices. In the past, the primary sources of information for these decisions have been (in descending order of prominence) the decision-maker's past experience, manufacturer representatives, and trade journals. Unfortunately, the person responsible for equipment selection (generally the property owner or manager) may not be fully informed of the latest technologies and may even be misled by inaccurate information. This informational gap offers a niche that utilities can fill within the lodging industry. By providing good advice on heating, ventilation, and air conditioning (HVAC) equipment, utilities can help property owners and managers make wise decisions and avoid poor equipment choices that could hamper their profits over the long run. The benefits to utilities of offering this service will take the form of improved customer relations and strengthened customer loyalty.

This guidebook is developed to assist utilities in advising the lodging industry about HVAC equipment options. By serving as a useful reference source, it can help them perform this much-needed, valuable service.

Industry Overview

According to the U.S. Census Bureau, there were a total of 43,251 hotels and motels in the United States in 1995. California, Florida, Texas, and New York led the list of the 10 states with the most hotel and motel establishments (see Figure 1-1). Pennsylvania is fifth on the list, followed by Michigan, North Carolina, Wisconsin, Ohio, and Colorado. California leads Florida by a margin of more than 2200 establishments, and has more than four times as many establishments as tenth-place Colorado. In addition, tourism is the number-one industry in nine states (AHMA 1998a).

Regionally, the South census region has the majority of the lodging establishments, followed by the Midwest, Northeast, and West regions.

State	Hotels/ Motels
1) CA	5956
2) FL	3695
3) TX	2989
4) NY	2545
5) PA	1816
6) MI	1713
7) NC	1586
8) WI	1430
9) OH	1414
10) CO	1395

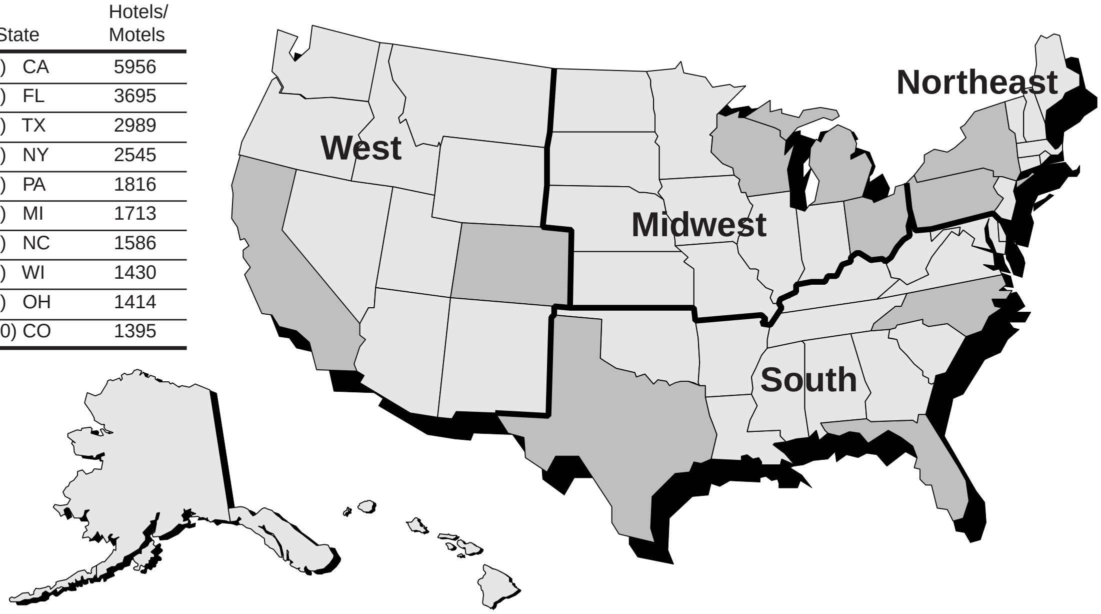

Figure 1-1
The 10 States with the Most Lodging Facilities
Source: U.S. Census Bureau, *County Business Patterns*, 1995 (Web source).

Composition and Size

As shown in Figure 1-2, the lodging industry is made up of a variety of property types. These property types constitute what the American Hotel and Motel Association (AHMA) calls the "hospitality" industry. This report uses the same classification for the lodging industry. However, the U.S. Department of Energy (DOE) has a broader definition of the lodging industry which includes long-term residences such as dormitories and nursing homes.

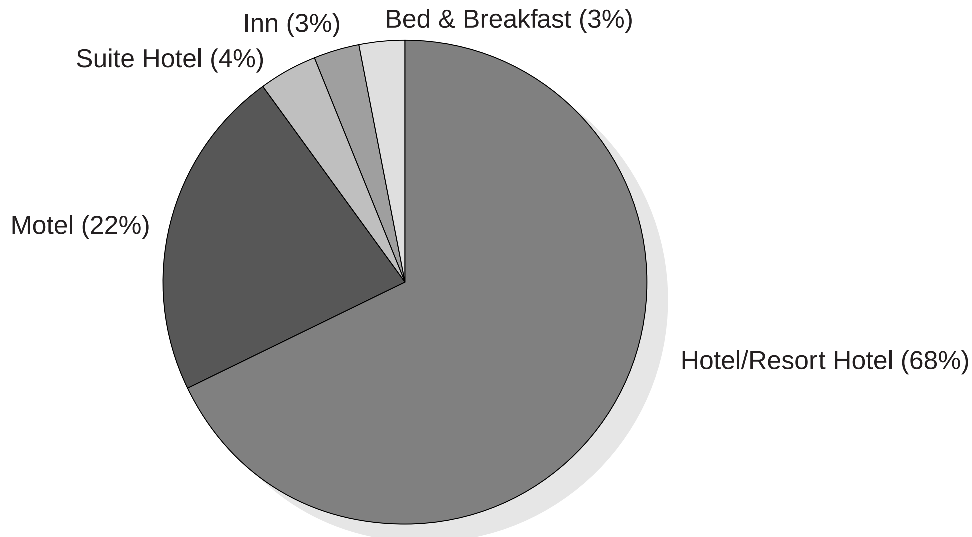

Figure 1-2
Lodging Industry: Distribution of Floor Space, by Type of Establishment (1997)
Source: American Gas Association, *Commercial Market Segmentation Study, Lodging Sector*, 1998.

Lodging establishments come in a broad range of sizes as measured by floor space and the number of rooms. However, the majority of lodging capacity can be classified as relatively small establishments (see Figure 1-3). Almost 58% of all establishments have fewer than 150 rooms. Figure 1-4 also shows that 86% of lodging properties have fewer than 50 employees, and more than 50% of lodging properties have fewer than 10 employees.

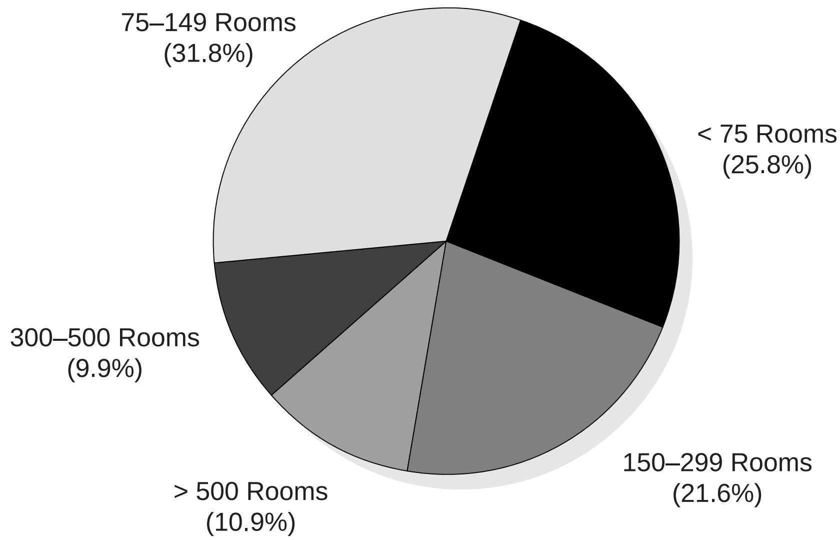

Figure 1-3
Lodging Industry: Industry-Wide Distribution of Rooms by Number of Rooms in Establishment, 1996
Source: American Hotel & Motel Association Lodging Industry Profile, 1997.

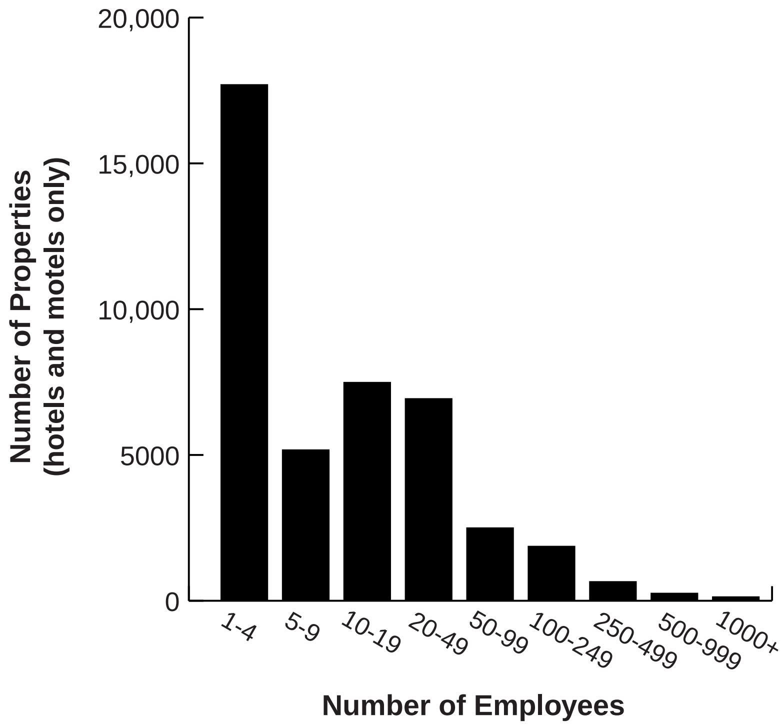

Figure 1-4
Lodging Industry Properties, by Number of Employees
Source: U.S. Census Bureau, *County Business Patterns*, 1995.

The variety of building types and sizes requires a wide spectrum of different equipment to meet energy needs—be it space conditioning, water heating, etc. Based on its unique operating circumstances, each lodging establishment must screen the numerous products available for every application and select a combination of equipment that meets its particular selection criteria (e.g., minimum cost over the equipment life).

Economic Outlook

In recent years, the economic performance of the U.S. lodging industry has been exceptional. In 1997, 49,000 properties, representing 3.8 million rooms, generated revenues of $85.6 billion at an average occupancy rate of 64.5% (AHMA 1998b). Occupancy rates declined slightly from 66% in 1996 to 64.5% in 1997 and are expected to drop below 64% in 1998 (WSJ 1998). Although profits have been rising sharply (including a 50% gain from 1995 to 1996 and another 40% gain in 1997), the occupancy rate statistics could be an indication that the industry is moving toward over-capacity. Lodging establishments must therefore remain vigilant in their cost-cutting efforts in order to stay profitable in the future.

Lodging in this country is closely associated with the U.S. tourism industry, which in 1997 accounted for $481.5 billion in revenues (AHMA 1998b). Tourism constitutes a major portion of lodging clientele (and the primary clientele for many establishments), but business travelers account for the largest single lodging customer constituency. In 1997, transient business travelers comprised 30% of the industry's customer base, followed by persons attending conferences or group meetings (26%), and those traveling for other purposes (24%) (AHMA 1998a). The U.S. Department of Commerce expects domestic travel to increase by 2–3% per year from 1997 through 2001. This prediction means bright prospects for the lodging industry as a whole.

Although lodging industry profits have recently reached record levels, profit margins remain relatively slim.[1] Reductions in operating costs can have a significant impact on properties with marginal profitability. Effective management of energy consumption should be an integral part of any lodging establishment's overall business strategy as well as capital investments in energy-conserving equipment that could substantially reduce costs and increase profit margins.

[1] Data from the record year of 1996 indicate that profit was 16.6% of total revenues (AHMA 1997).

Energy Use in the Lodging Industry

Historical Perspective

Energy efficiency of commercial buildings has improved considerably over the past two decades. Following the oil supply interruptions of 1973 and 1979 and the ensuing attention paid to environmental affairs, energy conservation became a major concern in the 1980s (EIA 1994). Since then, new commercial buildings have been tailored for specific climates and older buildings have been retrofitted with energy-saving features.

Energy requirements of the lodging industry are greatly affected by guest service offerings (EPRI 1996). Amenities such as swimming pools, saunas, fitness rooms, and business services are now commonplace and contribute significantly toward overall energy usage.

Between 1989 and 1995, end-use energy intensities[2] for space heating, ventilation, cooking, and refrigeration have decreased, while cooling, water heating, lighting, and office equipment usage have increased. The increases may be attributable in part to changes in applications—for example, the need for increased security may have increased lighting power consumption, and the rapid growth in personal computers and fax machines undoubtedly contributed to an increase in office energy use (EIA 1994).

Over the years, building size and age have shown little correlation with average energy intensity in lodging buildings (EIA 1998a[3]). However, geographic factors have made a discernible difference. Table 1-1 shows average energy intensities of lodging buildings in the four U.S. census regions: West, Midwest, Northeast, and South (see Figure 1-1 for census region breakdown).[4] Lodging facilities in regions requiring more heating consumed more energy per square foot than facilities in regions requiring only cooling or limited heating. In all regions, natural gas and electric intensity is relatively even, while the Northeast and Midwest regions make more use of other energy sources (e.g., oil, liquid propane).

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[2] Annual energy consumption per square foot of floor space.
[3] In 1995, the average energy intensity was just over 120,000 Btu/ft^2 for most lodging facilities.
[4] Includes: convention hotels, hotels, inns, motels, shelter homes, tourist homes, boarding houses, convents, monasteries, dormitories, sorority and fraternity houses, orphanages, and skilled nursing homes.

Table 1-1
Lodging Energy Intensity by Census Region (thousands Btu/ft^2)

Census Region	Total	Electric	Natural Gas	Other
Northeast	178	68	62	48
Midwest	150	45	75	30
South	112	57	47	8
West	110	42	59	9

Source: *Energy End-Use Intensities in Commercial Buildings*, U.S. Department of Energy, Energy Information Administration, 1995.

Current Perspective

The lodging industry not only comprises a good fraction of GDP and commercial building floor space in this country, but is also a large consumer of energy. Energy expenditure is a significant portion of the average hospitality operating budget regardless of property size (see Figure 1-5).

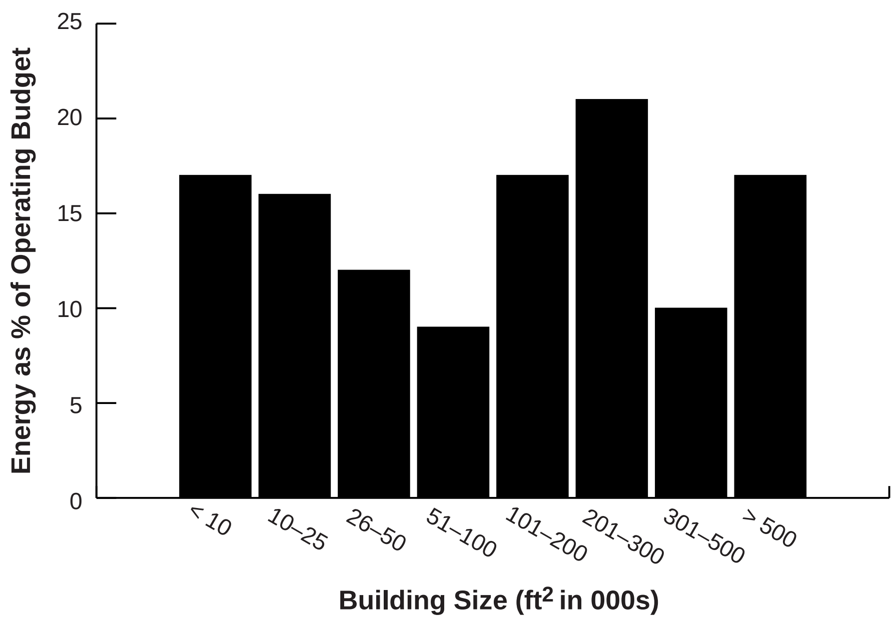

Figure 1-5
Lodging Industry: Energy Expenditures as Percentage of Operating Budget, by Building Size (1997)
Source: American Gas Association, *Commercial Market Segmentation Study, Lodging Sector*, 1998.

Lodging energy needs span a multitude of end-uses, namely, lighting, space conditioning, water heating, laundry service, food service, pool/sauna/spa heating, office equipment, and various plug-in usage ranging from coffee pots to vacuum cleaners. This energy comes from a variety of sources, but primarily takes the form of electricity and natural gas. Industry-wide energy intensity by end-use for 1995 is shown in Table 1-2.

Table 1-2
Lodging Buildings: Annual Energy Intensity, by End-Use and Source (thousand Btu/ft^2), 1995

End-Use	Total Energy	Electricity	Natural Gas
Space Heating	22.7	3.2	13.5
Cooling	8.1	8.0	N/A*
Ventilation	1.7	1.7	N/A
Water Heating	51.4	3.4	51.4
Lighting	23.2	23.3	N/A
Cooking	6.6	0.5	7.9
Refrigeration	2.3	2.3	N/A
Office Equipment	3.8	3.8	N/A
Other	7.5	5.7	2.4

Source: *Energy End-Use Intensities in Commercial Buildings*, U.S. Department of Energy, Energy Information Administration, 1995.
* Data are not reported by DOE

The energy source for any end-use will invariably depend upon the equipment chosen to do the job. Electricity is widely used for space heating (57% of lodging floor space) and almost exclusively for space cooling (99% of lodging floor space) (AGA 1998). In addition, 79% of energy used in dehumidification is electricity-based. However, natural gas-fired equipment is the primary fuel for other applications such as water and pool heating. Table 1-2 shows that water heating represents the largest single energy end-use in lodging buildings, followed by space conditioning (heating, cooling, and ventilation). However, lighting is the highest single end-use for electricity. Electricity end-uses, broken down by percentages, are shown in Figure 1-6.

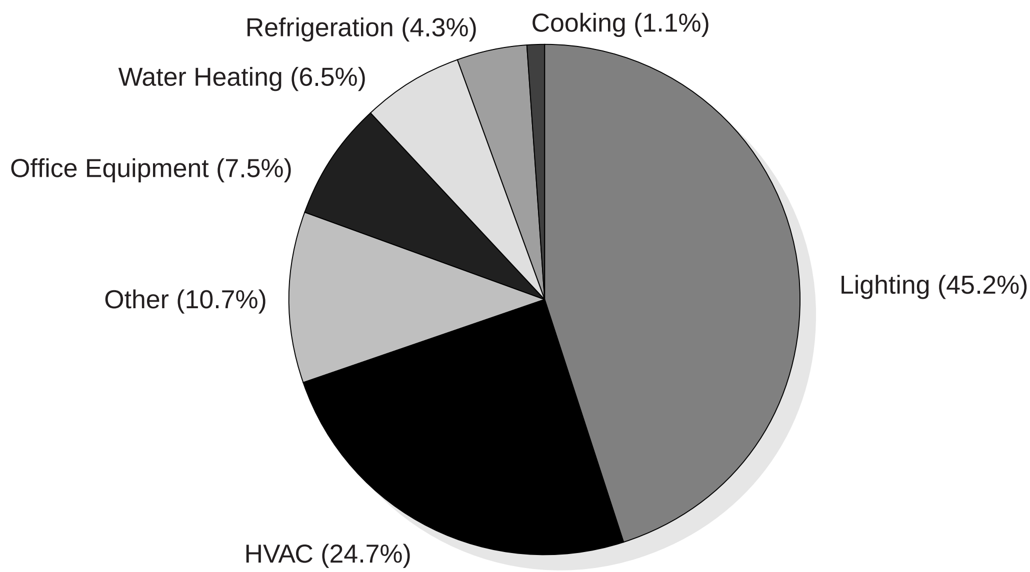

Figure 1-6
Lodging Buildings: Electricity End-Uses, 1995
Source: *Energy End-Use Intensities in Commercial Buildings*, U.S. Department of Energy, Energy Information Administration, 1995.

Guidebook Organization

Following this chapter, technical information in this guidebook is presented in two primary sections. The commonality of room space conditioning units in smaller lodging properties lends itself to specific treatment. Chapter 2 is dedicated to discussion of this type of equipment. Larger properties are more likely to utilize central heating and cooling systems with multiple components as opposed to individual room units, and these are covered in Chapter 3. The topic of Chapter 4 is moisture. The Guidebook concludes with Chapter 5, which is focused on indoor air quality control. Appendix A is a summary of contacts made with lodging industry representatives. A glossary and list of references are also included.

2

GUEST ROOM HEATING AND COOLING SYSTEMS

Packaged terminal units (or window/wall units) are widely used throughout the lodging industry, especially in smaller hotels and motels, to provide both heating and cooling in individual rooms. They are a popular means of conditioning individual guest rooms—their capacity is well matched to the requirements of an individual room, the investment per unit is small, the occupant has control over the temperature setting, and no duct work or plumbing is required. Window or wall units cool more than half of the lodging floor space in buildings less than 50,000 ft^2 in size, and are used more than any other space cooling equipment in lodging buildings under 200,000 ft^2 (AGA 1998).

On an industry-wide basis, 37% of lodgings (by floor space) uses window/wall units for space cooling, and 29% uses window/wall units for space heating. Recent market statistics show that 45% of packaged units are Packaged Terminal Heat Pumps (PTHPs), 49% are Packaged Terminal Air Conditioners (PTACs) with electric resistance heat, and the remainder (6%) are PTACs that use some other means of heating such as steam or gas (ASHRAE 1996). Hence, one piece of equipment satisfies both the heating and cooling needs of the room in the majority of applications.

This chapter presents an in-depth look at packaged terminal units appropriate for use in lodging facilities. In addition to technology descriptions, it contains an examination of factors that must be considered in proper equipment selection.

Technology Description

Packaged terminal room air conditioning and heating units used in the lodging industry are complete, self-contained units that require no ducting or plumbing and fit through an exterior wall aperture[5] or window frame (see Figure 2-1). Packaged terminal units come in two basic varieties:

- Packaged Terminal Air Conditioners (PTACs): These electrically driven devices use the vapor-compression cycle to absorb heat from the cooled space, which is then

[5] Aperture dimensions commonly 16" H x 42" W.

rejected to the warmer outdoors. Unless designated as "cooling only" units, PTACs will generally contain a component for space heating (most often electric resistance).

- Packaged Terminal Heat Pumps (PTHPs): These are similar to PTAC units, except that the vapor-compression cycle is reversible so that heat can be absorbed from the outdoors and transferred to the interior space. Electric resistance heating is usually included in the units for quicker warm-up and/or to provide a supplemental heating source when outdoor temperatures are particularly low.

PTAC and PTHP units are technologically similar, so a combined description of the two is presented below.

Components

PTAC/PTHP units contain a number of components used for refrigeration, heating, air movement, condensate removal, and controls, all encased in a multi-part housing. The modular construction of these units is shown in Figure 2-1.

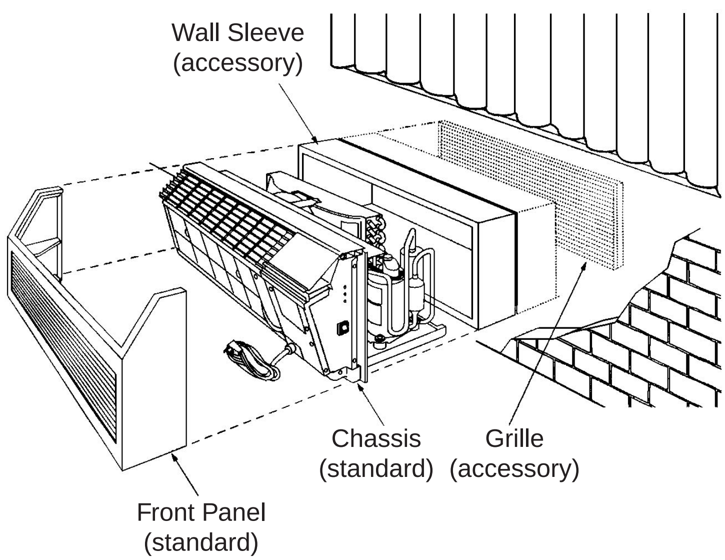

Figure 2-1
Exploded View of Packaged Terminal Unit

Cooling

The cooling system consists of four primary components: compressor, outdoor heat exchanger, expansion device, and indoor heat exchanger. If the unit is a PTHP, the same components are used for heating and cooling, with the addition of a refrigerant-reversing valve. The compressor is the power-consuming device of the cooling system and normally operates on single-phase power.[6] Newer units use rotary instead of reciprocating compressors because they are more efficient and have lower noise and vibration levels. The compressors are operated by efficient motors with power factors up to 0.95.

Heating

PTAC units that are not designated as "cooling only" units may incorporate various space heating devices. Most use electric resistance heating, although steam, hot water, and gas heating are other alternatives.

PTHP units are used for space heating and may include supplemental heat sources (such as electric resistance heating) to ensure continued operation in regions where the outdoor heat exchanger is in danger of frosting. A coil defrost cycle may be incorporated into the heat pump to lower the outdoor temperature heat pump operating range to as low as 10°F.

Air Movement

Indoor and outdoor fans are present in PTAC and PTHP units to circulate air through the heat exchangers and also to draw fresh air into the room for ventilation. Both fans may be driven by the same electric motor, although separate variable-speed motors are often used in more deluxe models (ASHRAE 1996). In order to conserve energy, PTAC units with separate motors may automatically shut off the outdoor air mover when operated in heating mode. Air filters made of fiberglass, metal, or plastic foam usually operate in conjunction with the fans to remove large particulate matter from the incoming air.

Condensate Removal

Condensate is often produced within the packaged terminal unit when indoor or outdoor air is cooled below its dew point. The condensate must be directed away from the unit to avoid water stains on the building exterior or water leakage into the room. Most PTAC and PTHP units use a simple drain system. However, some recycle the condensate for other purposes, e.g., room humidification or to facilitate heat rejection in the outdoor heat exchanger when the unit is operating in cooling mode. To ensure that the condensate formed during heat pump operation does not freeze in extremely cold weather, an electric drain pan heater is often included in the unit.

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[6] 115V in smaller units and 208V, 230V, and 265V in larger units.

Controls

Conventional PTAC and PTHP units are manually controlled by the room occupant. Typical controls include a mode selector (cool, heat, fan only, off), thermostat set points (high, normal, low), and fan speed selector (high, low) These controls are generally located on the unit, although remote temperature operating controls such as a wall thermostat are also available. Some units offer occupant-inaccessible controls which allow the property manager to limit room temperatures and prevent evaporator freeze-up. Some manufacturers also offer the option of low-voltage central desk controls whereby lodging staff may turn the unit on or off or override occupant-specified settings.

Package terminal units are completely self-enclosed and require no ductwork. Most PTAC and PTHP units fit into a standard dimension (16" H x 42" W) wall sleeve or box which surrounds the unit within the wall aperture. Smaller units are available which will fit into different-sized wall apertures or windows. The interface between a packaged terminal unit and the wall sleeve is important as it must keep rain, snow, wind, and insects from entering the room. The outdoor face of the packaged unit will consist of removable or separable louvers which must also keep rain, snow, birds, vermin, and other outdoor debris from entering the unit, and it must fit flush to the building exterior to meet most codes (ASHRAE 1996). The indoor face of the packaged unit must be aesthetically pleasing and should blend well with the room decor.

Energy Efficiency

Energy consumption constitutes the primary operating cost associated with space conditioning. Therefore, in selecting HVAC equipment, energy efficiencies of different systems should be thoroughly investigated and compared. While much depends on the operating environment itself, there are ratings derived from standardized equipment testing[7] which are useful metrics for cross comparison purposes. Different measures of the heating and cooling efficiencies of PTAC and PTHP units are described below.

[7] Testing is performed in accordance with the Air-Conditioning and Refrigeration Institute (ARI) Standard 310/380, Standard for Packaged Terminal Air Conditioners and Heat Pumps (ASHRAE 1996). Test results are generally available from equipment manufacturers and also published in the ARI "Directory of Certified Applied Air-Conditioning Products."

Heating Efficiency

Heating efficiency can be measured by the "Coefficient of Performance," or COP, defined as:

$$COP = \frac{(\text{total space heating produced in watt - hours})}{(\text{total electrical energy consumed in watt - hours})} \qquad \text{(eq. 2-1)}$$

Notes:
1. Total space heating produced excludes all supplemental forms of heat, such as electric resistance heating, but does include the heating effect of the indoor air blower.
2. Total electrical energy consumed includes energy used to drove the compressor, controls, and fans.

Another indicator of heating efficiency is the "Heating Season Performance Factor" (HSPF), which measures the average energy efficiency of the equipment for the heating season only. HSPF may be defined as:

$$HSPF = \frac{(\text{total space heating provided during the heating season in Btu})}{(\text{total electrical energy consumed in watt - hours})} \qquad \text{(eq. 2-2)}$$

Cooling Efficiency

The "Energy Efficiency Ratio" (EER) is the counterpart of the COP and is a measure of the cooling efficiency of a piece of equipment. It is defined as:

$$EER = \frac{(\text{total space cooling produced in Btu})}{(\text{total electrical energy consumed in watt - hours})} \qquad \text{(eq. 2-3)}$$

Note: Both latent and sensible cooling are accounted for in the space-cooling term, as well as the heating effect of the indoor air blower.

The average energy efficiency of an air conditioner for the cooling season can be measured by the "Seasonal Energy Efficiency Ratio" (SEER), defined as:

$$SEER = \frac{(\text{total space cooling provided during cooling season in Btu})}{(\text{total electrical energy consumed in watt - hours})} \qquad \text{(eq. 2-4)}$$

Note: SEER accounts for equipment cycling under part-load conditions.

Factors Affecting Efficiency

Performance ratings of PTAC and PTHP units cannot be expected to be achieved under all operating conditions. Actual performance depends upon other factors, such as:

- <u>Indoor and outdoor temperatures</u>: Performance of a space cooling unit will diminish when outdoor temperature increases or indoor temperature decreases. Similarly, performance of a space-heating unit will diminish when outdoor temperature decreases or indoor temperature increases.

- <u>Cycling loss</u>: HSPF and SEER ratings account for cycling and part-load losses through the use of a cyclic degradation factor (EPRI 1997). The EER of a single-speed heat pump may be corrected using the cyclic degradation factor to obtain a SEER value.

- <u>Outdoor humidity</u>: Higher humidity levels can increase the defrost cycle requirements of heat pumps operated at low outdoor temperatures and increase the latent cooling load of air conditioners.

Regulation

The energy policy act of 1992 requires states to adopt minimum energy-efficiency requirements of ASHRAE/IES Standard 90.1-1989 by October 1994. Efforts are currently underway to revise this standard, and the new standard is not expected to be approved until 1999. Because there is a two-year manufacturers' lead time built into the standard, this means that HVAC equipment incorporating new efficiency standards may not appear on the market until the year 2001.

Minimum EER and COP requirements for packaged terminal units as stipulated in ASHRAE/IES Standard 90.1-1989 are summarized in Table 2-1.

Table 2-1
Standard Rating Conditions and Minimum Performance for PTAC/PTHP Units

Rating Conditions	Outdoor Temp. (°F)	Rating	Minimum Performance
Cooling Mode	95 DB 82 DB	EER EER	10.0-(0.16 x Cap./1000) 12.2-(0.20 x Cap./1000)
Heating Mode	47 DB, 43 WB	COP	2.9-(0.026 x Cap./1000)

Source: ANSI/ASHRAE/IESNA Standard 90.1-1989.

Table 2-2 shows that the performance of packaged terminal units decreases with larger capacity equipment, consistent with Standard 90.1.

Table 2-2
Manufacturer-Cited PTAC and PTHP Performance Ratings

Capacity (Btu/h)	PTAC EER	PTHP COP	PTHP EER
6000–8000	10.0–11.6	3.0–3.3	10.0–11.6
8000–10,000	11.0–11.3	3.2–3.5	11.0–11.3
10,000–12,000	9.8–10.7	3.2–3.3	10.0–10.7
12,000–14,000	9.2–10.8	2.9–3.1	9.2–10.6

The energy efficiency rating of room air conditioners has steadily increased over the past two decades (see Figure 2-2).

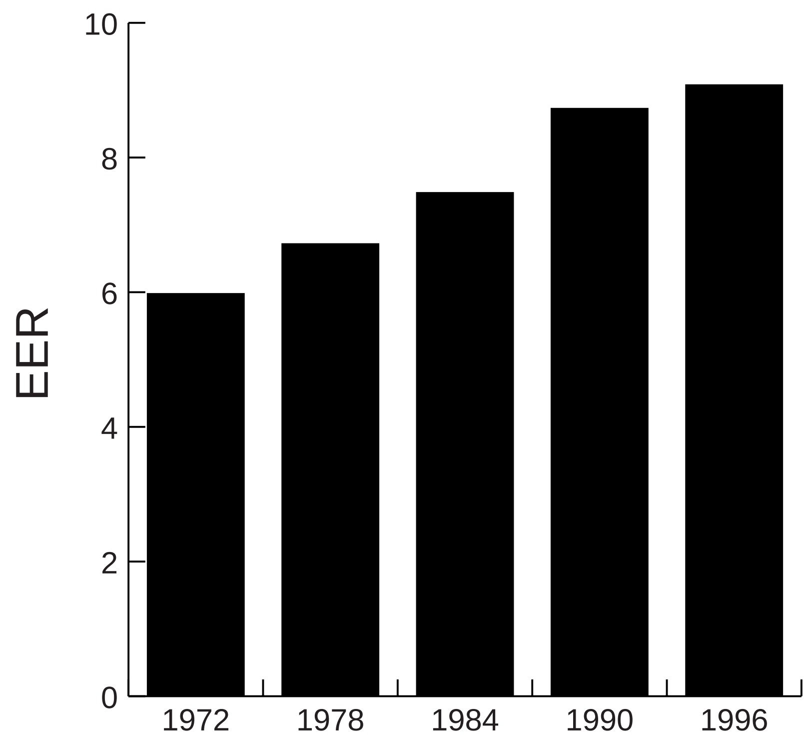

Figure 2-2
Room Air Conditioner EER Trends
Source: Association of Home Appliance Manufacturers, *Room Air Conditioners Energy Efficiency and Consumption Trends* (Web source).

Equipment Cost

Packaged terminal units are composed of several components integrated to form a complete unit. The basic chassis includes the cooling system, heat source, and fans. Secondary components include the front panel, outside grille, and wall sleeve. Many options, such as additional remotely located controls or corrosion packages, are available. Approximate costs for the typical bare chassis range from $500–$700, with additional features costing about $40–$50 per option. The final package may carry a price tag of $800–$1000. Labor costs vary by location, but average installed costs range from $950–$1150 for units with capacities of 6000–15,000 Btu/h (R.S. Means 1998). Incremental capacity additions have marginal impact on the purchase price—$40–$50 increases may be expected for 3000-Btu/h increments of capacity. The choice of a PTHP unit over a PTAC unit will increase purchase price by approximately $75, as hardware modifications are relatively minimal.

An example of cost breakdown for a typical PTHP unit is shown in Figure 2-3.

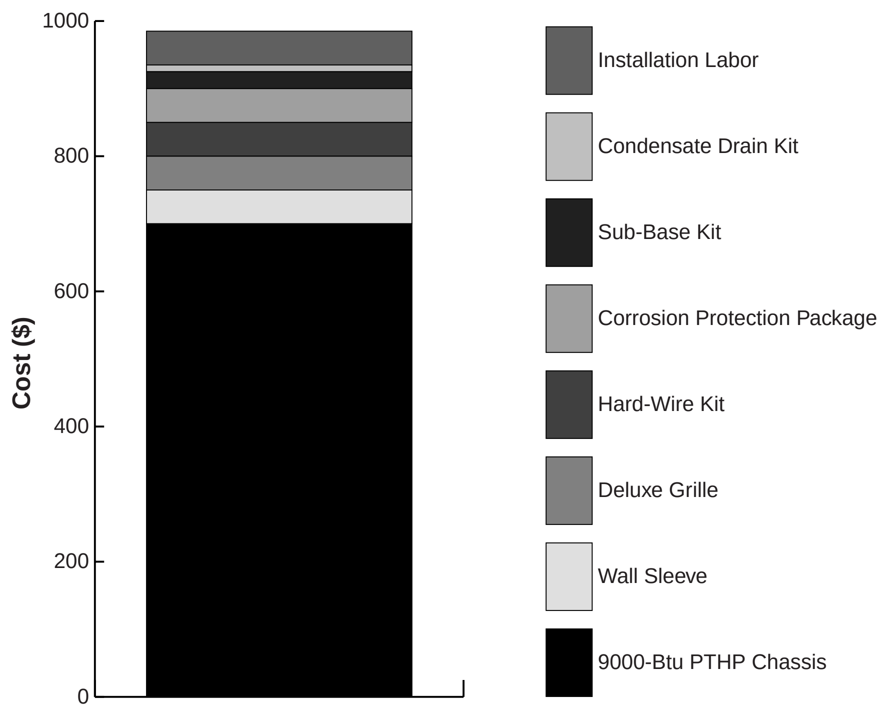

Figure 2-3
Example of PTHP Unit Cost Breakdown (approximate)

Some manufacturers offer different product lines (such as economy vs. deluxe models) which may be mechanically identical but have minor differences in aesthetics, controls, etc. In selecting equipment, the buyer is advised to closely examine and compare the features of differently priced models and to inquire about the possibility of quantity discounts.

Operating Cost

Energy Cost

Space conditioning energy operating costs depend upon two factors: energy consumption and prevailing utility rates. Energy consumption for a given space depends on the space conditioning load and the capacity and performance of heating and cooling equipment.

Energy consumption in lodging establishments can be somewhat difficult to establish. The problem lies in estimating the load of each space (e.g., guest room, restaurant, convention hall) within the facility. Heating and cooling loads rely strongly on predictions of occupant behavior and may result in errors as large as ±50% in energy consumption estimates (EPRI 1997). Room conditions necessary for thermal comfort for occupants will vary with differences in humidity, metabolism, and clothing. Additional thermal loads due to hot showers, appliances, and lighting will also affect heating/cooling requirements, as will windows and doors that are left open for prolonged periods of time.

Heating and cooling loads can be estimated using a variety of methods ranging from simplified approximations to computerized building models. Once loads are computed, energy consumption can be estimated by incorporating equipment performance ratings. Based on this consumption, energy costs will depend upon the rates charged by the utility.

Maintenance Cost

The ease of maintenance is a key selling point for packaged terminal units. They require routine servicing (such as cleaning of air filters and coils) to ensure efficient operation. Easy-to-access and easy-to-clean air filters and fully accessible components in a slide-out chassis are common and reduce overall maintenance time and cost.

Commercial through-the-wall units may be expected to last 10–15 years with proper maintenance. Most manufacturers offer a one-year warranty on all parts and labor, and a five-year, parts-and-labor warranty on sealed parts. Other major components are often covered under the five-year warranty as well. Thus, many repairs are covered under warranty for one-third to one-half of a typical unit's life (ASHRAE 1996).

Equipment Selection

Packaged terminal units are available in a wide variety of sizes and features. Equipment selection is mainly dictated by the following factors:

1. Heating mode: The type of heating provided with the unit such as heat pump or electric resistance heating should be considered. Packaged terminal air conditioners can be provided with no heating source, in which case the guest room is heated by some other method, such as an electric baseboard.

2. Cooling capacity (6000–18,000 Btu/h): In most cases, especially in cooling-dominated climates, cooling capacity is the primary selection factor.

3. Heating capacity (4000–17,000 Btu/h): Packaged terminal units must be selected to also meet the heating needs of the room. In some heating-dominated climates, the heating capacity may dominate the selection decision.

4. Voltage (115V, 208V, 230V, 265V): The voltage requirement may be especially important in retrofit applications.

In addition to these primary determinants, there are numerous secondary considerations, including:

1. choice of optional remote control thermostats
2. central desk control
3. corrosion protection package
4. internal condensate removal
5. powered vent door
6. key-lock control door
7. duct extension for adjoining rooms
8. exterior grille options
9. interior cover color

Some equipment-selection decisions depend upon individual or corporate preferences (e.g., color and style). Other issues, such as determining appropriate equipment capacity and heat source, may involve complex engineering and economic analyses.

Some manufacturers offer architect and engineering manuals, technical assistance hotlines, and load calculation worksheets as services to the buyer, but if in-house expertise is unavailable, it may be advisable to seek the advice of a qualified consultant or engineer.

Equipment Sizing

Room air-conditioning units in lodging facilities have traditionally been oversized. One reason for this is the low marginal cost of increasing the size of a packaged terminal unit. Nevertheless, correct sizing of space conditioning equipment[8] has the dual benefits of ensuring guest comfort and minimizing long-term costs. ASHRAE recommends that HVAC systems are to be "sized to provide no more than the space and system loads calculated," although there are some broad exceptions to which PTAC units may apply (ASHRAE 1997a).

Cooling load computations for equipment sizing take into consideration structural dimensions/characteristics, ambient conditions, ventilation/infiltration rates, and internal sources of heat generation. The external cooling load depends upon structural dimensions and heat transfer coefficients, window reflectivity, solar time, and outdoor temperature. The indoor cooling load depends upon all sources of heat generation including people, appliances, lighting, and power-consuming devices. Cooling load due to ventilation depends upon the difference between indoor and outdoor temperatures and humidity levels as well as ventilation/infiltration rates.

Heating load computations for equipment-sizing purposes assumes a worst-case scenario where all sources of internal heat generation and solar heating are not present. This leaves only the building envelope load due to conduction and the heating load associated with conditioning ventilation and infiltration air.

Procedures and data for choosing interior and exterior design conditions at a multitude of worldwide locations are provided in the ASHRAE Handbook of Fundamentals. Simplified versions of the ASHRAE procedures have been developed by the Air Conditioning Contractors of America (ACCA).[9]

Using the ASHRAE method, sample calculations of design conditions for individual room cooling and heating sizing loads are shown in Tables 2-3 and 2-4 for 13 cities across the United States.

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[8] ASHRAE Standard 90.1 specifies criteria for sizing HVAC equipment, referencing heating and cooling load computation procedures in the ASHRAE Handbook of Fundamentals, and ventilation rate computation procedures in ASHRAE Standard 62-89.

[9] This method is called Manual J (for residential buildings) or Manual N (for commercial buildings).

The room characteristics used in the computations are:

- 300-ft^2 floor space
- flat roof with R-20 equivalent insulation value
- 105-ft^2, west-facing wall with R-15 equivalent insulation value
- 15-ft^2, west-facing window, double 1/8" glass pane with ¼" air space, double glazing, reflective coated
- 72 cubic feet per minute (CFM) ventilation rate
- electrical load: 468 W lighting, 240 W television
- four-person occupancy

Table 2-3
Design Cooling Load Components for Typical Guest Room

City	State	Total (Btu/h)	Roof (Btu/h)	Walls (Btu/h)	Windows (Btu/h)	People (Btu/h)	Electric (Btu/h)	Ventilation (Btu/h)
Miami	FL	11,203	1047	557	1261	1551	2300	4484
Houston	TX	11,536	1054	562	1266	1551	2300	4801
Dallas	TX	11,386	1090	582	1291	1551	2300	4570
Phoenix	AZ	11,468	1194	643	1362	1551	2300	4417
St. Louis	MO	10,980	1042	554	1258	1551	2300	4274
San Diego	CA	8437	954	503	1197	1551	2300	1929
New York	NY	9910	1008	535	1234	1551	2300	3281
Chicago	IL	9982	974	514	1211	1551	2300	3430
Los Angeles	CA	7961	942	496	1189	1551	2300	1481
Montpelier	VT	8583	905	474	1163	1551	2300	2188
Minneapolis	MN	9640	977	516	1213	1551	2300	3082
San Francisco	CA	6468	871	454	1140	1551	2300	149
Anchorage	AK	5309	776	398	1075	1551	2300	-792

The first column of Table 2-3 indicates the total design cooling load for the guest room in each city. The subsequent columns contain the contributions of various load components. In most of the cities, especially those that are cooling-dominated, the ventilation load (both sensible and latent) is the largest component. The internal electric appliances and lighting can also contribute significantly to the cooling load.

Table 2-4 contains design heating load data for the same cities. In most situations, the cooling load is greater than the heating load. The ventilation component is also the largest contributor to the heating load.

Table 2-4
Design Heating Load Components for Typical Guest Room

City	State	Total (Btu/h)	Roof (Btu/h)	Walls (Btu/h)	Windows (Btu/h)	Ventilation (Btu/h)
Miami	FL	2129	240	140	165	1584
Houston	TX	4152	468	274	321	3088
Dallas	TX	4898	552	323	379	3643
Phoenix	AZ	3514	396	232	272	2613
St. Louis	MO	6602	744	436	511	4910
San Diego	CA	2555	288	168	198	1900
New York	NY	5856	660	386	453	4356
Chicago	IL	7560	852	499	585	5623
Los Angeles	CA	2662	300	175	206	1980
Montpelier	VT	8092	912	534	627	6019
Minneapolis	MN	8625	972	569	668	6415
San Francisco	CA	3301	372	218	255	2455
Anchorage	AK	8412	948	555	651	6256

Economic Analysis

In the lodging industry, the most important consideration in the selection of space conditioning equipment is customer comfort (AGA 1998). The temperature and humidity range necessary for customer comfort will vary from occupant to occupant, so the first step in equipment choice is to evaluate what capacity is required of the heating/cooling equipment. Once this criterion is satisfied, the focus shifts to the initial and operating costs of comparable equipment. Lodging establishments that are most likely to use packaged terminal units place more emphasis on lower purchase cost than lower operating cost by a factor of almost 3 to 1 for space-cooling equipment, and a factor of 16 to 1 for space-heating equipment. Therefore, packaged terminal units are generally selected on the basis of capital costs.

However, the energy cost of the unit may also be a significant factor. As an illustration, consider a 300-ft^2 guest room with a north-facing exterior wall in Chicago, Illinois (see Table 2-5). Simple equipment-sizing computations suggest that such a room will require a PTHP unit with minimum 8700-Btu/h cooling capacity and 7600-Btu/h heating capacity for design purposes. The heating and cooling loads of this room can be met by a variety of equipment. For this purpose, two units are compared: one with an EER of 9.5 and the other with an EER of 11.3. Referring to these two units as "unit A" and "unit B," the comparison shown in Table 2-5 can be made.

Table 2-5
Economic Comparison of Two PTHP Units

	Unit A	Unit B
Cooling Capacity (Btu/h)	8800	9000
Heating Capacity (Btu/h)	7900	8400
EER	9.5	11.3
COP	2.8	3.5
Purchase Cost ($)	750	1000
Electricity Consumption (kWh)	2500	2025
Annual Electric Cost ($)*	300	243

* Assuming an average electric rate of $0.12/kWh, no demand charges

This very simplistic example illustrates the cost savings of purchasing a more efficient system. Given the numbers in the table, the purchase cost difference would be paid back in less than five years. A more comprehensive analysis is warranted for selecting equipment based on operating cost. Complex computer programs are available to provide accurate estimates of building energy consumption for a specific location.

Packaged terminal heat pumps and air conditioners are very widely used throughout the lodging industry, especially in motels and small hotels. Selecting packaged terminal units for a given location is relatively straightforward based on the limited number of significant differences among the products.

3

CENTRAL HEATING AND COOLING SYSTEMS

Packaged terminal units described in Chapter 2 have relatively small capacity and are specifically designed to cool or heat single guest rooms within a lodging facility. In this chapter, central space conditioning systems are described. They are designed to meet the load of larger spaces such as lobbies and ballrooms. In some facilities, central space conditioning equipment may be more cost-effective than packaged terminal units for conditioning guest rooms. However, architectural design, space configuration, geographic location, and fuel availability all play a role in determining the appropriate HVAC equipment for any lodging establishment.

Packaged terminal units (window/wall units) are used to cool about 37% of the floor space in the lodging industry. Central systems and other packaged equipment cool the remaining 63% (see Figure 3-1). Among central systems, chillers and packaged rooftop units rank highest in popularity. Chillers used in lodging buildings may be gas or electric driven, but the vast majority are powered by electric motors.

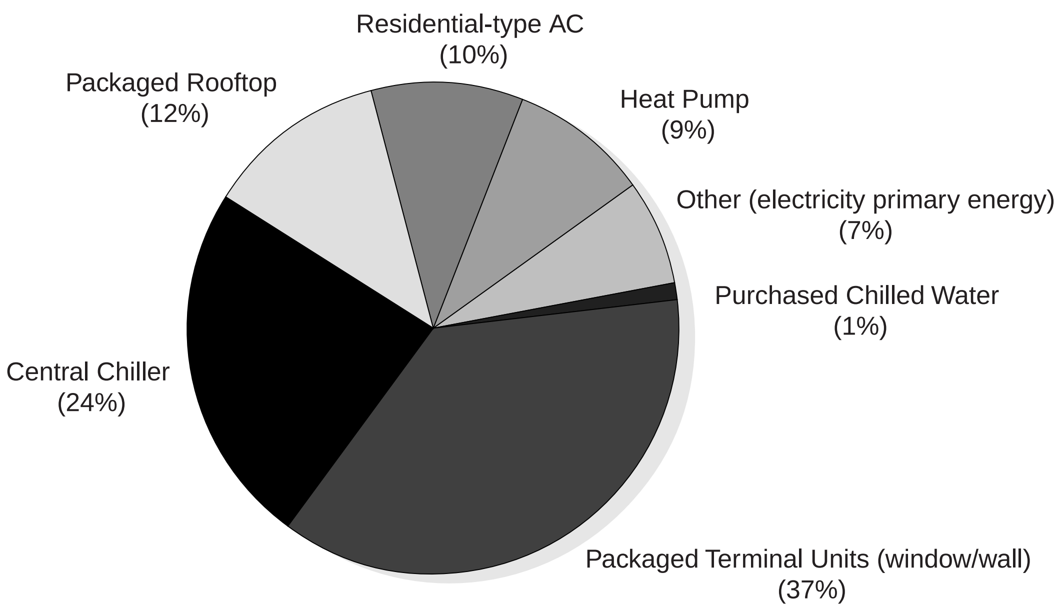

Figure 3-1
Lodging Space-Cooling Equipment, by Type (1997)
Source: *Commercial Customer Segmentation Study: National Lodging Sector*, AGA, 1998.

Heating needs of the lodging industry are met primarily by packaged terminal units, followed by central boilers and furnaces, and heat pumps (see Figure 3-2). Packaged rooftop units and electric baseboards also account for a significant share of the market. Boilers and furnaces can be either gas- or electricity-based.

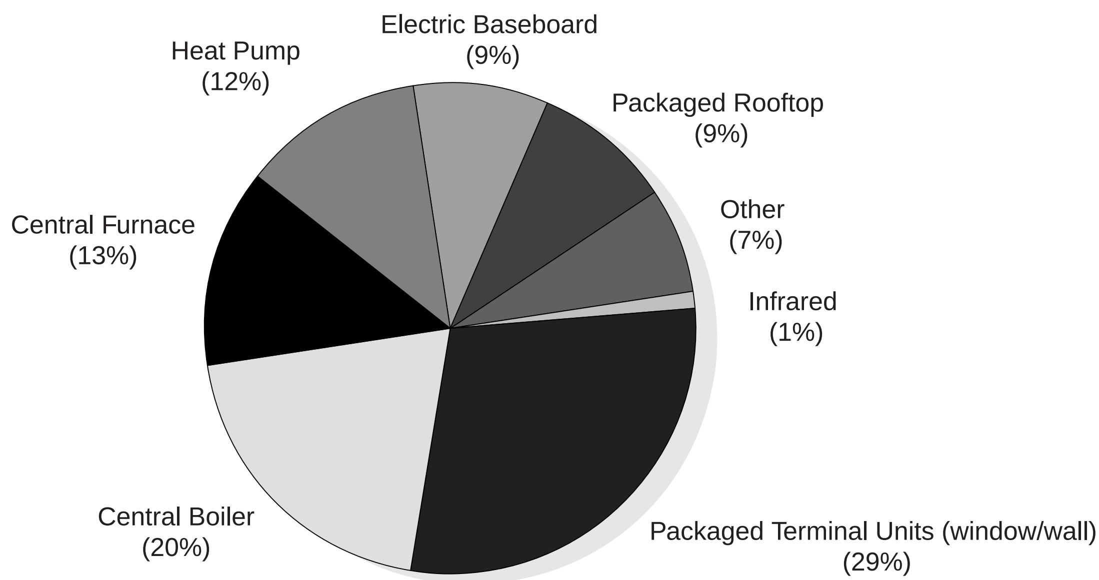

Figure 3-2
Lodging Space Heating Equipment, by Type (1997)
Source: *Commercial Customer Segmentation Study: National Lodging Sector*, AGA, 1998.

This chapter focuses on large-capacity, central space conditioning systems common in lodging facilities. Each system is composed of a centralized heating and cooling source and a distribution system. Options for heating and cooling sources and distribution systems are shown in Table 3-1 and discussed in the following sections.

Table 3-1
Configuration Options for Central Systems

Equipment Types	chillers unitary heat pumps boilers furnaces district heating and cooling thermal storage
Distribution Systems	all-air systems air-and-water systems all-water systems

In considering these central systems, lodging facilities may be able to reduce operating costs for the following reasons:

- High-efficiency chillers perform significantly better than standard-efficiency chillers or older model chillers.
- Heat recovery chillers can provide simultaneous heating and cooling when both are required (as is often the case with lodging facilities).
- Thermal storage can help reduce energy costs by shifting some of the load to off-peak periods.

Heating and Cooling Sources

Chillers

Central chillers supply the cooling requirements for approximately 24% of lodging floor space[10] and are typically found in larger facilities. A variety of energy sources (electricity, natural gas, diesel oil, or steam) can be used to drive the chillers, but electric chillers dominate the market—94% of all chiller shipments in the United States are electric-powered (EPRI 1998). Because of the dominance of electric chillers, this section focuses on these systems.

Technical Description

The chiller is the primary component of a chilled water system whose three main components are shown in Figure 3-3. They are:

- chilled-water loop
- chiller
- condenser-water loop

[10] For more information about central chillers including equipment selection and system optimization, the reader is referred to the EPRI publication entitled, "Electric Chiller Handbook", report #TR-105951-R1.

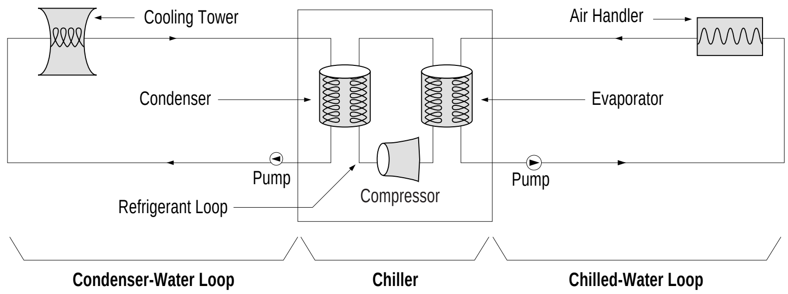

Figure 3-3
Chilled-Water System
Source: *Electric Chiller Handbook*, EPRI, 1998.

A chilled-water system provides cooling by extracting energy (i.e., heat) from a building and transferring it to the outside environment. The chilled-water loop extracts heat from the building via air handlers and terminal units such as individual room coils. The heat that is extracted from the room is transferred to the chiller refrigerant. Through the use of a compressor, evaporator, and condenser, the chiller transfers the heat from the chilled-water loop to the condenser-water loop. The heat is then released to the environment through either a cooling tower or an air-cooled heat exchanger.

Electric chillers operate on the same vapor-compression cycle as packaged terminal units, except that water is used as a heat transfer medium between the chiller and terminal equipment located in the space to be conditioned. The primary energy-consuming component of the chiller is the compressor. Three types of compressors are common in chiller applications:

- Reciprocating compressors: most commonly found in smaller applications (50–200 tons capacity[11]); characterized by low first cost but relatively poor efficiency

- Screw compressors: most commonly found in medium-sized applications (150–400 tons capacity); characterized by light weight, small size, and low full-load efficiency

- Centrifugal compressors: most commonly found in much larger applications (200–2000 tons capacity); exhibit good full-load efficiency; expensive for small applications

Performance

Minimum efficiency standards for chillers are set forth in ASHRAE Standard 90.1-1989,[12] and compliance is mandated by the 1992 Energy Policy Act. Electric chiller

[11] 1 ton cooling equals 12,000 Btu/h.

performance is dependent upon the efficiency of the chiller unit (commonly expressed as Coefficient of Performance [COP] or kW/ton) as well as the power consumption of ancillary equipment (such as cooling tower fans, pumps, etc.). Typical full-load efficiency values for both high-efficiency and standard-efficiency electric chillers are shown in Table 3-2.

Table 3-2
Comparison of Full-Load Efficiencies

	Full-Load Efficiency (kW/ton)	Full-Load COP
Electric centrifugal chillers (std. eff.)	0.65–0.80	5.4–4.4
Electric centrifugal chillers (high eff.)	0.49–0.65	7.2–5.4

Source: *Electric Chiller Handbook*, EPRI, 1998.

Electric chiller performance varies with load. Part-load efficiency falls dramatically at smaller load levels (i.e., below 30% of full load) and is generally at its peak at about 75% load. Therefore, it is very important to have a properly sized chiller, and operate it such that its efficiency is maximized.

Cost

The cost for a large chilled-water system can be significant. Chiller system costs are often broken down into the following categories:

- Chiller cost: the purchase price of the chiller
- Ancillary equipment cost: the remaining components of the chilled water system including pumps and piping, cooling tower, and control equipment
- Installation cost: the labor cost of installing the system
- Maintenance cost: the cost of maintaining a chilled-water system after installation
- Operating cost: the energy, water, and water treatment costs of operating the chiller

The chiller, ancillary equipment, and installation cost comprise the total installed cost of the chiller. The normalized average installed cost of an electric centrifugal chiller is

12 This standard includes limits on electric chiller power consumption of 0.93, 0.83, and 0.68 kW/ton of cooling for units with capacities of <150 ton, 150–300 tons, and >300 tons respectively (ASHRAE 1997b). High-efficiency chillers greatly exceed these standards, with power consumption of 0.58–0.60 kW/ton.

comparable to that of a packaged terminal unit—approximately $800/ton cooling, or $0.07 per Btu/h capacity. The chiller generally constitutes about half of the installed cost, while the cooling tower can account for approximately 25% of the installed cost (see Figure 3-4).

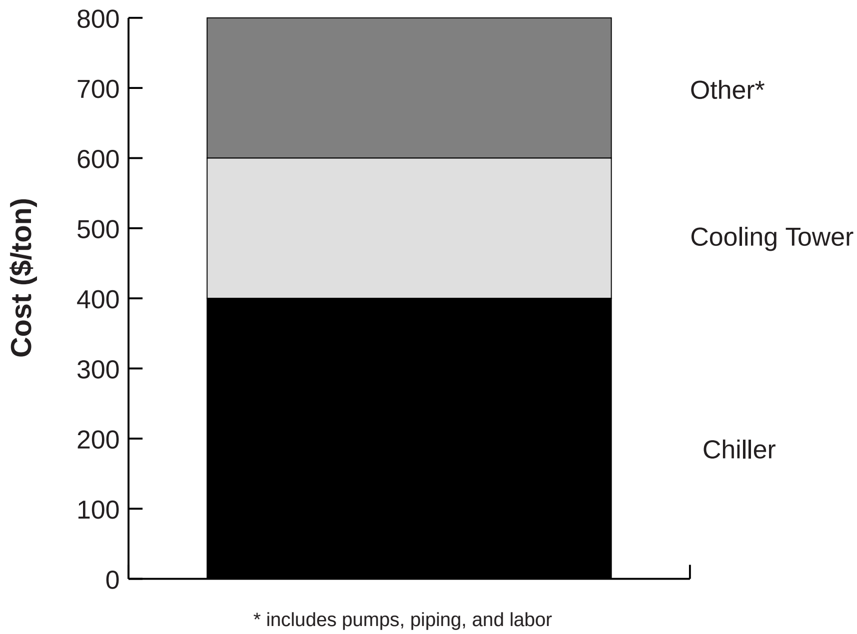

Figure 3-4
Chiller Installed Cost
Source: *Electric Chiller Handbook*, EPRI, 1998.

Maintenance costs range from approximately $25/ton/year for smaller units (120–230 tons) to $18/ton/year for much larger units (740–900 tons). Operating cost can vary significantly. They are dependent upon local energy rates, cooling load (climate, building construction, internal loads), water rates, and chiller optimization. An engineering analysis can be performed to estimate the operating costs for a specific lodging facility under local conditions.

Special consideration should be given to installing or upgrading to a high-efficiency chiller. Energy cost savings alone could justify the cost of the unit in a relatively short period of time, and result in energy savings over the long run.

Unitary Systems

Technical Description

Unitary air conditioners and unitary heat pumps[13] operate on the same principle as packaged terminal units. They have similar basic components and can perform the functions of heating, cooling, and dehumidification. Unitary systems and heat pumps can be used in a variety of ways in the lodging industry. The smaller units can condition common areas or small blocks of rooms. Larger unitary systems may be adequate for small motels or individual floors of hotels. Commercial unitary air-conditioning equipment sizes range from 5 to 50 tons (60,000 Btu/hr to 600,000 Btu/hr) capacity (ASHRAE 1996). They are typically available with the controls and ductwork necessary to route conditioned air from the unit to one or more zones within a building. For example, one unitary system could be used to condition a lobby and several adjacent rooms such as gift shops or conference rooms. Unitary equipment units may be classified as either “outdoor” or “indoor” units.[14]

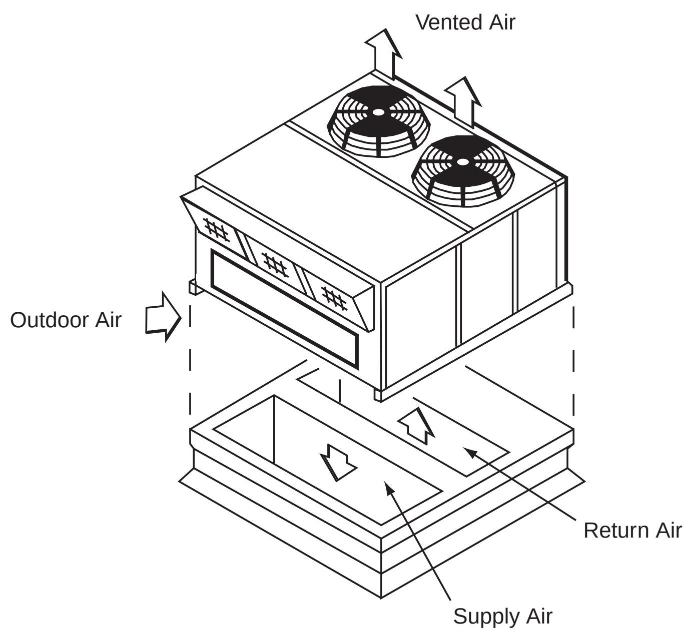

Figure 3-5
Rooftop Air Conditioner Unit
Source: *R.S. Means Mechanical Data*, R.S. Means Company, Inc., 1998.

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[13] For further information regarding heat pump sizing, energy consumption, and economic comparison, the reader is referred to the EPRI publication titled, *Heat Pump Manual*, report TR-109222.

[14] With both types, positioning of the equipment in a central location in the lodging establishment will minimize wiring and ductwork requirements and installation costs.

- Outdoor unitary equipment: These units (see Figure 3-5) are generally mounted on building roofs with air ducted to the conditioned zone(s). They may be used to supply the heating and cooling load of an entire building, but multiple smaller units are recommended to avoid the incidence of complete system failure and to lessen repair/replacement cost in the case of malfunction (ASHRAE 1996).

- Indoor unitary equipment: These units are similar in principle to outdoor unitary equipment except that they are located within the building and are connected to outdoor water-based or remote air-based heat exchangers. They are commonly used to condition entire buildings, often with multiple floors.

Heat pumps provide both heating and cooling through a reversible cycle (see Figure 3-6).

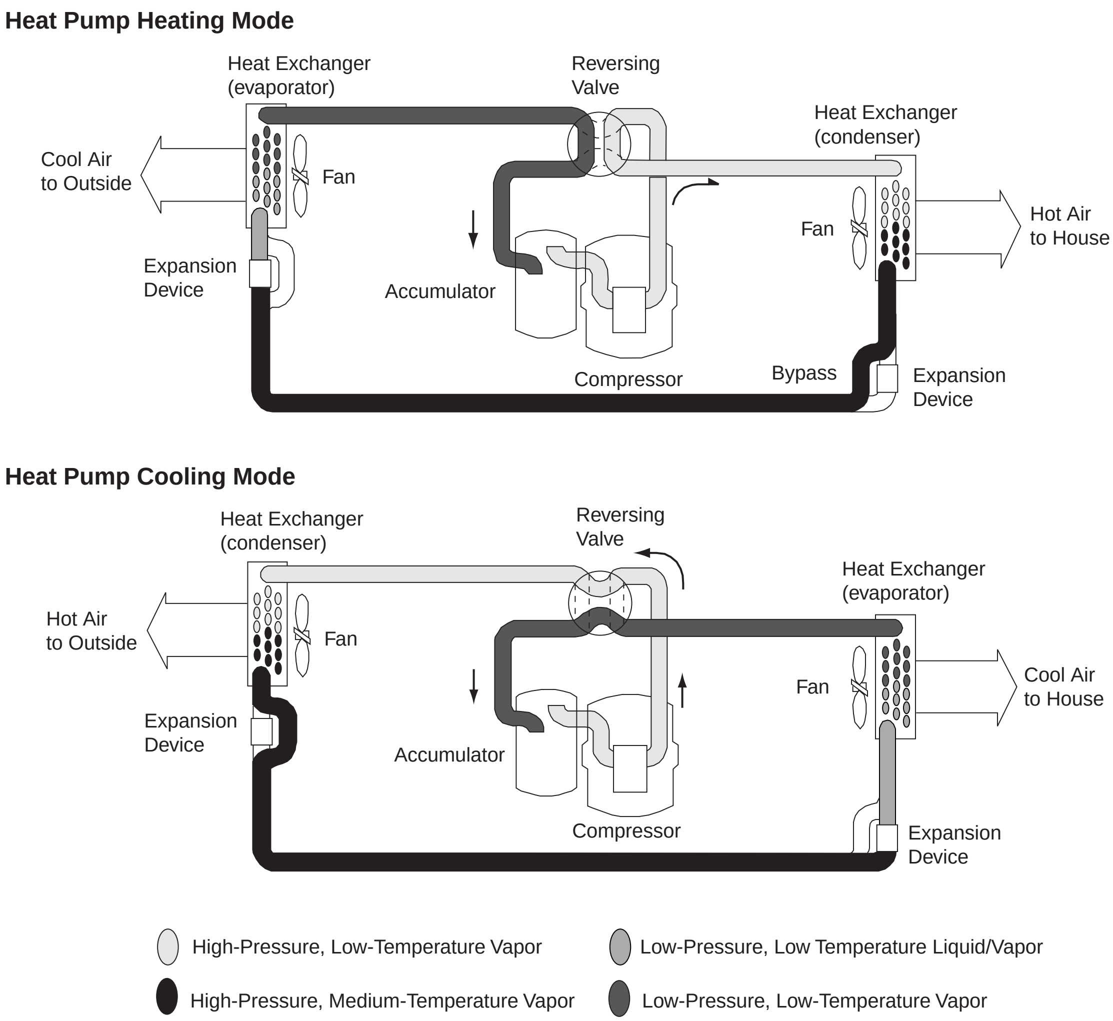

Figure 3-6
Basic Heat Pump Operation
Source: *Heat Pump Manual*, EPRI, 1998.

Several kinds of unitary heat pumps are appropriate for lodging facilities:

- Ground-source heat pumps: cycle water or antifreeze through underground plumbing circuits to draw heat from, or reject heat to, the ground. Heat exchange plumbing may simply be buried in soil (Figure 3-7), or may exchange heat with underground water or a body of surface water such as a pond or lake. Purchase and installation of the underground plumbing circuit poses an additional investment, although these systems pay for themselves with lower operating costs. The ground-source heat pump exchanges heat with a source (the ground) of relatively constant 44–55°F temperature. Thus operational efficiency of a ground-source heat pump is not greatly affected by low outdoor temperatures in the winter and high outdoor temperatures in the summer. Under standard rating conditions, the COP value of an air-source heat pump ranges from 2.0 to 3.0, compared to 3.8 for the ground-source heat pump (ASHRAE 1997b).

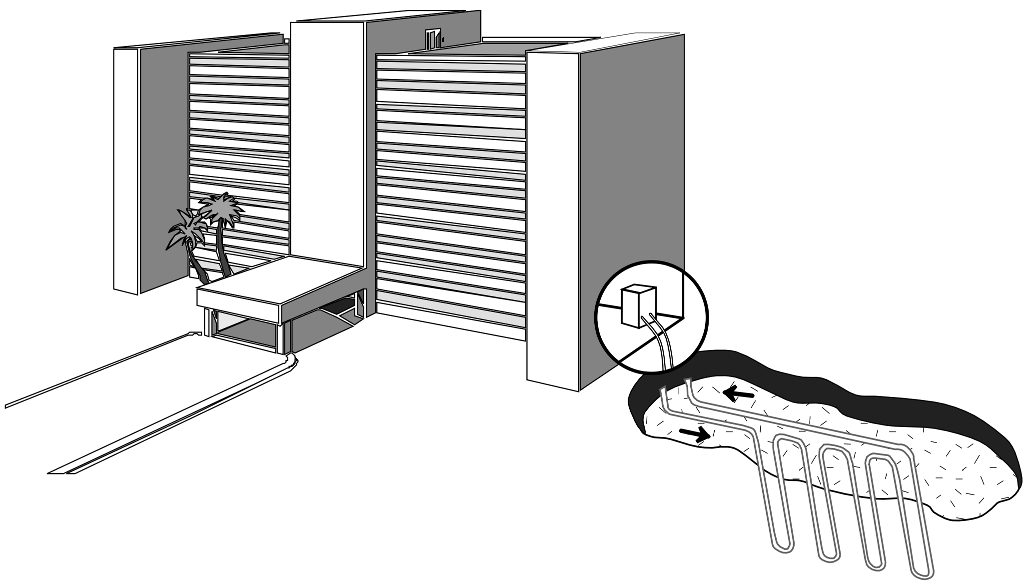

Figure 3-7
Ground-Source Heat Pump

- Closed-loop internal-source heat pumps: simply transfer heat between space(s). An example might be to transfer heat from a warm interior conference room with a large number of people to a cooler lobby area (see Figure 3-8). Because the interior space temperatures are generally closer to each other than to the outdoors, the temperature gradient between the heat source and heat sink of a closed-loop internal-source heat pump circuit is less. Thus, less electrical energy is required to simultaneously provide the same amount of heating and cooling to the conditioned spaces. Most applications are in large buildings with mostly internally generated heating and cooling loads, as opposed to smaller buildings with heating and cooling loads primarily stemming from the external building envelope.

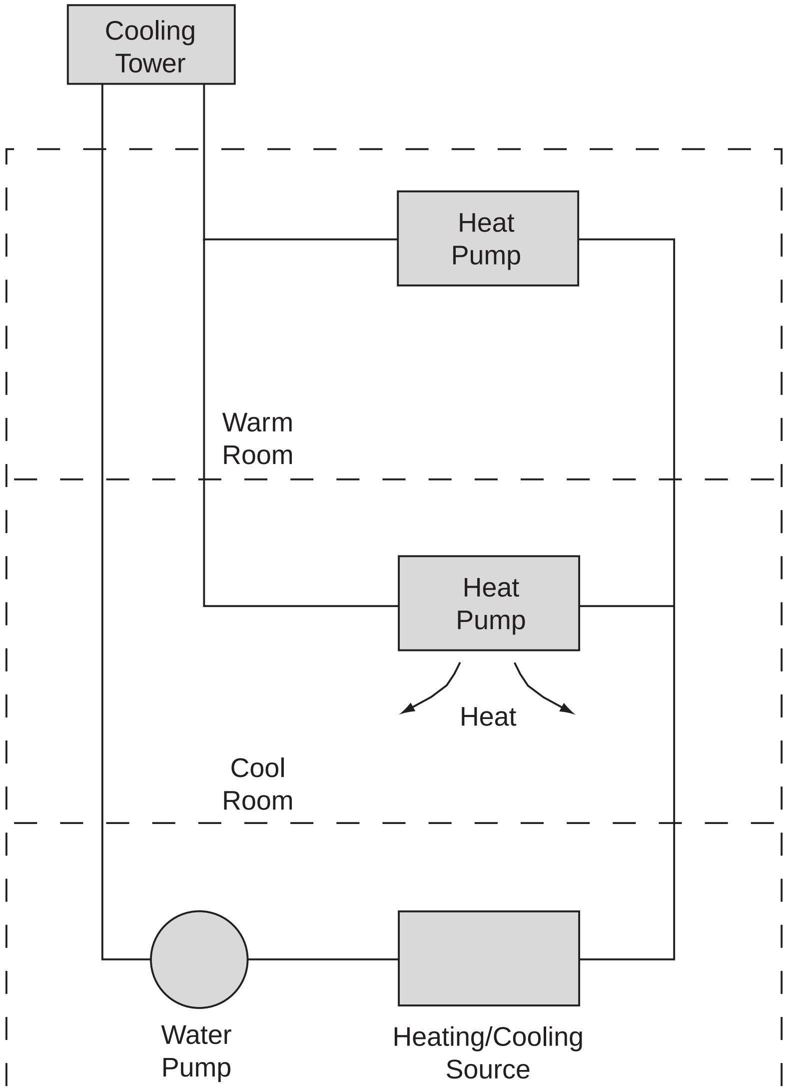

Figure 3-8
Closed-Loop Internal-Source Heat Pumps

- Heat reclaim water heating heat pumps: cool and dehumidify conditioned spaces while heating water with otherwise wasted heat. The building's hot water system may be preheated by this waste heat prior to being heated by a standard hot water heater (see Figure 3-9). Most of these devices are "desuperheaters", which remove 10–30% of total heat that would otherwise exit the building through the condenser (EPRI 1992). Kitchens and laundry rooms are excellent applications for these units. Another common application of this technology is to cool and dehumidify swimming pool rooms while heating pool water.

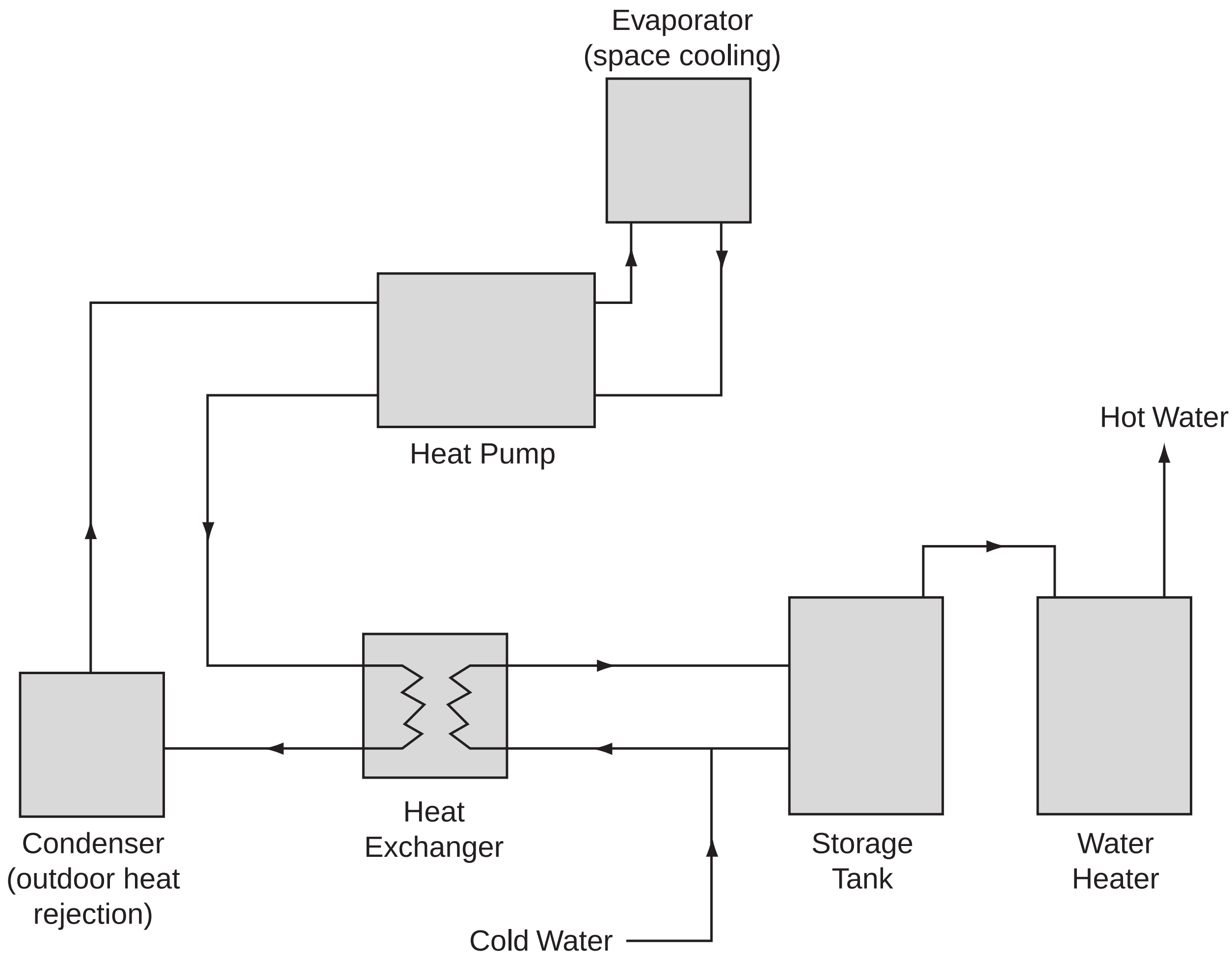

Figure 3-9
Heat Reclaim Water Heating Heat Pump

A relatively recent development has been the inside air-source heat pump (Figure 3-10). This heat pump is a completely self-contained unit that fits into an interior space about the size of a residential furnace. It exchanges heat with outdoor air drawn in and rejected through a duct to the outside. It delivers 1.5–3.0 tons cooling capacity and is suitable for large guest rooms and suites.

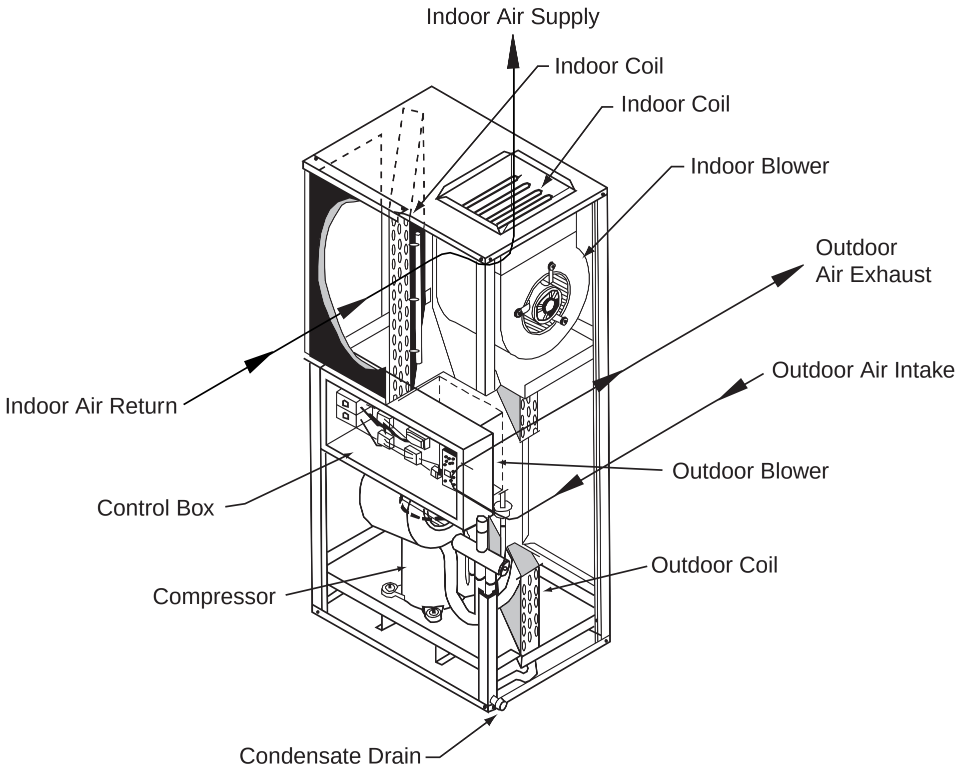

Figure 3-10
Insider™ Heat Pump

Performance

ASHRAE Standard 90.1-1989 contains performance standards for unitary air conditioners and heat pumps. Standard rating conditions and minimum performance requirements are prescribed for discrete size intervals between 0, 65,000, 135,000, 760,000 and more than 760,000 Btu/hr cooling capacity. Minimum performance requirements are specified for each equipment category, while reference is made to ARI standards for accompanying test conditions. As an example, electrically operated, air-cooled, unitary heat pumps are required to meet EER values of 8.5–8.9 at outdoor temperatures of 47°F and 17°F, respectively. Requirements vary depending on the size and type of equipment.

Cost

Table 3-3 presents installed cost data for some common sizes of unitary rooftop heat pumps and air conditioners. They include all ductwork, controls, and labor. The costs of the economizer and supplemental electric heat are also included where applicable.

Table 3-3
Installed Costs for Rooftop Unitary Systems

Capacity (tons)	Installed Cost ($)	
	Heat Pump	Air Conditioner
20	29,400	28,000
30	47,300	45,000
40	65,100	62,000
50	77,700	74,000

Source: *R.S. Means Mechanical Cost Data*, R.S. Means Company, Inc., 1998 and industry contacts.

Boilers

Technical Description

A boiler is a "pressure vessel designed to transfer heat produced by combustion to a fluid" (ASHRAE 1996). In most applications, this fluid is water. Boilers may be used to generate steam or hot water for heating systems. Steam may heat the indoor space directly or indirectly through the use of heat exchangers (see Figure 3-11). Both steam and water boilers encompass a range of capacities from 50,000 Btu/h to more than 100,000,000 Btu/h. They can be fired by a variety of fuels, but natural gas is most commonly used for heating purposes in the lodging industry (AGA 1998).

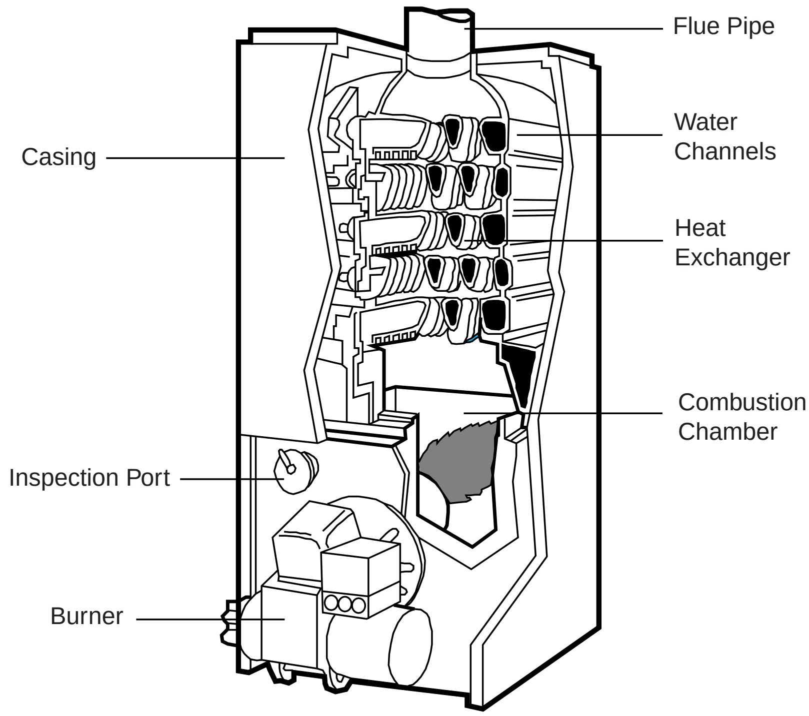

Figure 3-11
Fossil-Fuel Boiler

Boiler systems are the most common solution for meeting the heating loads of larger lodging facilities. In total, boilers provide space heating to 20% of all lodging facilities. However, boilers provide space heating to more than 40% of lodging floor space in buildings larger than 500,000 ft^2 (AGA 1998). They should be sized to satisfy the heating load of the coldest design day with extra system output to compensate for piping losses and additional pickup load following extended shutdown or low nighttime setback.

Performance

Combustion efficiency of boilers nominally ranges from 88% to 95%, with overall boiler efficiency somewhat less due to radiative heat losses from the boiler (ASHRAE 1996). Boiler output may vary by as much as a 20:1 ratio by varying fuel flow (usually accomplished through continuous modulation).

The amount of fuel consumed for heating will depend not only on the building heating load but also on piping losses and losses within the boiler itself. Equipment cost goes up with operating pressure, so relatively low pressure boilers (15 psig, 250°F) are best suited for space heating. Compared to hydronic (hot water) systems, steam systems have the advantage of operating at relatively low pressure in taller lodging establishments where hydraulic pressure of water at lower floors can be excessive.

Cost

Steam boilers cost slightly more than hot water boilers; however, the smaller size or fewer number of steam terminal units required in the total system configuration can compensate for the higher cost in some situations (R.S. Means 1998). Estimated installed costs[15] for a complete commercial hot water heating system in different-sized buildings are shown in Table 3-4.

Table 3-4
Installed Hot Water System Cost Estimates, Gas-Fired Boiler

System Size (building ft^2)	$/$ft^2$
1000	17.15
10,000–100,000	5.76
100,000–1,000,000	2.59

Source: *R.S. Means Mechanical Cost Data*, R.S. Means Company, Inc., 1998.

Since cost per square foot decreases with building size, steam or hot water systems may be a more cost-effective heating solution for larger rather than smaller lodging establishments (e.g., a packaged terminal unit needed to heat a 300-ft^2 room will involve a capital investment of about \$3.67/ft^2). On the basis of initial cost alone, the packaged terminal unit appears to be the best option in smaller facilities, but disparities in life-cycle, maintenance, and energy costs (a location-dependent factor) often make steam or hydronic systems more appealing.

Furnaces

Technical Description

Furnaces use combustion of a variety of fuels to directly heat air without the use of an interim heat transfer medium such as water or steam. Commercial furnace capacities range from 150,000 to more than 2,000,000 Btu/h. Combination package units (or “gas packs”), wherein an air conditioning unit is paired with a natural gas furnace, are most common. Cooling capacities of these units typically range from 5 to 50 tons with heating capacities ranging from 1 to 1.5 times the cooling capacities.

[15] Includes plumbing, controls, fin-tube radiators, and installation.

Performance

A common measure of gas-furnace efficiency is the "annual fuel utilization efficiency" (AFUE) index, which is a measure of the furnace efficiency after deducting losses due to exhaust heat, cyclic effects, and infiltration. AFUE values for commercial furnaces are approximately 80%. In selecting commercial furnaces, it is recommended that lodging facilities size them at 30% over the design heating load requirement.

Cost

Table 3-5 presents installed equipment cost data for some common sizes of gas furnaces. The largest furnace in Table 3-5 requires an investment of approximately $8.00 per thousand Btu/hr capacity—about one-tenth that of a packaged terminal unit. However, additional furnace ductwork and controls will involve additional costs, not only for purchase and installation but also in terms of valuable building space.

Table 3-5
Gas Furnace Estimated Installed Costs

Capacity (thousand Btu)	Cost ($)
100	935
200	2275
300	2500
400	3150

Source: *R.S. Means Mechanical Cost Data*, R.S. Means Company, Inc., 1998.

District Heating and Cooling

District heating and cooling is a means by which a building can be heated or cooled without source equipment on site. Steam, hot water, or chilled water are supplied by a remotely located production plant through a distribution network. If such a source is available within reasonable proximity to its facility, a lodging establishment may find it convenient and/or cost effective[16] to purchase steam and/or chilled water. This resource is then plumbed directly to heat exchange terminals within the building or routed through a heat exchanger at a central location within the building. The particular advantage of this arrangement is that the risks associated with investment

16 Central plants can generally produce heating and cooling more efficiently and cleanly than a large number of smaller, on-site equipment.

and maintaining sources such as boilers and chillers are directly borne by the producer, not the lodging establishment.

The bulk (50–75%) of the capital costs of a district heating/cooling system is incurred in setting up the transmission and distribution system. Lodging establishments that are made up of closely clustered groups of buildings or high-rise structures are all good candidates for district heating and cooling. They represent areas with high concentrations of cooling loads and thermal load densities.

Thermal Storage

Thermal storage systems involve a storage medium from which heat may be removed or added for use at desired times. Thermal storage media include tanks of water or brine, hydrated salts, brick, or ceramic. The stored energy may be used to meet peak heating and cooling loads. For example, electric chiller usage on demand generally coincides with times of peak electric rates and may result in high demand charges. A thermal mass such as a tank of water may be chilled during off-peak periods when electric rates are low, and used for building cooling in lieu of the electric chiller during times when electric rates are high. Thermal storage generally consumes more energy than conventional cooling systems, but the overall energy cost may be less due to reduced power rates.

Heating and Cooling Distribution Systems

The heating and cooling sources described in the first section of this chapter require some form of distribution system to transfer the thermal load between the space and the source. These systems can be classified into three general categories according to the medium by which energy is transferred: "all-air systems," "air-and-water systems," and "all-water systems." Heating and cooling distribution systems are not commonly changed as part of a retrofit because the cost associated with installing plumbing or ductwork in an existing building is prohibitively high. Therefore, a central distribution system is generally integrated into a lodging facility when it is first constructed.

All-Air Systems

Technology Description

All-air systems satisfy the heating, cooling, dehumidification, and humidification loads of a zone by ducting conditioned air into the zone without requiring any additional form of space heating or cooling (see Figure 3-12). They may be classified as follows:

- <u>Single-duct systems</u>: Air is centrally conditioned to a given temperature and humidity level and transferred through a single duct to individual spaces or zones within a building. Terminal apparatus then adjust either the temperature or air flow quantity to meet the requirements of each space or zone.

- <u>Dual-duct systems</u>: Two air flows are centrally and independently heated or cooled, and then routed through parallel ducts to terminal apparatus or mixing dampers where the hot and cool air flows are mixed to achieve the desired temperature before entering the space or zone.

Both single-duct and dual-duct systems may be further classified as either "constant-volume" or "variable-air-volume" (VAV) systems. Constant volume systems deliver a steady quantity of air with variable temperature to the conditioned space, while VAV systems deliver a variable quantity of constant-temperature supply air to the conditioned space.

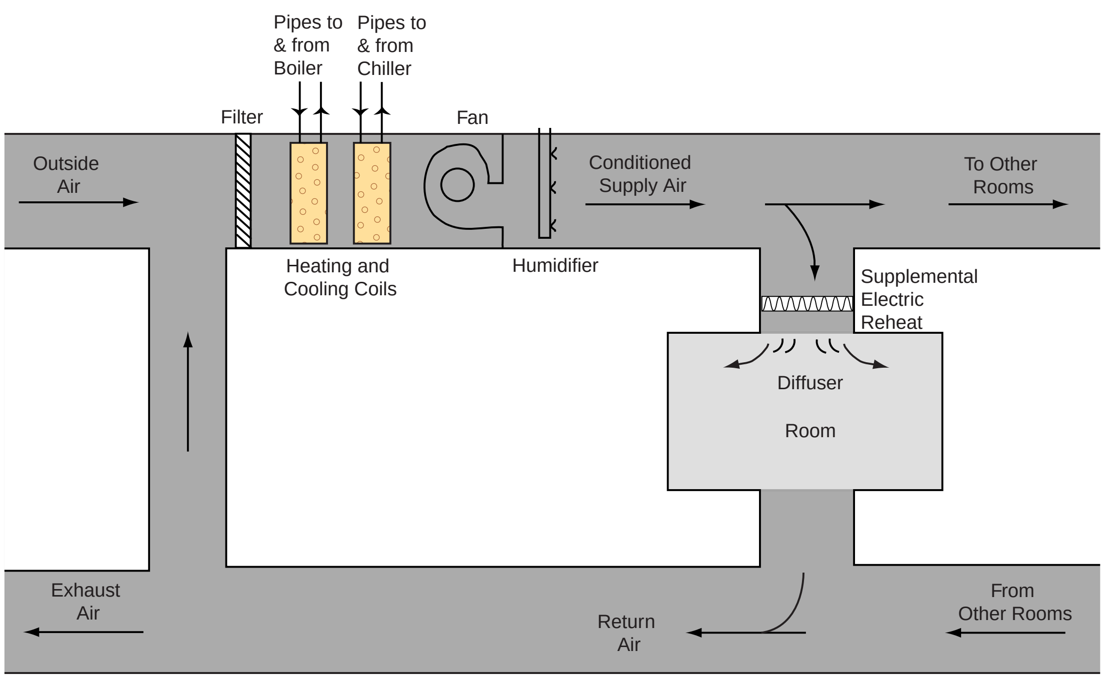

Figure 3-12
All-Air System

Advantages

All-air systems are highly versatile and are common in hotels and other applications where temperature and humidity control of multiple zones is required. Among the distribution systems discussed here, all-air systems offer the most precision in temperature and humidity control. Vibration- and noise-producing equipment is kept away from the occupied space, further enhancing guest comfort. Also, centralizing all equipment and plumbing enables maintenance to be performed without disturbing occupied spaces.

Disadvantages

The quantity of ductwork required by an all-air system reduces the amount of usable floor space due to vertical shafts and requires greater overall building height due to its horizontal ducts. This can increase the cost of constructing a larger building, and/or reduce the quantity of usable floor space, which is highly valued in lodging establishments.

Cost

Equipment commonly used as the heating/cooling source for an all-air system (furnaces and unitary heat pumps) were discussed in the first section of this chapter. The cost of the air distribution system associated with this equipment varies considerably, depending upon the size of the system, the number of duct joints and elbows required, the type of materials used, and labor-related variables such as installation height. For example, 6" diameter, non-insulated spiral sheet-metal duct costs approximately $3.70 per linear foot (installed), and the insulated version costs $8.00 per linear foot (Mechanical Estimating 1995).

Air-and-Water Systems

Technology Description

Air-and-water systems are most suitable for buildings which have a high thermal load due to heat loss/gain through the building exterior but do not require much humidity control (ASHRAE 1996). Air-and-water systems involve two separate heat transfer circuits: a “primary air” circuit of preconditioned ventilation air, and a “secondary water” circuit of hot or chilled water supplied by a boiler or chiller (see Figure 3-13). The air portion of the air-and-water system filters, dehumidifies/ humidifies, and precools/preheats (if necessary) a constant volume of ventilation air which is ducted to each space. The water portion of the air-and-water system involves water-based heat exchangers located in or near the rooms, which may be completely separate from the air system (as in radiant panels), integral to the air system (as in induction units), or a combination (as in fan-coil units).

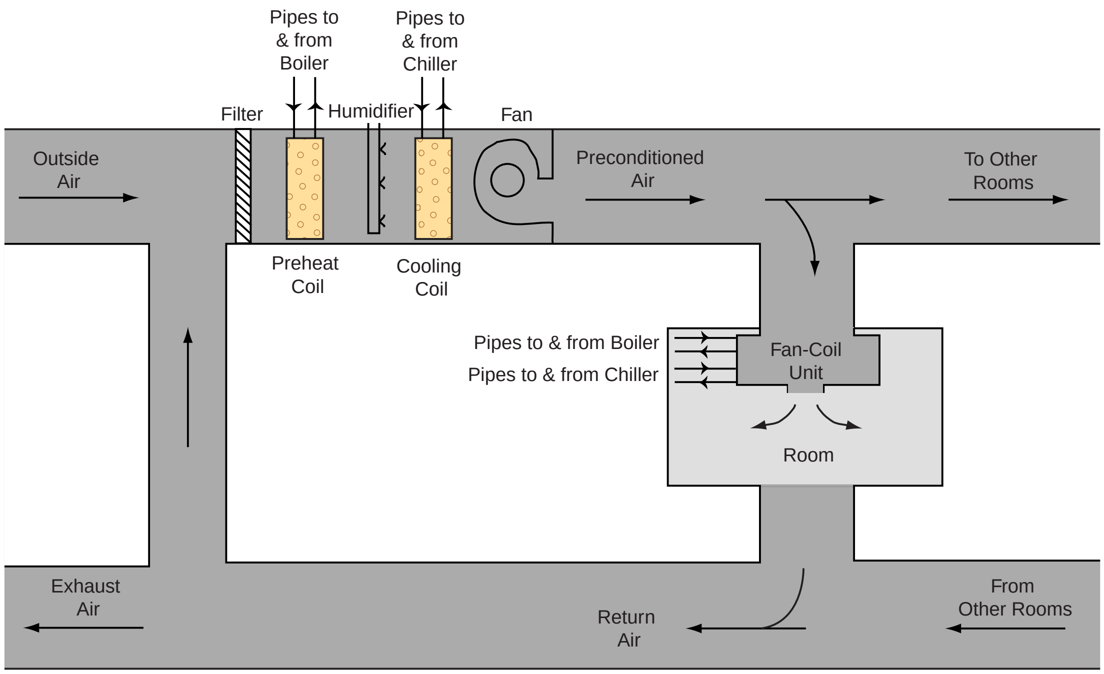

Figure 3-13
Air-and-Water System

The water circuit may be classified as a "two-pipe" system (consisting of one water supply pipe and one water return pipe), a "three-pipe" system (consisting of hot and cold water supply pipes with a common return), or a "four-pipe" system (consisting of separate supply and separate return plumbing for hot and chilled water). Two-pipe systems are not commonly used in most modern buildings, as they cannot concurrently provide both cooling and heating to the building. Three-pipe systems are rarely used today due to excessive energy consumption. Four-pipe systems are preferable because they overcome the shortcoming of two-pipe systems by enabling some parts of a building to be heated while other parts of a building are cooled.

Advantages

Air-and-water systems offer easy control of room temperatures with individual thermostats. Preconditioning of air is also done centrally, thereby enabling most maintenance to be carried out without disturbing occupants. Less space is required for air distribution than for an all-air system because much of the heating and cooling load is carried by the water portion of the system.

Disadvantages

The primary air supply is usually steady with no provision for guests to turn off ventilation air; hence, guest comfort may be compromised. Also, two-pipe systems may not be able to provide heating or cooling when a guest chooses, as different rooms may have heating and cooling loads at the same time while the system is capable of providing only cooling or heating to all rooms concurrently. Greater operating complexity is also inherent in two-pipe systems as the entire system must be switched between heating or cooling mode depending on the overall building's thermal load.

Cost

The cost of an air-and-water system includes both ductwork and plumbing material. Energy consumption of air-and-water systems is greater than that of most other systems due to the increased power requirement resulting from the pressure drop of primary air across the terminal units (ASHRAE 1996). Furthermore, the initial cost of four-pipe systems is greater than that of all-air systems. Two-pipe systems offer some economic advantage with less plumbing required, but the inability to concurrently heat and cool different rooms at the same time precludes the use of a two-pipe system in most lodging applications.

All-Water Systems

Technology Description

All-water systems use hot or chilled water alone for heating and cooling by conduction, convection, or radiation (see Figure 3-14). The most common all-water heat transfer device used in lodging establishments is the fan-coil unit. This resembles a packaged terminal unit in appearance and may be wall-mounted. Fan coil units are generally equipped with water coils, air movers, and filters. Ventilation air is provided by a separate, central air pretreatment system which cleans and dehumidifies the outside air to avoid condensation in the terminal units. Within the terminal unit, the air is heated or cooled by heat transfer through the water coils. As with the air-and-water systems, all-water systems may generally be classified as “two-pipe” or “four-pipe” systems.

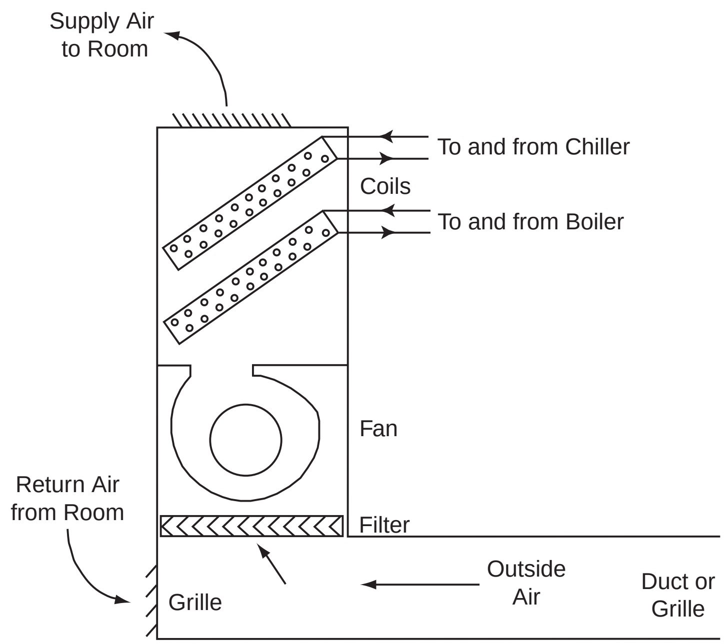

Figure 3-14
All-Water System

Advantages

All-water systems with fan-coil terminal units offer individual room temperature control and minimize cross-contamination from one room to another. Because they require less space for ductwork and plumbing than all-air systems, they have a particular advantage in lodging facilities with space constraints and are much more feasible as a retrofit than an all-air system due to ductwork space considerations.

Disadvantages

All-water systems require more routine maintenance than all-air systems and this work needs to be done in occupied areas (ASHRAE 1996). This maintenance includes cleaning filters and draining condensate pans.

Cost

Much of the cost of an all-water system is enveloped in the central chiller or boiler (see the first section of this chapter). Individual room-size, four-pipe fan-coil units may be expected to cost from $1000–$1200, including installation and plumbing.

4

HUMIDITY CONTROL SYSTEMS

Indoor humidity control is an important issue in the lodging industry and inattention to moisture control can have serious financial consequences. Humidity levels that are either too high or too low can result in guest/employee discomfort and create problems for physical structures. Aside from the discomfort factor, humans can experience health-related problems through the increased growth and spread of viruses, bacteria, fungi, and other microorganisms.

Excessive moisture can cause visible physical damage to lodging facilities in the form of mold on walls, floor coverings or fabrics; wood warping; paint streaking; and staining.[18] More importantly, high humidity levels can contribute toward various kinds of structural degradation, including decreased strength and stiffness of some building materials and reduced insulation effectiveness. In contrast, low humidity levels can cause drying, shrinking, and cracking of furniture, wood floors, and interior trims and can generate static electricity, which can interfere with smooth operation of electronic equipment. In general, the lodging industry is apt to face the problem of excess humidity much more frequently than that of insufficient humidity.

Optimum relative humidity (RH) levels for human health and comfort have been established by ASHRAE to be 40–60% (see Figure 4-1).

[18] The American Hotel and Motel Association estimates that replacing or repairing mold- and mildew-damaged wall coverings, furniture, carpets, and draperies costs the lodging industry approximately $70 million annually.

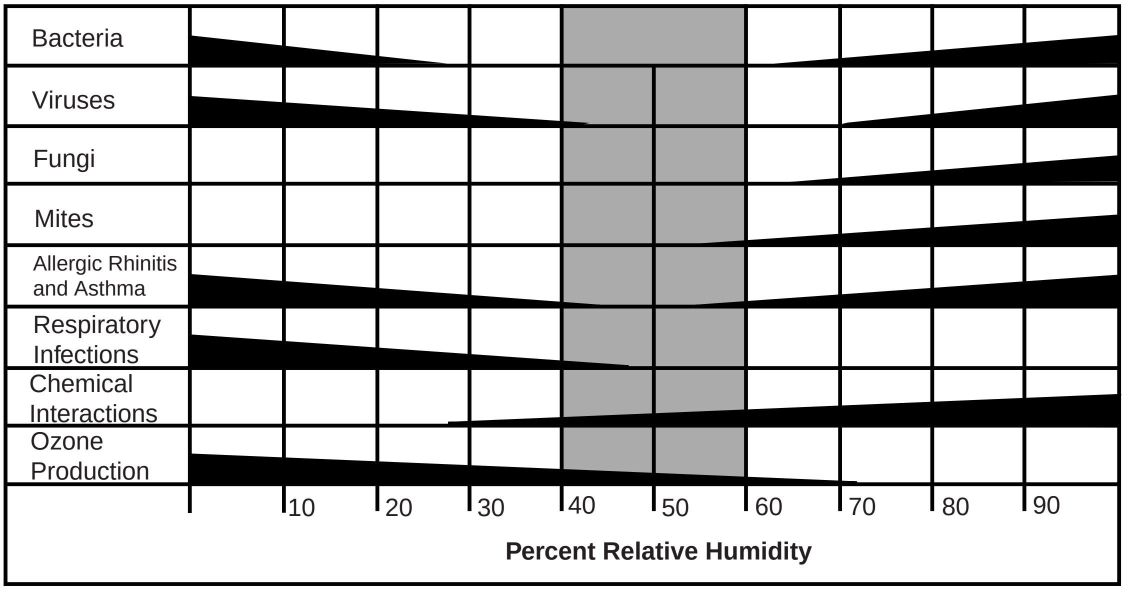

Figure 4-1
Optimum Relative Humidity Ranges for Occupant Health
Source: *Criteria for Human Exposure to Humidity in Occupied Buildings*, ASHRAE, 1985.

Relative humidity levels of less than 30% or greater than 60% are conducive to the spread of microorganisms (bacteria, viruses, fungi, and mites), and tend to aggravate respiratory diseases and disorders such as asthma and allergies (ASHRAE 1996). This chapter discusses the humidification and dehumidification options available to lodging establishments for maintaining a healthy environment for their guests and preserving the physical condition of their facilities.

Dehumidification

Dehumidification may be required when moisture levels get too high (e.g., above 60% RH) and remain there for extended periods of time. A humid outdoor environment is not necessarily the only indicator of the need for dehumidification in a lodging facility. Substantial moisture loads result from food preparation, hot showers, spas, swimming pools, and indoor fountains (see Table 4-1). Swimming pools in particular represent a unique dehumidification need. Large amounts of moisture are generated from evaporation of pool water and must be removed to maintain indoor temperature and humidity at human comfort levels.

Table 4-1
Moisture Sources

External Moisture Sources	• permeation through the building envelope • infiltration through intermittent opening of doors • infiltration through fixed openings such as cracks, windows, and elevator shafts • fresh air ventilation from outside the space
Internal Moisture Sources	• evaporation and transpiration from building occupants • showers • swimming pools and spas • plants • decorative fountains

When the combination of external and internal moisture generation gets too high, a mechanical dehumidification system may be needed. The principle types of dehumidification technologies are:

- refrigeration-based dehumidification
  - direct expansion
  - chilled liquid
- desiccant-based dehumidification
- hybrid systems

Refrigeration-Based Dehumidification

Most hotels and motels utilize refrigerant-based air conditioning systems to perform dehumidification. The general principle is to over-cool the air to remove moisture and then re-heat the air to achieve the desired temperature (see Figure 4-2). Refrigeration-based dehumidification systems remove moisture based on the principle that cool air cannot hold as much water vapor as warm air. A refrigeration system cools the supply air; when air is cooled below its dew point, the moisture contained in the air condenses onto a nearby surface (cooling coil). This quantity of air is now at a lower temperature and contains less moisture. It may then be mixed with return air or reheated to provide the proper air temperature at a lower relative humidity.

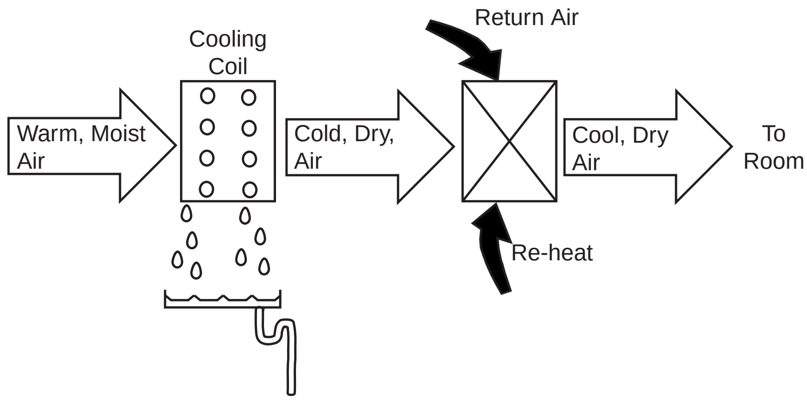

Figure 4-2
Refrigeration-Based Dehumidification Process

Two primary variations of this technology are used in the lodging industry: direct expansion and chilled liquid. The direct expansion method is suitable for lodging facilities requiring 50–5000 CFM. In direct expansion systems, supply air is cooled when it comes in direct contact with the system's evaporator coils. Excess moisture condenses on the coils and is removed in liquid form. Packaged terminal cooling units, rooftop air conditioners, and heat pumps are examples of equipment types that utilize direct-expansion dehumidification.

Chilled-liquid systems are more economical for use in applications greater than 500 CFM. These systems cool the supply air below its dew point by circulating a chilled liquid (e.g., water) through a heat exchanger. The chilled liquid is produced by a refrigeration system (e.g., chiller) and piped to the heat exchanger near the room. The direct expansion and chilled liquid processes are described in greater detail in Chapter 3.

Desiccant-Based Dehumidification

Desiccant dehumidification is based on attraction of water vapor to the surface of a solid[19] material (i.e., desiccant). Most solid materials can attract some level of moisture. However, desiccant materials can attract 10–1000% their own weight in water vapor. Desiccant systems adsorb (attract) water vapor at low temperatures and desorb (release) water vapor at high temperatures. Desiccant-based dehumidification systems come in a variety of configurations,[20] but all desiccant dehumidifiers use the same three-step cycle:

[19] Liquid desiccant materials are also available.
[20] Typical equipment configurations include spray tower, solid packed tower rotating horizontal bed, multiple vertical bed, and rotating honeycomb wheel.

1. The desiccant, in a dry and cool state, comes into contact with moist supply air and adsorbs water vapor from the air.

2. After some contact with the supply air, the desiccant becomes saturated with moisture. At this point, the desiccant is placed in contact with a heated "regenerative" air flow, which causes the desiccant material to release the moisture. Regenerative air is outside air which is heated (by electricity or gas) for the purpose of absorbing moisture from the desiccant. It is then returned to the outside environment.

3. After the desiccant releases moisture to the regenerative air, the desiccant is cooled and the process can be repeated.

The regenerative air used for desorption of moisture from the desiccant may be heated by a number of sources, such as waste heat, electric resistance, or fossil fuel. Both liquid and solid desiccant materials are available, as are a number of variations of equipment hardware. However, the most common desiccant system is the solid desiccant rotating wheel.

Desiccants remove moisture from air by attracting or absorbing water vapor. In the process, the latent heat of vaporization of the water vapor is released to the air. Thus, desiccants raise the temperature of air while removing moisture. However, the need for dehumidification is typically accompanied by a need for cooling rather than a need for heating. As a result, cooling coils often follow the desiccant to lower the temperature of outdoor air and treat the sensible heat load stemming from water vapor removal (see Figure 4-3).

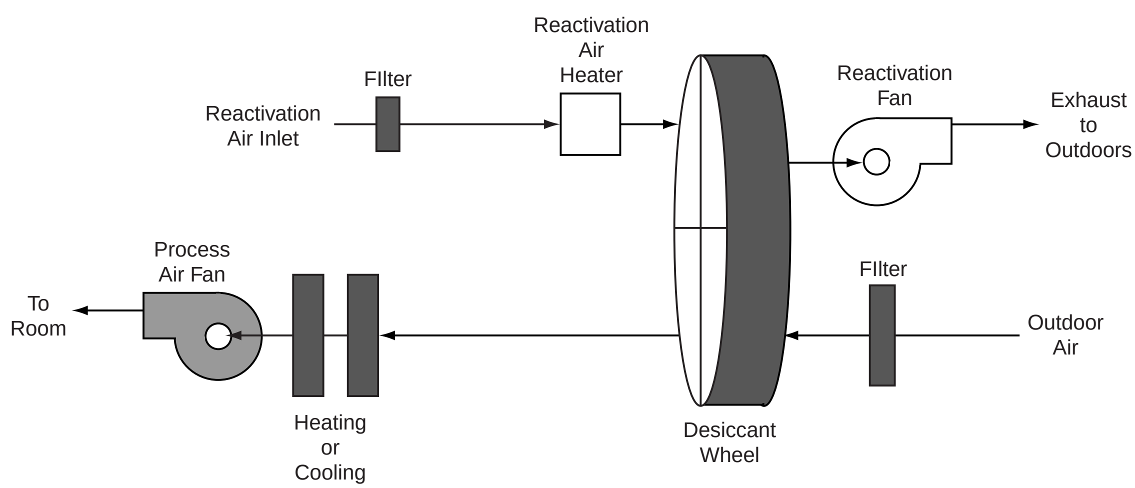

Figure 4-3
Desiccant Rotary Wheel System

Hybrid Systems

In general, refrigeration-based dehumidifiers are most efficient under high temperature and humidity conditions, while desiccant-based dehumidifiers are most efficient for dehumidifying at lower temperature and humidity conditions. These individual advantages suggest that desiccants and refrigeration systems may be used in conjunction for dehumidification purposes, thereby enabling the advantages of each technology to compensate for the limitations of the other.

A variety of configurations may be constructed. One example is a combined dehumidification system which includes a desiccant unit preceded by a cooling coil (Munters 1990). This enables the desiccant system to remove the balance of moisture from relatively lower temperature and lower humidity air exiting the refrigeration cooling coil (see Figure 4-4). Cooling and/or heating coils may again follow the desiccant to meet the remainder of the sensible load.

Other variations are also available. In many situations, a desiccant system upstream of the air conditioning system will be the best solution. An engineering analysis should be performed for selecting the optimum system for a specific situation.

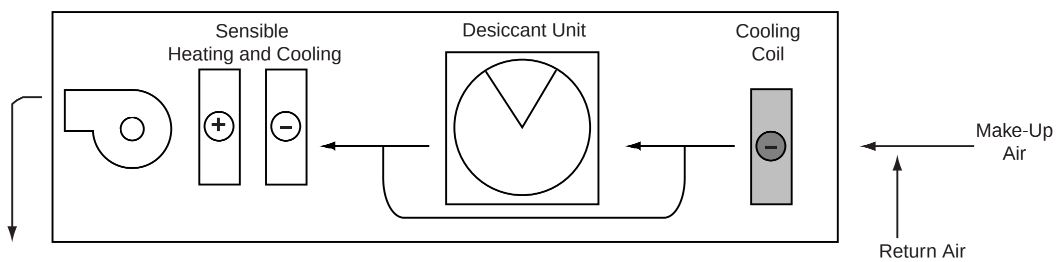

Figure 4-4
Hybrid System

Equipment Selection

The moisture load of most lodging spaces may be met by dehumidifying supply air, which not only abates introduction of moisture from humid outdoor air, but also acts as a sponge to remove moisture introduced by internal sources and infiltration. This may be accomplished through a central system or in individual room units. For example, outdoor air (and return air) may be dehumidified by the cooling equipment of a central system which then ducts dry supply air to conditioned spaces. In the case of an air-and-water or all-water system, this is accomplished in the air preconditioning portion of the system. All-air environmental control systems are available that provide cooling, heating, and dehumidification from one packaged unit. These systems can utilize either refrigeration-based and/or desiccant-based methods for precise humidity control.

Dehumidification is often a thermodynamic necessity associated with cooling. Cooling devices such as PTAC units are a common example where dehumidification is accomplished as a by-product. However, air conditioning equipment alone is often not the most effective means of dehumidification. If dehumidification is produced merely as a by-product of cooling, air may be overcooled or too humid when the thermal load and moisture load do not coincide at the same refrigeration system operating point. Air subcooling followed by reheat avoids this problem, but with an energy penalty. For this reason, specialized unitary dehumidification systems are frequently implemented.

Both refrigeration-based and desiccant-based unitary dehumidification systems are readily available. The equipment is commonly produced as a unitary package which may be integrated with a central conditioning system to provide not only dehumidification but also filtration and cooling in some cases. Packaged dehumidifier capacities cover a broad spectrum from small, 300-CFM rooftop units to large, skid-mounted systems in excess of 30,000 CFM capacity.

Pool Applications

Swimming pools present a unique dehumidification problem due to the need to maintain indoor temperature and humidity levels necessary for occupant comfort, and the large amounts of moisture generated from pool water evaporation. Several manufacturers produce specialized dehumidification equipment for swimming pools. Standard pool systems use high rates of exhaust ventilation and standard refrigeration-based makeup air. However, this option substantially increases the space conditioning load on the pool enclosure.

Other equipment types are available that include energy-conserving devices to retain the latent heat of moisture in pool rooms. For example, simple air-to-air heat exchangers or total heat recovery heat exchangers may be used to conserve energy from vented pool-room air. Heat pump water heaters, a highly efficient option, cool and dehumidify pool-room air by refrigeration, with waste heat being transferred to the pool water (see Figure 4-5). This option provides not only economic savings, but also produces a more comfortable environment. Manufacturers generally offer equipment sizing and system design guidelines for equipment installations—moisture removal capacities of 10–60 lb./h are recommended for pool sizes commonly found in lodging properties.

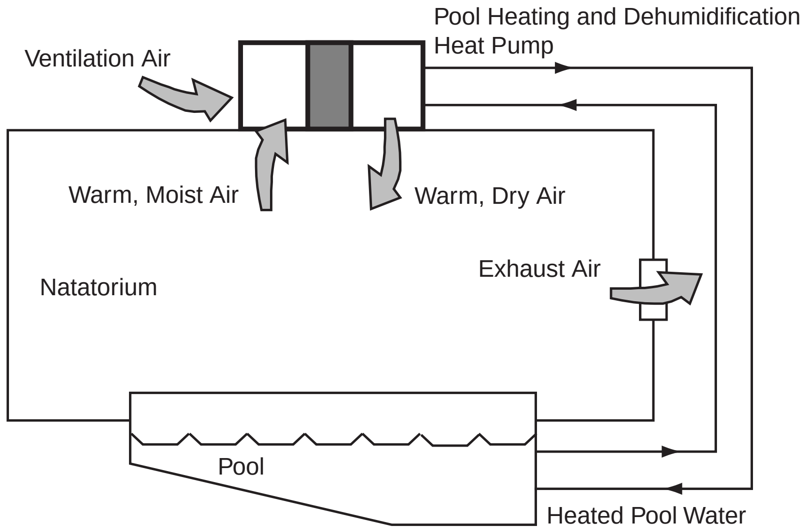

Figure 4-5
Pool Heating Heat Pump System

Energy Recovery Ventilation

The high ventilation rates required for many lodging spaces suggest the use of heat recovery devices to recycle energy from vented air to re-treat fresh ventilation air from the outdoors. This same principle may also be applied to water vapor by use of a heat recovery wheel coated with a desiccant material (known as total energy recovery wheels). These energy recovery ventilators draw moisture from the inbound air stream and reject it to the outbound air stream, thereby reducing the amount of dehumidification necessary for ventilation air. They can typically recover 50–80% of the total heat load (latent and sensible) associated with ventilation air.

Controls

Humidistats located in the occupied space or in the supply air duct can be connected to central microprocessors to control the relative humidity level. However, if a facility has separate controls for temperature and humidity for an air conditioning system, the following problems could occur:

- The cooling system is operated only as necessary to satisfy the space cooling load, while the moisture load exceeds the dehumidification capacity associated with the amount of cooling supplied. Hence, the thermal load is met while moisture continues to accumulate in the space. This scenario is very common in hotel and motel rooms.

- The refrigeration system is operated to meet the moisture removal load regardless of temperature. Hence, the air is sufficiently dry, but the space is too cold. Under these conditions, a separate re-heat system is required to bring the temperature back up to comfortable levels.

A more economical solution that results in greater occupant comfort is to separate dehumidification from cooling, performing each operation only as necessary. Input from thermostats and humidistats can specify when and where space cooling and dehumidification are necessary. Operation of a desiccant system with a cooling system may more efficiently meet cooling and dehumidification loads than conventional systems.

Humidification

Most lodging facilities do not require humidification. However, in some cold and particularly arid climate regions, relative humidity may easily drop below 30%, resulting in an environment conducive to sickness, bacteria, and viruses. Lodging properties in cold areas such as winter or ski resorts are the most likely candidates for humidification systems.

Humidifiers are available in a wide range of sizes. Small humidifier units with 3–5 lb./h capacity are more appropriate for individual hotel/motel rooms, while units with several hundred lb./h capacity are available for larger central systems. There are two basic types of humidifiers: steam and non-steam.

Steam Humidifiers

Steam humidifiers inject steam into ducted air flows (see Figure 4-6). This steam is generated through a heating process either within the unit or in a remote steam generator. Some of the technologies include:

- Direct-steam injection humidifiers inject steam under pressure directly into the duct air flow with little change in air temperature.

- Heat exchanger humidifiers are supplied with heat from either steam or hot water. This supply heat is used to generate steam for injection into the supply air ductwork. These units are well suited to lodging buildings equipped with steam or hydronic heat.

- Electrically heated steam humidifiers use an electric heating element to produce steam. These units are free-standing and are commonly offered in 20–200 lb./h capacities.

- Gas-fired steam humidifiers utilize a gas flame to generate steam which in turn is injected directly into the air ductwork.

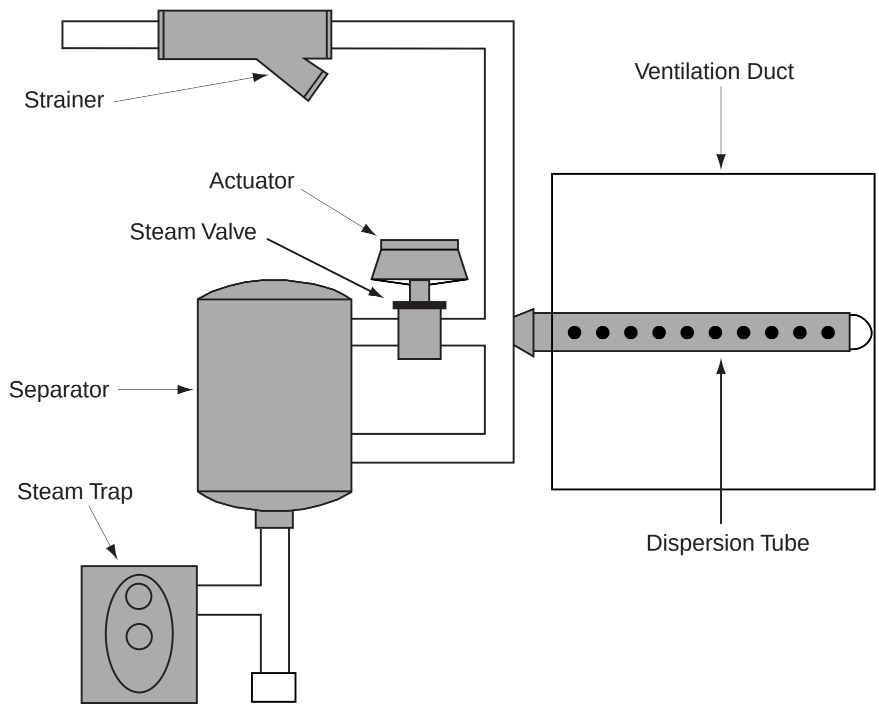

Figure 4-6
Steam Humidifier in a Central Air System

Non-Steam Humidifiers

Non-steam humidifiers generate water vapor by means other than heating water. Non-steam humidifiers are often free-standing, and include the following technologies:

- Ultrasonic humidifiers generate an atomized mist of water by electrically vibrating a container of water at ultrasonic frequency. They commonly have capacities of 10–20 lb./h.

- Centrifugal humidifiers generate an atomized mist of water by centrifugally slinging water through a fine mesh.

- Compressed air nozzle humidifiers use an air jet to break a flow of water into a fine mist which is entrained into the air flow. Capacity of these units is 10–50 lb./h, and applicability is limited to buildings with compressed air, so they are not likely to be used in hotels and motels.

- Wetted media humidifiers circulate liquid water over a porous medium. Air is blown through this porous medium, which entrains air droplets that soon vaporize in the air flow.

Equipment Selection

Direct-injection steam humidifiers are the most frequently chosen equipment for commercial buildings because of their lower cost, wide capacity ranges, and excellent output control. In most of these applications, steam is generated by a central boiler, making them a likely choice if a boiler is present. The other option is to use self-contained humidifiers that generate and distribute the steam. They may be the only option when a boiler is not available in the lodging facility. Humidifiers often come with such accessories such as microprocessors with remote humidistats, modulating controls, or on/off controls. A remote humidistat may be located in the conditioned space or in the return air duct. Information from the humidistat is used by the microprocessor to regulate humidifier output.

Total energy recovery wheels may also benefit humidification applications. They can draw moisture from vented air and add this moisture to the inbound air stream. Therefore, in a situation where there is low outdoor humidity and inadequate internal moisture generation, an energy recovery ventilator could be used to maintain the humidity level in the space. They can also be used in conjunction with a humidifier to reduce the potential humidification load on the system.

5

INDOOR AIR QUALITY

Guest comfort and satisfaction constitute the cornerstone of the lodging industry. Even more important than the services offered, a lodging establishment must provide a safe and hospitable environment that presents no threats to health or life. Maintaining acceptable indoor air quality (IAQ) is part of this responsibility.

The quality of indoor air in lodging facilities is generally determined by the interaction between five major components: 1) the HVAC system, 2) human occupants, 3) internal activities, 4) building components and furnishings, and 5) external pollution sources.

This chapter examines different kinds of contaminants likely to be found in lodging facilities and discusses specific control technologies for eliminating them or reducing their presence to acceptable levels. The chapter contains the following sections:

- IAQ Regulations
- IAQ Contaminants
- IAQ Control
- HVAC Systems and IAQ

IAQ Regulations

There are no Federal regulations pertaining to IAQ in lodging facilities. However, guidelines for maintaining a good indoor environment in commercial buildings are provided by the U.S. Environmental Protection Agency[1] and the American Society of Heating, Refrigeration, and Air-Conditioning Engineers.[2] ASHRAE Standard 62-1989R defines acceptable indoor air quality (IAQ) as "air in an occupied space toward which a

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[1] The EPA conducts ongoing programs aimed at reducing human exposure to indoor contaminants. The primary objectives of the programs are to disseminate information, facilitate good IAQ practices, advance the science of IAQ, and leverage resources dedicated to IAQ issues.

[2] ASHRAE has published guidelines specifying "ventilation for acceptable indoor air quality" in its "Standard 62-1989" and "Standard 62-1989R" revision which is currently in review. This standard specifies general IAQ-related requirements, design ventilation rates, and construction and system startup requirements, and operation/maintenance procedures.

substantial majority of occupants express no dissatisfaction and in which there are not likely to be known contaminants at concentrations leading to exposures that pose a significant health risk."

IAQ Contaminants

Chemical Contaminants

Within lodging establishments, chemical pollution of indoor air most frequently take the form of gases generated by people and activities. In some cases, chemical contaminants may be carried into the facility by the outdoor air supply or emitted by furnishings. Those that significantly affect IAQ are:

- carbon dioxide
- carbon monoxide
- volatile organic compounds (VOCs)

Carbon dioxide is produced by human metabolism and may accumulate to unacceptable levels in high-occupancy lodging facilities if the buildings are inadequately ventilated for the amount of human activity present. Although carbon dioxide is not a highly toxic gas, concentration levels[3] in excess of 5000 ppm[4] will have potential negative health effects on lodging occupants.

Carbon monoxide is a highly toxic gas of which lodging management must be continually vigilant. Sources of carbon monoxide are usually vehicle exhaust fumes entering the building, or fumes leaking from poorly ventilated furnaces and boilers within the building. Recommended limits range from 0–1 ppm for rural areas and 2–5 ppm for metropolitan areas; indoor levels should never exceed the 9 ppm specified by the EPA for prevailing outdoor levels. The only way to provide assurance that carbon monoxide is not present in buildings is through routine or automated monitoring and testing.

Volatile organic compounds originate in many of today's building materials, finishes, and furnishings. Because there are more than 1,000 VOCs that can originate from hundreds of different sources, it is uncertain at what levels these vapors begin to have effect on human health. However, the highest levels of VOCs can occur in hotels and motels after new carpeting and other furnishings have been installed. Products with

[3] ASHRAE Standard 62R recommends that indoor carbon dioxide concentration not exceed 1000 ppm, or 700 ppm more than outdoor concentration in order to avoid excessive body odor concentration.
[4] PPM = Parts per million (generally by volume basis).

low levels of VOCs can be selected; otherwise, the rooms must be well ventilated before making them available to guests.

Physical Contaminants

Physical contaminants exist as discrete grains or particles varying in size from 0.01 to 100 µm, such as pollen, microorganisms, skin flakes, fine dust, and tobacco smoke. In general, particles of 10 µm or less pose the greatest health hazard to lodging occupants since they are small enough to penetrate the defenses of the body's respiratory system.

Biological Contaminants

Biological contaminants include airborne agents originating from dead or living organisms. Inhaling these agents (sometimes called bioaerosols) may cause some lodging occupants to experience allergic reaction and respiratory disorders, or contract infectious diseases. Common indoor biological contaminants include dust mites, molds and mildews, and fungi.

IAQ Control

The principle technologies available for preventing and/or resolving IAQ problems in lodging facilities are as follows:

1. contaminant detection
2. air cleaning
   - ventilation design
   - filtration
   - disinfection

Contaminant Detection

Chemical contaminants (gases) can be detected and measured by sensors that are targeted toward individual gases or a combination of gases. These instruments vary considerably in complexity and price. Due to the intricacies of modern buildings and the limitless number of sources of contamination, a combination of diagnostic devices is probably necessary to determine the quality of indoor air in a lodging establishment.

Gas sensors fall under two general categories:

- Color-detector tubes: These offer the simplest but least accurate form of gas measurement, and should only be used to determine if further measurements are warranted. Contaminant concentration levels are indicated by the length of stains in the tubes. Each tube may only be used once, so measuring the quality of air in an entire building may require numerous tubes. The average price of a tube is approximately $250.

- Meters: These provide more precise measurements than color-detector tubes and can monitor and record a series of measurements over time (see Figure 5-1). Chemical concentration levels are indicated by direct-read (analog or digital) LCD displays. Prices of carbon dioxide and carbon monoxide meters range from $600 to $1500.

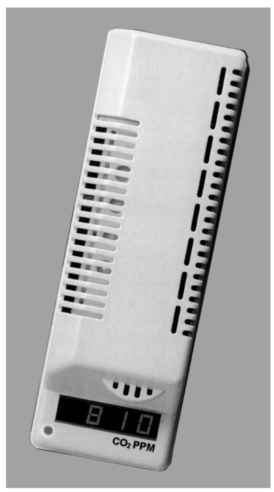

Figure 5-1
Typical Gas Sensor Meter

In selecting IAQ sensors, the features described in Table 5-1 should be considered.

Table 5-1
Gas Sensor Features

Feature	Description
Precision	Finesse of measurements as indicated by margin of error specified by manufacturer.
Selectivity	Ability to measure a specific gas without contamination from other gases.
Poisoning	Potential of sensor to react with the gas it is trying to measure. Once “poisoned,” the sensor has to be replaced.
Drift	Tendency of a sensor to shift its calibration over time. A sensor whose accuracy drifts more than 100 ppm annually is considered unreliable.
Useful Life	Durability of the sensor and frequency of replacement of individual parts, e.g., batteries.

A special kind of sensor known as a demand-control ventilation sensor may be particularly useful in lodging establishments that experience considerable variability in occupancy and activity levels. In designing HVAC equipment, outdoor air supply guidelines are generally based on the peak design occupancy of a building. In reality, changes in occupancy and activity rates throughout the day will affect the rate at which carbon dioxide is generated and the need for supply air in a building. Demand-control ventilation sensors are carbon dioxide sensors located in the HVAC system that can accommodate these variations by signaling the need for reduced or increased ventilation. Monitors attached to air economizers can adjust the outdoor air supply to meet indoor air requirements as indicated by these sensors. In lodging facilities with highly variable occupancy, use of demand-control sensors can result in energy savings.

Air Cleaning

Air cleaning involves using different technologies to eliminate or reduce particulate, gaseous, or biological contaminants in the air. These can be useful tools when contaminants are generated within a building or when the source of pollution is the outdoor air supply. Major air-cleaning techniques are discussed below.

Ventilation Design

Pollutants within a lodging establishment can be reduced by increasing ventilation rates and/or manipulating the distribution of air. Dilution involves mixing contaminated room air with clean air to reduce the concentration of contaminants to acceptable levels. Dilution can be achieved by:

- increasing the total air supply to a zone

- increasing the proportion of outdoor air in supply air

One common dilution system, overhead mixing, is shown in Figure 5-2. In this system, ventilation air enters at the ceiling, and room air also exits at the ceiling. Ventilation air is blended with room air, and a portion of the room air is continuously exhausted. High and low particle concentrations are mixed into a homogeneous level, diluted, and eventually removed.

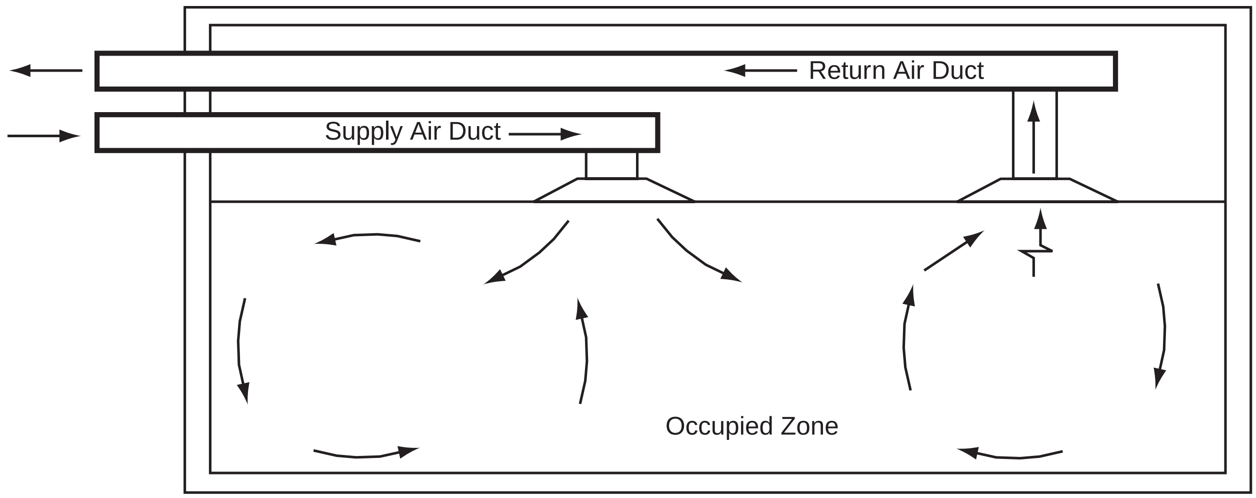

Figure 5-2
Dilution Ventilation

Filtration

Particulate contaminants can be removed from the air or reduced to acceptable concentration levels by media filters installed in HVAC systems. Media filters are usually made of polyester or glass fibers which trap particles carried in the air stream. They come in a variety of sizes, densities, thicknesses, and configurations. Regular maintenance is absolutely necessary as filters lose their efficiency with time.

Many types of particulate filters are appropriate for use in lodging facilities. Standard or medium-efficiency filters are designed to remove only large airborne particles, while high-efficiency filters can remove microscopic organisms as small as a fraction of a micron in diameter. High-efficiency filters represent state-of-the-art technology in achieving clean air. However, they are more costly and have higher operating costs. Because their pores are so small, they present considerably more resistance to airflow than standard filters. As a result, they often require a fan capable of operating at high static-pressure levels to force air through them.

There are three basic types of high-efficiency filters. They are distinguished by their efficiencies in removing particles of certain defined sizes, e.g., a filter that is 95% on 0.3

microns is certified to remove 95% of microorganisms 0.3 microns and larger, and is less effective in removing smaller ones (see Table 5-2).

Table 5-2
High-Efficiency Filters

Type	Efficiency (%)	Particle Size (micron)
HE (high efficiency)	95	0.3
HEPA (high-efficiency particulate air)	99.99	0.3
ULPA (ultra-low penetration air)	99.9995	0.12

While gas detection and filtration can effectively identify or remove a significant number of common particulates and gaseous pollutants from the lodging environment, the best way to achieve good IAQ still lies in taking preventative measures, such as instituting smoking restrictions, allowing time for building materials in new or remodeled areas to off-gas pollutants before occupancy, and rapidly replacing any water-damaged furnishings and carpeting. Particular attention also needs to be paid to all aspects of the HVAC system (e.g., maintaining cleanliness and dryness of intake and exhaust openings, air handler liners, drain pans, access panels, and casings) and exercising proper humidity control (see Chapter 4 for appropriate technologies).

Disinfection

Filters and proper ventilation are effective means of removing dust, pollen ,and other airborne particles from indoor air but are less effective against microorganisms such as bacteria and viruses. These germs are most prevalent where people congregate: hospitals, offices, hotels, and stores. Since the indoor air is often recirculated in these establishments, the chance of spreading these viruses and bacteria is significant. Consequently, many public facilities (especially medical) are installing air-sanitation units.

Air-sanitation units such as ultraviolet (UV) disinfection of air can kill microorganisms and can be used to sterilize the air and reduce the transmission of disease. UV disinfection units are easy to install (similar to fluorescent lights) and maintain, but direct exposure to people must be avoided. The cost is approximately $500 per unit, which is adequate for a room with seven people.

HVAC Systems and IAQ

A 1993 survey conducted for the Electric Power Research Institute evaluated common HVAC systems in terms of temperature control, humidity control, particulate removal, ventilation effectiveness, and occupant satisfaction. The results of the survey are shown in Table 5-3. This table gives an indication of the effects of different HVAC systems on indoor air quality.

Note that window A/C (PTAC) units receive relatively low rankings in most categories. For hotels and motels with PT units, this would imply that some additional IAQ control may be necessary. The table also indicates that central systems such as those with all-air distribution rank relatively high.

Table 5-3
IAQ Evaluation of HVAC Systems

System	Temperature Control	Humidity Control	Particulate Removal	Ventilation Effectiveness	Occupant Satisfaction
Window AC	P	P	P	F	L
Heat Pump	F–G	F	F	G	M
Heat Pump with Distribution	F–G	F	F	F–G	M
Water Loop Heat Pump	G	P	P	P	L–M
Traditional Constant Volume	G–E	G	G–E	G–E	M–H
Single & Dual Path VAV	E–O	F–E	E	F	H
Induction Reheat	G–E	O	F–G	F	M–H
Induction with Coil Reheat	G–O	E–O	F–G	F–E	M–H
Terminal Reheat	G–E	E–O	G–E	G–E	M–H
Coil in Box Reheat	E–O	E–O	—	G	M–H
Baseboard Reheat	E–O	G–E	—	G	M–H
Dual Duct	E–O	E	G–E	E–O	H
Fan Coil	G	P	P	P	L–M
Fan Powered	E–O	F–E	P–E	P	M–H
Induction Box	E–O	F–E	P–E	P	M–H

P = Poor; F = Fair; G =Good; E = Excellent; O = Outstanding; L =Low; M = Medium; H = High; S = Superior
Source: *Space-Conditioning System Selection Guide*, EPRI, 1993.

A

EXAMPLE LODGING INDUSTRY MARKET INQUIRY

A simplified needs assessment study was conducted to demonstrate the kind of market research needed to gather information on lodging establishments in a utility's service territory. The study is not intended to be a comprehensive, statistically valid survey of the lodging industry. Rather, its purpose is to show by example the type of data necessary to construct an industry profile on which to base utility services.

In all, 17 lodging establishments were contacted and presented with a set of questions on energy-related equipment and usage in their facilities. A deliberate attempt was made to seek participation from well-established organizations in each of the following classes: economy, moderate, upscale, and luxury. Selection was random and mainly consisted of participants who were willing to share their time and information. The number of respondents were distributed as follows—economy: 5; moderate: 5; upscale: 3; luxury: 4. All five economy chains operate limited service properties, both moderate and upscale chains primarily operate full-service properties, and all four luxury chains operate only full-service properties (see Table A-1).

Table A-1
Property Descriptions

	Economy	Moderate	Upscale	Luxury
Limited Service	5	1	1	0
Full Service	1	3	3	4
Extended Stay	1	1	2	0
Total Surveyed	**5**	**5**	**3**	**4**

When possible, decision-makers at the corporate level were contacted. However, just under half of the chains contacted make energy equipment decision locally. The relation between the type of facility and the business level of decision-makers is shown in Table A-2.

A copy of the questionnaire is attached to the end of this appendix, and the results are reported on the following pages.

Table A-2
Business Level of Decision-Makers, by Property Type

	Economy	Moderate	Upscale	Luxury
Corporate	2	2	2	3
Local	3	3	1	1

Heating, Ventilation, and Air Conditioning

Among the 17 respondents, 13 said that choice of HVAC equipment is location dependent. Some of the respondents have properties at worldwide locations which have considerably different HVAC needs. As such, a given chain may use multiple types of HVAC systems depending on where the properties are located. Climate also has a bearing upon equipment choice among domestic chains. For example, one respondent uses the same packaged terminal heat pump units in all of its locations but uses steam heat at its Alaska properties to accommodate the severe winters.

The type of HVAC equipment used also depends on the property type (luxury, upscale, moderate, or economy). Higher-end properties tend to use central systems more than lower-end properties (see Table A-3). As higher-end properties are in general larger than lower-end facilities, HVAC use appears to be related to property size. Again, some chains use multiple types of equipment depending upon the property location.

Table A-3
Guest Room HVAC Equipment Choice, by Property Type

	Economy	Moderate	Upscale	Luxury
Packaged Terminal Air Conditioner	2	3	0	1
Packaged Terminal Heat Pump	4	3	0	0
Window Unit	0	1	0	0
Electric Chiller	1	0	3	4
Gas Chiller	0	0	1	2
Central Boiler	0	1	2	4
Heat Pump	0	1	1	2
Total Surveyed	**5**	**5**	**3**	**4**

Among the 17 respondents, only two use special systems for humidity control and both of these are rated as luxury lodgings. Seven respondents indicated that they use special systems for indoor air quality control, although measures are very limited. For example, one respondent uses electrostatic filters in conference rooms, while another simply checks the indoor air quality every six months. Most respondents who implement indoor air quality measures operate upscale or luxury properties, and none operate economy properties.

Lighting

With regard to lighting equipment, all respondents indicate that both fluorescent and incandescent lamps are used (Table A-4). Incandescents are the predominant means of illuminating guest rooms, and there is about a 50/50 split between incandescent and fluorescent lamp usage in common areas among those surveyed. There is also a tendency among lower-end properties for local decision-makers to choose incandescent lighting over fluorescent lighting, more so than corporate-level decision-makers.

Table A-4
Lighting Equipment, by Property Type

	Economy	Moderate	Upscale	Luxury
Guest Room Incandescents	3	3	3	4
Guest Room Fluorescents	2	2	2	2
Common Area Incandescents	3	3	1	3
Common Area Fluorescents	2	3	3	2
Total Surveyed	**5**	**5**	**3**	**4**

Water Heating

The types of water heating equipment used in lodging facilities is highly varied (see Table A-5). Only six respondents knew the age of their water-heating equipment, and five of these indicated that the equipment is as old as the facility. However, a strong majority use natural gas-fired water heaters.

Table A-5
Water-Heating Equipment, by Property Type

	Economy	Moderate	Upscale	Luxury
Electric Storage HW Heater	1	0	1	0
Gas Storage HW Heater	4	5	3	2
Instantaneous HW Heater	0	1	1	2
Other HW Heater	0	0	0	1
Water-Conserving Shower Heads	2	2	1	1
Total Surveyed	**5**	**5**	**3**	**4**

Room Appliances

Energy-using room appliances tend to be more common in higher-end than lower-end properties. Economy lodgings all have color TV sets and bath fans, but few of these facilities offer other room appliances. Moderate, upscale, and luxury establishments have most of the appliances listed in Table A-6, with the exception of heat lamps and microwave ovens (in general, upscale and luxury lodgings do not cater to food preparation in guest rooms).

Table A-6
Guest Room Equipment, by Property Type

	Economy	Moderate	Upscale	Luxury
Color TV	5	5	3	4
Clock Radio	2	5	3	4
Heat Lamp	2	3	2	1
Bath Fan	5	5	3	3
Clothes Iron	1	4	3	4
Refrigerator	2	4	2	4
Microwave	0	3	0	1
Coffee Maker	2	4	3	4
Total Surveyed	**5**	**5**	**3**	**4**

Amenities

There is a significant correlation between property type and energy-consuming amenities offered. Higher-end properties tend to offer more special services than lower-end properties (see Table A-7).

Table A-7
Energy-Consuming Amenities, by Property Type

	Economy	Moderate	Upscale	Luxury
Restaurant	2	3	3	4
Pool	2	4	3	4
Spa	2	2	3	4
Exercise Room	2	3	3	4
Conference Room	2	3	3	4
Lounge	1	2	3	4
Coffee Shop	1	3	2	3
Retail	0	0	0	2
Total Surveyed	**5**	**5**	**3**	**4**

Laundry and Other Equipment

All but one moderate and one luxury respondent have in-house laundry equipment. Capacity and type of laundry equipment varies a great deal. Most respondents did not know the age of their laundry equipment. Four of the six who did stated that their equipment was as old as the facility. Other equipment such as walk-in refrigerators, bar refrigerators, freezers, and ice makers are more common in upscale and luxury properties equipped with food service facilities.

Table A-8
Laundry and Other Equipment, by Property Type

	Economy	Moderate	Upscale	Luxury
Walk-in Refrigerator	1	1	3	3
Freezer	1	2	3	3
Bar Refrigerator	1	2	3	3
Ice Maker	1	2	3	3
Total Surveyed	**5**	**5**	**3**	**4**

Remodels/Upgrades

When asked about remodeling/upgrade projects, most respondents indicated that soft goods are replaced about every five years, case goods about every seven years, and equipment only on an as-needed basis. It is noteworthy that no economy properties solicit outside help in choosing equipment. Consultation with outside sources appears to be more prevalent among higher-end properties. Only two properties use their utilities as sources of advice (Table A-9).

Table A-9
Renovation Advisory Sources, by Property Type

	Economy	Moderate	Upscale	Luxury
No Outside Source Indicated	5	4	1	2
Consultants	0	0	2	2
Manufacturers	0	0	1	1
Utilities	0	0	2	0
Other Outside Source	0	1	0	0
Total Surveyed	**5**	**5**	**3**	**4**

Perceived Energy-Related Problems

When asked to indicate some common energy-related problems encountered in providing comfort and convenience to guests, respondents gave the answers shown in Table A-10. It is interesting to note that most establishments perceive few or no energy-related problems.

Table A-10
Perceived Energy-Related Problems, by Property Type

	Economy	Moderate	Upscale	Luxury
Aged Equipment	1	3	2	1
High Energy Bills	1	2	1	1
Equipment Maintenance	2	1	0	1
Lack of Information	1	2	0	1
Other Problems	2	0	0	0
No Problems	3	1	0	1
Total Surveyed	**5**	**5**	**3**	**4**

Corporate decision-makers were more likely than local decision-makers to indicate that their properties have some energy-related problems. All four respondents who replied that they have no energy-related problems represented local properties (see Table A-11).

Table A-11
Perceived Energy-Related Problems, by Decision-Maker Business Level

	Corporate	Local
Aged Equipment	4	3
High Energy Bills	5	0
Equipment Maintenance	4	0
Lack of Information	3	1
Other Problems	2	0
No Problems	0	4
Total Surveyed	**9**	**8**

When questioned about the biggest perceived energy problem their establishments will face in the next five years, all respondents gave open-ended answers. Of the 17 responses, almost half cited "what do I do about deregulation" as their primary concern. Only three respondents were more concerned with issues directly related to equipment, and three others specified energy costs/cost management as their main concern (see Table A-12). Respondents most concerned about energy deregulation are almost exclusively corporate-level decision-makers.

Table A-12
Biggest Perceived Energy Problem, by Decision-Maker Business Level

	Corporate	Local
What to Do About Deregulation	7	1
Specific Equipment Issues	0	3
Specific Cost Issues	1	2
Total Surveyed	**9**	**8**

Additional Energy Services Required or Desired

When respondents were given a choice of additional services they would like to receive from their energy supplier, the least interest was expressed by economy-type properties. Among the others surveyed, respondents indicated a greater desire for energy-efficient equipment information than for other services (Table A-13). Moderate lodgings however, did unanimously favor equipment rebates.

Table A-13
Additional Services Desired of Energy Supplier, by Property Type

	Economy	Moderate	Upscale	Luxury
Energy Audit	1	4	3	2
Space Heating Information	0	5	3	3
High-Efficiency Space Cooling Equipment Information	0	5	3	3
High-Efficiency Lighting Equipment Information	1	5	3	3
High-Efficiency Appliance Information	1	5	3	3
High-Efficiency Water Heating Equipment Information	1	5	3	3
Power Quality Services	1	2	1	1
Staff Training	0	4	2	2
Rebates	1	5	3	2
Equipment Financing	1	1	1	2
Other	1	0	0	0
None	2	0	0	0
Total Surveyed	**5**	**5**	**3**	**4**

Corporate-level respondents showed more interest in additional services from their energy supplier than did local respondents (see Table A-14). However, this may be skewed by two respondents representing economy properties with local decision-making who showed no interest in additional services.

Table A-14
Additional Services Desired of Energy Supplier, by Decision-Maker Business Level

	Corporate	Local
Energy Audit	6	4
Space Heating Information	6	5
High-efficiency Space Cooling Equipment Information	6	5
High-efficiency Lighting Equipment Information	7	5
High-efficiency Appliance Information	7	5
High-efficiency Water Heating Equipment Information	7	5
Power Quality Services	3	2
Staff Training	5	3
Rebates	7	4
Equipment Financing	4	1
Other	1	0
None	0	2
Total Surveyed	**9**	**8**

Summary

A simplified need assessment study such as the one presented here can be useful in helping utilities to better assess the needs and priorities of their customers in the lodging industry. In addition to the generic issues addressed above, each utility should include questions on equipment and energy use more directly related to the specific attributes in its service territory, such as geographic factors and fuel availability. Open-ended questions are especially useful in gaining an understanding of how lodging decision-makers think and what issues they consider to be most pressing. The most successful interviews are obtained by contacting the appropriate persons responsible for equipment selection.

Lodging Industry Survey

Contact Information

Organization ____________________ Location ________________

Contact name ____________________ ________________

Title ____________________

Telephone ____________________

Fax ___________________

E-mail _________________________________

General Facility Questions

1 Type of operation:

____ Economy ____ Limited Service

____ Luxury ____ Full Service

____ Other ____ Extended Stay

2 How many establishments do you have?……………. __________

In what states are they located?…………………. __________

Are all facilities built on the same plan?………… __________

Average sq. footage of establishments………….. __________

Average age of facilities……………………………. __________

Average occupancy rates, summer / winter ….. __________

3 Typical number of rooms per establishment ………… ______

______ Average room size (ft^2)

4 Which additional facilities do you typically have?

______ Restaurant

______ Pool

______ Spa

______ Exercise Room

______ Conference Rooms

______ Lounge

______ Coffee Shop

______ Other (specify)

______ Sq. footage of common areas as % of total facility?

Heating and Cooling Equipment

5 What type of heating and cooling system generally serves the individual rooms?

______ Central

______ Room units

6 If room unit, what type?

______ Packaged terminal air conditioner

Electric resistance heating
_____
Packaged terminal heat pump
_____
Window air conditioner
_____
Size
_____

7 If central system, what type?

Electric chiller
_____
Natural gas chiller
_____
Central boiler
_____
Heat pump(s)
_____
Size
_____

8 Does your heating or cooling equipment differ depending on the location?

9 What factors are most important for selecting heating and cooling equipment?

Guest comfort
_____
Equipment cost
_____
Energy cost
_____
Maintenance
_____
Other (specify)
_____

10 Do you use any special systems for controlling humidity?

11 Do you use any special systems for controlling indoor air quality?

Domestic Hot Water System

12 What type of water heating do your establishments have?

_____ Electric storage water heater

_____ Gas storage water heater (boiler)

_____ Instantaneous water heaters (gas or electric?)

_____ Do rooms have water-conserving shower heads?

_____ Average age of equipment

Kitchen and Refrigeration Equipment

13 No. of dishwasher loads per week _____________

Do you have the following refrigeration equipment?

_____ Walk-in refrigerators

_____ Freezers

_____ Bar refrigerators

_____ Ice makers

Laundry Equipment

14 How many machines does a typical establishment have?

_____ Washers

Dryers

____ Capacity (pounds/unit)

____ # of loads per day

____

15 What type of washer do you have?

Vertical axis (top loading)

____ Horizontal axis (front loading)

____ Average age of equipment

____

Lighting

16 What type of lighting is predominant in the guest rooms?

____ Incandescent ____ Fluorescent

17 What type of lighting is predominant in the common areas?

____ Incandescent ____ Fluorescent

Room Electrical Equipment

18 What equipment is standard in rooms?

____ Color TV ____ Clothes iron

____ Clock radio ____ Refrigerator

____ Heat lamps ____ Microwave

____ Bath fan ____ Coffee maker

___ Other (specify)

Future Plans

19 When was your facility last remodeled/upgraded? __________

(if yes:)

What was done and what equipment replaced?

Where did you get assistance in selecting new equipment?

20 Do you plan to remodel/upgrade your facilities in the near future? ________________

What equipment will be replaced?

What equipment will you be looking for?

21 Are you considering offering additional technology amenities? ________________

If yes, which ones?

22 What, if any, are your current energy-related problems in providing comfort and convenience to your guests?

____ Aged equipment

____ High energy bills

Equipment maintenance
_____
Insufficient energy management information
_____
Other (specify)
_____

23 What services would you like to receive from your energy supplier?

Energy audit
_____
High efficiency equipment information
_____
space heating
_____
space cooling
_____
lighting
_____
appliances
_____
water heating
_____
Power quality services
_____
Maintenance staff training
_____
Rebates
_____
Equipment financing
_____
Other (specify)
_____

24 In the next 5 years, what do you feel the most important energy issues

you will face (or need assistance with)?

25 Can you recommend other energy managers who can assist in this survey?

B

GLOSSARY

Boiler — A pressure vessel designed to transfer heat produced by combustion to a fluid.

Brine — A water/antifreeze mixture often used for thermal storage or as the working fluid in a heat pump.

British thermal unit (Btu) — Amount of energy required to raise the temperature of one pound of water by one degree Fahrenheit.

Centrifugal compressor — A centrifugal compressor first raises a fluid's velocity by using a rotating impeller. The velocity is then converted to pressure at the outlet of the compressor due to the pump configuration.

CFM — Cubic feet per minute. A measure of volumetric flow rate.

Chiller — A system of components used to cool water for the purpose of air conditioning. A chiller system usually includes the following components: compressor, condenser, evaporator, flow control devices, and a control system.

Coefficient of Performance (COP) — Ratio of the total space heating delivered to the electrical energy consumed. Higher COP values represent higher efficiencies.

Combustion efficiency — Ratio of the total heat produced in a boiler to the chemical energy available in the fuel.

Compressor — A chiller component that increases the pressure of refrigerant. The three most commonly used compressor types are centrifugal, screw, and reciprocating.

Condenser — A chiller component that condenses high-pressure refrigerant vapor into high-pressure liquid. The condenser removes heat from the refrigerant and rejects it through a cooling tower.

Conduction — Transfer of heat by the collision of adjacent molecules in a solid, liquid, or gas.

Convection — Transfer of heat by the bulk fluid motion in a gas or liquid.

Cycling loss — Loss of efficiency due to repeated warm-up cycles as a unit is turned on and off to meet comfort demands.

Demand-control ventilation sensor — Carbon dioxide sensors located in the HVAC system that can signal ventilation rate adjustment to maintain acceptable levels.

Desiccant — Material which removes moisture from air by adsorbing or absorbing water vapor.

Dew point — Temperature at which water vapor in air will start to condense on nearby surfaces.

Electric resistance heating — Heating air via convection and radiation by passing it over electric coils that generate heat by resisting current flow.

Energy Efficiency Ratio (EER) — Ratio of the total space cooling produced in Btu to the total electrical energy consumed in Watt-hours. Higher EER values indicate higher efficiency.

Fan-coil unit — All-water heat transfer device equipped with water coils, air movers, and filters that is most common in all-water central heating and cooling systems. Fan-coil units resemble packaged terminal units in appearance and may be wall-mounted.

Heat exchanger — A mechanical device for exchanging heat between two fluids or between a fluid and a solid.

Heat pump — A device that uses electrical energy to absorb heat from a source, such as air or ground, and raise it to a higher temperature for space or water heating. Heat pumps can usually operate in reverse to provide cooling as well.

Heat transfer coefficients — A measure of the rate at which heat is transferred from a solid to a fluid by convection over a temperature difference. Heat transfer coefficients generally depend on the properties and flow conditions of the fluid, as well as the surface characteristics of the solid.

Heating Season Performance Factor (HSPF) — A measure of the average efficiency of a heater for the heating season. Ratio of the total space heating in Btu provided during the heating season to the total electrical energy consumed in Watt-hours.

Hydrated salts — Thermal storage medium that stores thermal energy in the form of latent heat of fusion. Hydrated salts are formulated such that their freezing point is above 32°F so that less energy is required to reduce them to freezing temperatures than is required for water.

Induction units — Heat transfer units which, as part of a mixed air-and-water central heating and cooling system, exchange heat between room air and centrally heated or cooled air and water. Room air is mixed with centrally conditioned primary air and passed over water coils to achieve the desired heating or cooling.

Latent heat of fusion — The amount of energy required to accomplish a change of phase from solid to liquid (i.e., ice to water).

Latent heat of vaporization — The amount of energy required to accomplish a change of phase from liquid to gas (i.e., water to steam). Water has a latent heat of vaporization of approximately 1000 Btu/lb.

Media filters — Media filters are usually made of polyester or glass fibers which trap particles carried in the air stream.

Package terminal units — Complete, self-contained air conditioning or heating units that require no ducting or plumbing and fit through an exterior wall sleeve or window frame.

Radiant panels — Panels which are heated or cooled to transfer heat to or from a room via radiation and natural convection.

Radiation — Transfer of heat by electromagnetic waves which travel in straight lines at the speed of light.

Reciprocating compressor — A reciprocating-piston type of positive-displacement refrigerant compressor.

Refrigerant — A heat transfer fluid that circulates inside the chiller. Usually a type of chlorinated fluorocarbon (CFC) or hydro-fluorocarbon (HFC) that alternately absorbs and rejects heat via phase changes between liquid and vapor, induced by alternate compression and expansion.

Refrigerant-reversing valve — The valve which changes a heat pump system between heating and cooling mode.

Screw compressor — A screw compressor rotates a single or pair of helical rotors to compress the refrigerant. A refrigerant entering from one end of the screw compressor is gradually compressed between the tightly sealed rotating components until it exits at the other end at the desired pressure.

Seasonal Energy Efficiency Ratio (SEER) — A measure of the average energy efficiency of an air conditioner for the cooling season. The ratio of the total space cooling in Btu provided during the cooling season to the total electrical energy consumed in Watt-hours.

Sensible heat — The energy of molecular motion; associated with temperature.

Thermal energy storage — A thermal storage device that provide additional cooling or heating capacity at peak demand hours.

Ultraviolet disinfection — Technique in which airborne microorganisms are killed by passing the air through ultraviolet radiation.

Vapor-compression cycle — Refrigeration cycle in which a refrigerant is alternately compressed and expanded, forcing it to condense and evaporate. Latent heat is rejected to a warmer space/environment while refrigerant condenses and is removed from a cooler space/environment while refrigerant evaporates.

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REFERENCES

AGA (1998).
Final Report, Commercial Market Segmentation Study: National Lodging Sector, American Gas Association, #S97104.

AHMA (1998a).
Hot Topics for 1998, American Hotel and Motel Association.

AHMA (1998b).
The 1997 Lodging Industry Profile, American Hotel and Motel Association.

ASHRAE (1997a).
1997 ASHRAE Handbook—Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., ISSN 1-883413-44-3.

ASHRAE (1997b).
ANSI/ASHRAE/IESNA Standard 90.1-1989, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., ISSN 1041-2336.

ASHRAE (1996).
1996 ASHRAE Handbook—HVAC Systems and Equipment Handbook, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., ISBN 1-883413-34-6.

ASHRAE (1995).
1995 ASHRAE Handbook—HVAC Applications Handbook, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., ISBN 1-883413-22-2.

EIA (1998a).
Energy End Use Intensities in Commercial Buildings 1992, U.S. Department of Energy, Energy Information Association, Web source.

EIA (1998b).
A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption and Expenditures, U.S. Department of Energy, Energy Information Association, DOE/EIA-0625(95).

EIA (1994).
Energy End-Use Intensities in Commercial Buildings, 1989, U.S. Department of Energy, Energy Information Association, DOE/EIA-0555(94)/2.

EPRI (1997).
Heat Pump Manual, Second Edition, Electric Power Research Institute, Final Report TR-109222.

EPRI (1996).
A Small Business Guide, Lodging, Electric Power Research Institute, Final Report TR-106676-V3.

EPRI (1992).
Commercial Water Heating Applications Handbook, Electric Power Research Institute, Final Report TR-100212.

E Source (1997).
Commercial Space Cooling and Air Handling Atlas, E Source, Inc., ISBN 1-58167-003-6.

Mechanical Estimating (1995).
Gladstone, John, Kenneth K. Humphreys. *Mechanical Estimating Guidebook*, Sixth Edition, McGraw-Hill, Inc., New York, 1995.

Munters (1990).
The Dehumidification Handbook, Second Edition, Munters Cargocaire.

R.S. Means (1997).
R.S. Means Mechanical Cost Data 1998, HVAC, Controls, R.S. Means Company, Inc., ISBN 0-87629-471-9.

U.S. Census Bureau.
County Business Patterns (1995), Bureau of the Census, U.S. Department Chamber of Commerce, Web source.

WSJ (1998).
Goetz, Thomas. "Lodging Industry Starts to Scale Back on Rapid Growth," The Wall Street Journal, Sept. 29, 1998.