EPRI

HVAC Technology Report

A Review of Heating, Ventilation and Air Conditioning Technology and Markets

Technical Report

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A Review of the Heating, Ventilation and Air Conditioning Technology and Markets

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REPORT SUMMARY

For many of us, roughly 95% of our time is spent indoors. To enable humans to spend this much time inside, mechanical equipment is necessary to provide space conditioning to control the temperature (heating and cooling), ventilation, humidity, and indoor air quality. This report introduces the heating, ventilation, and air-conditioning (HVAC) industry to EPRI member utility employees. The document describes the most common technologies and applications and provides an overview of industry statistics and current market trends.

Background

The space conditioning industry is of vital interest to the electric utility industry. Air conditioning equipment accounts for a large portion of the electric demand experienced on hot, summer days. With an understanding of the equipment options, an electric utility can change its electric demand profile by influencing the space conditioning technologies installed in its territory. Many utilities also have invested in the HVAC industry or considered doing so. Utilities have formed alliances with local contractors, started Energy Services Companies to develop performance-contracting opportunities, and have sold HVAC equipment directly to customers and dealers. Last year, HVAC industry shipments approached $22 billion from U. S. companies according to the U.S. Census Bureau.

Objective

To provide information on various HVAC technologies, recent equipment developments, market trends, and updates on codes, standards, and industry issues.

Approach

Project authors discuss both residential and commercial technologies with an emphasis placed on equipment for commercial cooling applications and additional factors affecting the HVAC marketplace. The authors have structured the report for either cover-to-cover reading or browsing for quick reference.

Results

This report includes background information and market trends for residential and commercial air conditioning markets. Key areas covered include

- residential space conditioning technologies
- residential unit sales and market trends
- commercial space conditioning technologies
- commercial unit sales and market trends

- factors affecting HVAC technologies
- U.S. and international codes, standards, and treaty agreements affecting HVAC industry
- current industry market R&D efforts

EPRI Perspective

EPRI has traditionally provided utility members with updates on technology available to the HVAC industry through annual meetings, Innovators, Technical Briefs, brochures, and design guides. To facilitate a quicker flow of information to utility members, this report provides a technology and industry overview to help electric utility representatives keep up with the HVAC industry.

Keywords

Air conditioning
HVAC
Space conditioning
Heating,
HVAC systems

ABSTRACT

This document serves to introduce the heating, ventilating and air conditioning (HVAC) industry to EPRI member utility employees. The report explains the predominant technologies used and the applications they typically apply too. Additionally, this report provides an overview of the number of units sold, the current market trends and the factors influencing those trends.

In 1995, commercial buildings in the U.S. consumed 687 Billion kWh at a cost of $50.8 billion to meet their air conditioning needs. (U.S. Census Bureau, 1997b). Additionally, air conditioning loads will peak on hot days when utility generating sources are strained. For these reasons, the HVAC systems are very important to electric utilities.

It has been estimated that for many of us, roughly 95% of our time is spent indoors. To enable humans to spend this much time inside, mechanical equipment is necessary to provide space conditioning to control the temperature (heating and cooling), ventilation, humidity and indoor air quality. This mechanical equipment is often referred to as the HVAC system.

Various component combinations are able to meet a wide range of criteria dictated by different enclosed spaces. Some equipment is exclusively designed to meet the needs of a specific type of space, while other technologies apply to a broad range of environments. Equipment choice not only depends on operating characteristics, but also on the affordability of the equipment's capital, installation and operating costs. To accommodate a wide range of needs, a variety different equipment, subsystems and key components, manufactured by hundreds of companies, are available on the market.

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INTRODUCTION

This document is intended to introduce the heating, ventilation, and air-conditioning or HVAC industry to EPRI member utility employees. The report describes the most common technologies and applications, and provides an overview of industry statistics and current market trends.

In 1995, commercial buildings in the U.S. consumed 687 Billion kWh at a cost of $50.8 billion to meet their air conditioning needs. (U.S. Census Bureau, 1997b) Additionally, air conditioning loads will peak on hot days when utility generating sources are strained. The value of HVAC industry shipments from U. S. companies for 1999 approached $22 billion. (U.S. Census Bureau, 1999a). The industry consumed over $12 billion in materials and employed over 90,000 people throughout the U.S. last year. (U.S. Census Bureau, 1999b). For these reasons, the HVAC industry is very important to electric utilities.

Heating, ventilating, and air-conditioning equipment can be divided into two major categories: residential and commercial. The primary differences between the two are size, available options, and controls. Both technologies are discussed in this report with emphasis placed on equipment for commercial cooling applications. With fewer customers to focus on and a single user, the commercial and industrial markets attract more attention from electric utilities, manufacturers, energy service companies and related industries.

It has been estimated that for many Americans, roughly 95% of their time is spent indoors. To enable humans to spend this much time inside, mechanical equipment is necessary to control the indoor temperature (heating and cooling), ventilation, humidity and indoor air quality. This mechanical equipment is referred to as the HVAC system.

HVAC systems consist of equipment designed, integrated, and operated to perform several functions:

- Maintain occupant comfort by removing or adding heat to the space
- Maintain occupant comfort by removing or adding humidity to the space
- Maintain occupant health and safety
- Provide fresh air and ventilation
- Control odors and indoor pollutants
- Protect the structure of the building and its contents

The manufacturers in the HVAC industry produce equipment that can condition any enclosed space including:

- Residential dwellings (houses, condominiums, apartments)
- Commercial buildings (office, retail)
- Public facilities (schools, courthouses, libraries)
- Institutional facilities (healthcare, correctional)
- Industrial facilities (factories, cold storage warehouses)
- Mobile vehicles (cars, trucks, airplanes, boats, submarines)

To accommodate the wide range of needs, hundreds of companies manufacture many varieties of equipment. Some equipment is exclusively designed to meet the needs of a specific type of space, while other technologies apply to a broad range of environments. Equipment choice not only depends on operating characteristics, but also on the equipment's capital, installation and operating costs.

The following sections discuss residential space-conditioning technology, commercial space-conditioning technology, and additional factors affecting the HVAC marketplace. Additional information on the HVAC industry is available from many sources, such as EPRI and other trade organizations, which are listed in appendixes of this report.

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RESIDENTIAL SPACE CONDITIONING TECHNOLOGY

The goal of residential space conditioning is to provide a comfortable and healthy environment for the occupants of the dwelling. Historically, residential systems were smaller, easier to operate and less efficient, but this trend is changing. Modern space conditioning systems are designed to achieve a high quality indoor environment by providing humidity control, air filtration and ventilation air to the space while meeting the residential customer's requirements for low first cost and low operating cost. Additionally, the efficiency of residential equipment is approaching that of many products designed for commercial applications. This report will provide an introduction to residential space conditioning technology, but further information can be found in several of the EPRI publications listed in appendix B.

Residential Heating Systems

The most common type of residential heating system is the forced air or warm air furnace. Approximately 55% of homes in the U.S. use this type of system (Census Bureau, 1997a). The majority of these utilize natural gas or propane as the fuel source, but fuel oil is also commonly used. In addition to warm air furnaces other types of heating systems include hydronic, radiant, electric resistance, heat pumps, and unit heaters. Figure 2-1 shows the distribution of heating system types.

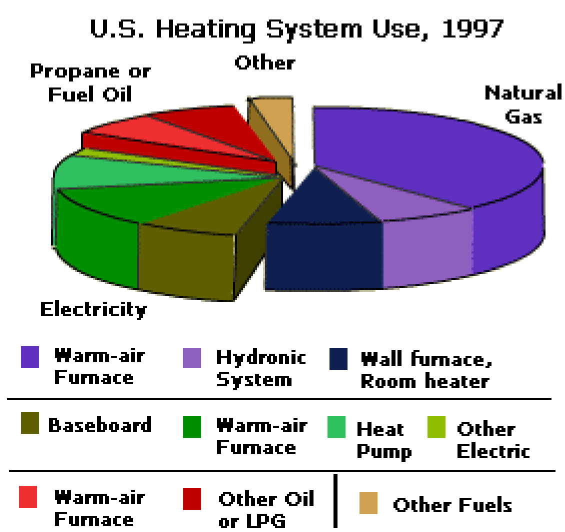

Figure 2-1
U.S. Residential Heating Systems (Census Bureau, 1997a)

Forced Air System

A forced air system consists of a heat source and an air-handling unit to distribute the heated air. As shown in Figure 2-1, the majority of these systems use natural gas, propane, or fuel oil for the heat source. Furnaces may also operate with electric heat sources such as resistance heaters or heat pumps.

In an ***electric resistance*** furnace, a fan blows air across a set of electric resistance elements that heat the air directly. In combustion furnaces, an intermediary heat exchanger is used to prevent combustion products (carbon monoxide, carbon dioxide and other gases) from entering the house.

Electric heat pumps are vapor compression machines, like air conditioners, that can operate to provide either cooling or heating as required. Their operating modes (heating or cooling) are mutually exclusive. During the summer, heat pumps move heat from inside the house to the outdoors, like a traditional air conditioner. In the winter, the process is reversed to move heat from the outdoors to inside the building.

Heat pumps are grouped as air-source and water-source, referring to the medium they reject or pull heat from. Typically, the heat pump will provide heat to a coil in an air handler to warm a home, but geothermal units can provide hydronic heating to a residential dwelling.

Hydronic Systems

A hydronic system consists of a boiler or water heater and a delivery system comprised of pipes, valves, pumps, and a water-to-air heat exchanger. The boiler generates heat by fuel combustion, electrical resistance or through the use of a heat pump.

The steam or hot water is piped to heat exchangers such as baseboard convectors, radiators or fan coil units located in the conditioned space. Radiant systems circulate hot water through tubes embedded in the floor, from which heat radiates up into the occupied space.

Electric Resistance

Various types of electric resistance heating systems are in use. Electric baseboards are typically found in less expensive housing, in seasonal homes, or in areas with light or infrequent heating requirements, because of their lower first cost. Apartment dwellers often purchase portable electric heaters to supplement their heating systems. More permanent installations of electric resistance heat include baseboard radiators and zonal heaters, which are often built into the wall and include a timer to provide a temporary boost of temperature during high heating load conditions.

Residential Cooling Systems

Three methods for removing heat are commonly employed to provide air conditioning in homes. These are natural ventilation, evaporative cooling, electric-powered vapor compression. A fourth method, gas-fired absorption systems, is infrequently used. The most widely used type is an electric, centrally located split system. Heat pumps supplying a centrally located split system and unitary packages supplying individual rooms are also popular. Figure 2-2 shows the relative use of the most common types of cooling systems. A special variety of heat pumps, called geothermal heat pumps, have become popular in recent years.

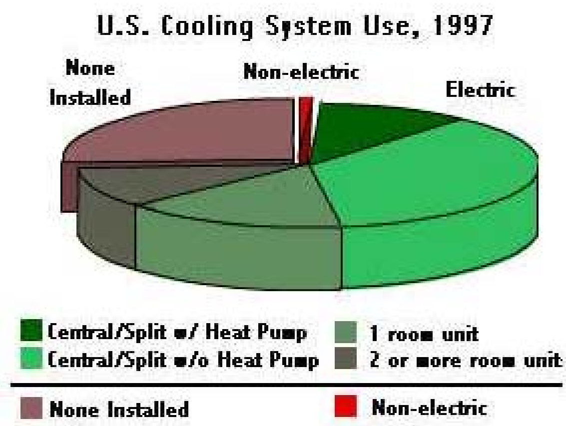

Figure 2-2
U.S. Residential Cooling Systems (Census Bureau, 1997a)

Natural Ventilation

Natural ventilation is the lowest cost method of air conditioning. Using natural ventilation is often as simple as opening a door or window to allow outdoor air into the house. More elaborate home designs include architectural features that funnel the outdoor air through the house, optimizing this effect.

The single greatest disadvantage of natural ventilation is that the house cannot be cooled below the ambient temperature and humidity. Natural ventilation also allows infiltration of dust and other contaminants.

Evaporative Cooling

Evaporative cooling is the least expensive mechanical method for providing air conditioning, but it is not practical in all climate types. An evaporative cooler saturates the air stream with water, either by spraying water into the air stream or by passing the air through a pad of damp, porous material. When warm, dry air comes in contact with the water, the water evaporates. This evaporation lowers the dry bulb temperature of the air and raises its humidity.

In the hot, arid southwestern U.S., this method is very effective since both an increase in humidity and a decrease in temperature are desirable. In humid regions of the U.S., this method is ineffective. The cooling effect is limited because little evaporation is possible to the already humid air. Adding moisture to the air is also undesirable for comfort and air quality reasons.

Vapor Compression Air Conditioning and Heat Pump System

The most common method of providing air conditioning is through the use of an electrically driven vapor compression system. This system alternately vaporizes and compresses a working fluid (a refrigerant such as HCFC-22 or R-410a) to transfer heat from inside the house to the outdoors. The compressor squeezes the refrigerant vapor to a higher pressure and temperature. Heat is rejected to the outdoors through a condenser. The refrigerant is then sent through an expansion valve, which lowers its pressure and temperature. The refrigerant is passed through the evaporator, removing heat from the air inside the house, and returned to the compressor.

Most of the air conditioners and heat pumps are air cooled or air source. Air cooled conditioners pick up indoor air heat and transfers it to the outdoor air. Air source heat pump work as a reverse air conditioner; it picks up heat from outside air and transfers it to indoor in winter. Water source heat pumps transfer heat between indoor air and a circulating water or fluid.

Geothermal Heat Pumps

Geothermal heat pumps, or geo-exchange heat pumps, transfer heat to or from the earth through circulating fluid. The principal advantage to this approach is the relatively constant earth temperature, which is favorable for high efficiency heat pump operation.

There are several variations of the geothermal heat pump system. The indoor portion may consist of one or two heat pumps, or many water-source heat pump units arranged on a water loop. The geothermal heat exchanger portion may be open-loop or closed-loop. An open-loop heat exchange ruses water drawn from a well or a source of surface water. The water passes once through the heat pump’s heat exchanger, and is then rejected to another location such as a different well, a different area in the body of surface water or a new location entirely.

Closed-loop systems continuously circulate the same water through plastic pipe buried underground or in contact with a body of water. Ground heat exchangers are classified as horizontal or vertical. A horizontal ground heat exchanger is buried 4 to 8 feet below the surface, with pipe looping over a large area. A vertical ground heat exchanger consists of a double length of heat exchange pipe inserted in a number of boreholes or wells. Closed loop water heat exchangers have a similar length of pipe that is submersed in a pond, lake, or other body of water.

Gas-Fired Absorption Cooling

An absorption cooling system uses heat to drive a chemical refrigeration cycle, which absorbs heat from indoors and rejects it outdoors. Residential absorption systems are fueled by natural gas or propane. These systems have relatively high first costs and are primarily used where electricity is not available.

Residential Filtration

Filters physically remove particulates from the air stream. Filtration not only protects the space conditioning equipment but also plays an important role in maintaining a high level of indoor air quality. According to the National Air Filtration Association, air filters are used for:

- Protecting the health of residents
- Protecting furnishings and decor
- Reducing cleaning and maintenance requirements of building interiors
- Protecting the contents of the residence
- Eliminating fire hazards such as lint and other materials which might accumulate in ductwork.

There are two general classes of air filters used in residential environments: mechanical and electronic. Most residential space conditioning systems use impingement-type mechanical filters. A mechanical filter is made of a stationary medium (glass fibers, synthetic fibers, or metal) supported in a rigid frame. Mechanical filters are generally installed at the inlet of the air-handling unit. The filter entrains airborne particulates from the air stream prior to delivery through the duct system.

Electronic air cleaners introduce an electrical charge on particles flowing through the cleaner. The particulates are then removed downstream by electrostatic attraction to oppositely charged plates or by mechanical filtration.

The trend in residential space conditioning systems today is to install higher efficiency static media filtration devices to enhance indoor air quality. A principal benefit is that high-quality, high-efficiency filters remove a greater percentage of airborne allergens providing a more comfortable environment for residents with allergies.

Residential Humidity Control

Humidity control has become increasingly important to homeowners in recent years. In most residential applications, humidistats are used in conjunction with humidifiers to increase relative humidity levels during the winter heating season. A humidistat controls a whole-house humidification system similar to the way that a thermostat controls the heating and cooling systems. As the humidity drops, the humidistat initiates operation of the humidifier. When the humidity level in the space reaches the desired setpoint, the humidifier is stopped.

Humidistats are also used to control humidity during the summer months. In this application the humidistat typically controls the operation of a dehumidifier, which attempts to maintain the ambient humidity in the conditioned space within a desired range.

Residential Ventilation

"Ventilation" refers to the introduction of fresh air into a space to dilute odors and contaminants. Mechanical ventilation, using a fan to introduce fresh outdoor air, is not mandated for most single-family homes, but is nevertheless becoming a popular addition to residential space conditioning systems. This trend is largely a result of the improved construction methods used by today's homebuilders. In the past, homes contained enough cracks and leaks to allow in all the fresh air necessary. For today's airtight homes, mechanical ventilation is important to indoor air quality, occupant health and satisfaction.

The three types of home ventilation are exhaust, supply, and balanced. Exhaust ventilation is achieved by local fans that draw air out of areas of high contaminants, such as bathrooms and kitchens. This ventilation method relies on leakage of air from outside to make up for the air that is exhausted.

Supply air ventilation uses one or more fans to push air into the house. The ventilation air is typically introduced to a furnace unit where it is filtered and heated or cooled before being delivered to the rest of the house. The primary advantage of this method is that it pressurizes the house, preventing unconditioned and unfiltered air from infiltrating. An equal amount of air leaves the house through ductwork or out of cracks and leaks.

Balanced air ventilation uses matched supply and exhaust fans to introduce the same amount of air that is exhausted. Balanced ventilation is often used with an air-to-air heat exchanger. In the heating season, this unit recovers heat from the exhaust air to preheat the incoming ventilation air. In the cooling season, the relatively cool exhaust air precools the incoming air. This reduces the energy cost of conditioning the ventilation air.

Residential Unit Sales and Trends

Historically, the manufacture, distribution and sale of residential space conditioning equipment has been highly seasonal. Furnace sales rise throughout the fall and taper off during the spring. Air conditioner sales follow an inverted trend of rising in the spring and dropping off in the fall. The local weather has the largest effect on unit sales. For example, a record setting heat wave typically causes sales of air conditioners to skyrocket. For this reason, warehousing and sales predictions are important to ensure that sharp increases in demand can be met.

Residential Equipment Distribution

Most companies distribute their equipment using a two-step process. The manufacturer sells units to a distributor. The distributor warehouses the equipment until the market demand rises and then sells the equipment to dealers. The dealers sell the equipment to customers, often providing the labor for installation. This method allows for a very large sales force at little expense to the manufacturer and minimal overhead costs for storage of completed units. On the other hand, manufacturers have little control over the quality of the dealers and installers. A manufacturer's reputation can be tarnished if their equipment is improperly installed or sized.

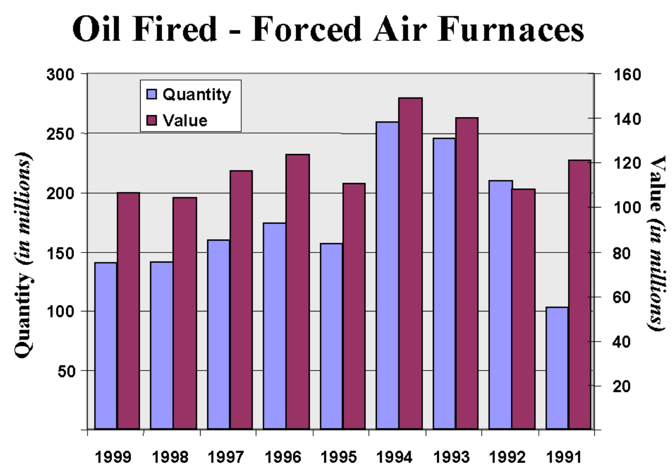

Figure 2-3
Oil Fired - Forced Air Furnace Unit Sales and Value (Census Bureau, 1999c)

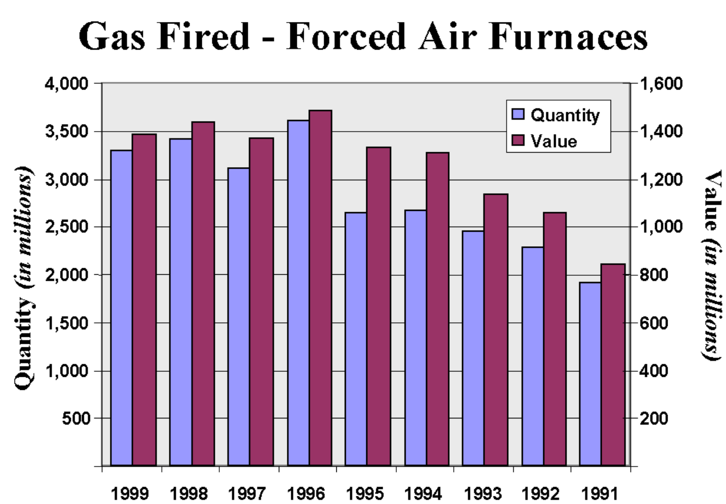

Figure 2-4
Natural Gas and Propane Fired - Forced Air Furnace Unit Sales and Value (Census Bureau, 1999c)

Only a few residential equipment manufacturers, Lennox being the largest, use a one step distribution system. The manufacturer sells the equipment directly to the dealer. This method offers more control over the quality of the dealers, but limits the number of dealers available to sell the manufacturer's product. It also forces the manufacturer to warehouse the units until the market demand rises.

Residential Equipment Competition

The residential market is not dominated by any single company and the competitors with the market share of individual companies changes fairly often. In 1980, over 50% of the market was controlled by Carrier, General Electric, Lennox, and Rheem-Ruud. The remainder of the market was split among over a dozen other companies. By the mid 1990's, the market was dominated by Carrier, Goodman, Rheem, Trane, York, Inter-City Products, and Lennox while most other companies held less then 1% market share.

Unit Sales

Sales of forced air furnaces follow the housing market quite closely. Oil fired units are predominantly found in the Northeast U.S. where older houses traditionally relied on fuel oil. The remainder of the nation burns natural gas or propane depending on pipeline availability.

Split system air conditioners are a standard feature of homes in the southern U.S., and are offered on almost all new homes in the north. The hotter than normal summers experienced in the northern states during the late 1990's may account for this market trend.

Sales of room air conditioners are quite volatile. As the temperature rises, so do unit sales.

Air source heat pumps suffered from a bad reputation during the earlier years of their manufacture. Those problems have since been corrected and sales are changing accordingly. EPRI's *Heat Pump Manual, Second Edition* provides more information on heat pump sales statistics.

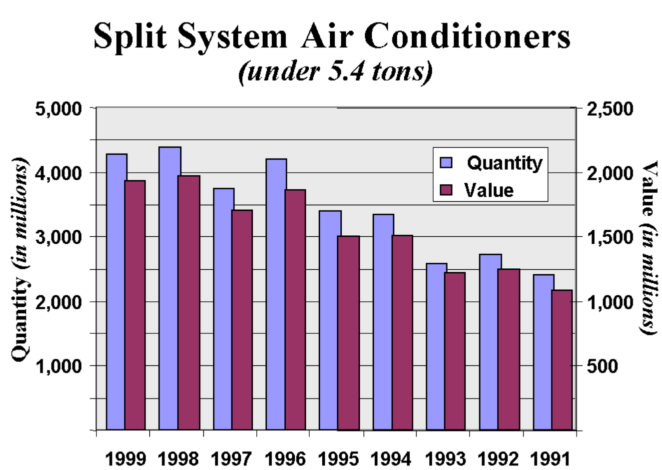

Figure 2-5
Split System Air Conditioner Unit Sales and Value (Under 5.4 tons) (Census Bureau, 1999c)

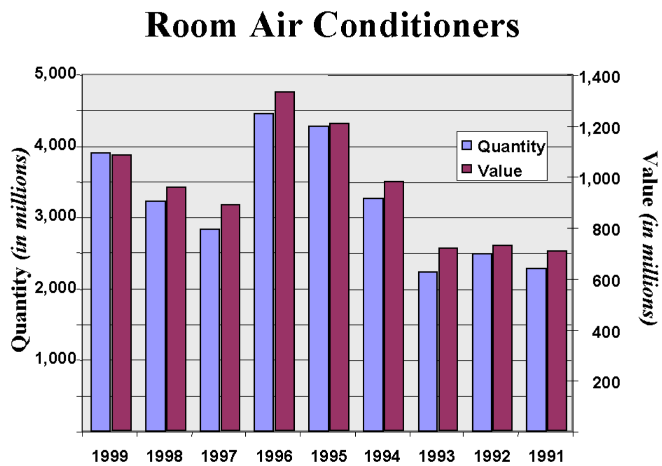

Figure 2-6
Room Air Conditioner Unit Sales and Value (Census Bureau, 1999c)

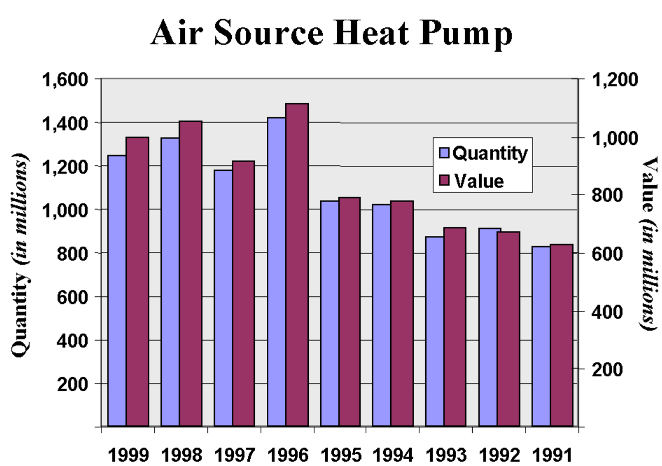

Figure 2-7
Air Source Heat Pump Unit Sales and Value (Census Bureau, 1999c)

3
COMMERCIAL SPACE CONDITIONING TECHNOLOGY

Many technologies are available to meet a commercial building's space conditioning needs. Equipment ranges from small, packaged equipment, which can be installed in less than a day, up to large systems, designed by specialized engineering staff, that are purchased as separate components, and field-assembled by a specialized engineering staff. This section identifies and explains those technologies commonly available in the market place. For more detailed information on these technologies, refer to the EPRI publications listed in appendix A.

Centralized Systems

Centralized, or indirect, space conditioning systems are complex systems that are built up from individual components that may come from one or many different manufacturers. Typically, a centralized space conditioning system uses chilled water as the energy transport medium. The chilled-water system provides cooling by extracting energy (i.e., heat) from a building and transferring this energy to the outside environment, generally through a cooling tower. A diagram of a basic chilled-water system with a single chiller is shown in Figure 3-1. The chilled-water system comprises three main elements:

- Chiller
- Chilled-water loop
- Condenser-water loop

The chiller is the heart of a chilled water system. It is ordinarily packaged and supplied by the manufacturer as a single skid-mounted unit. The chiller contains the condenser and evaporator components that are connected in the field to the condenser- and chilled-water loops, respectively. The chilled-water loop connects the chiller to the building and includes a chilled-water pump, miscellaneous piping, and an air-handling unit. The chilled water loop circulates cold water to the building to provide a source for air conditioning and returns warmer water to the chiller. The chiller then moves the heat absorbed from the building in the chilled water loop to the condenser water loop.

The condenser-water loop connects the chiller to the cooling tower and includes a condenser pump and miscellaneous piping. A variety of energy sources are used to drive the chiller cycle (e.g., electricity, natural gas, diesel fuel, or steam). Each type may be used as the chiller element in Figure 3-1. Regardless of chiller type, the components and functions of the chilled-water loop and condenser cooling-water loop remain the same. The following sections provide descriptions of the predominant chiller technologies today.

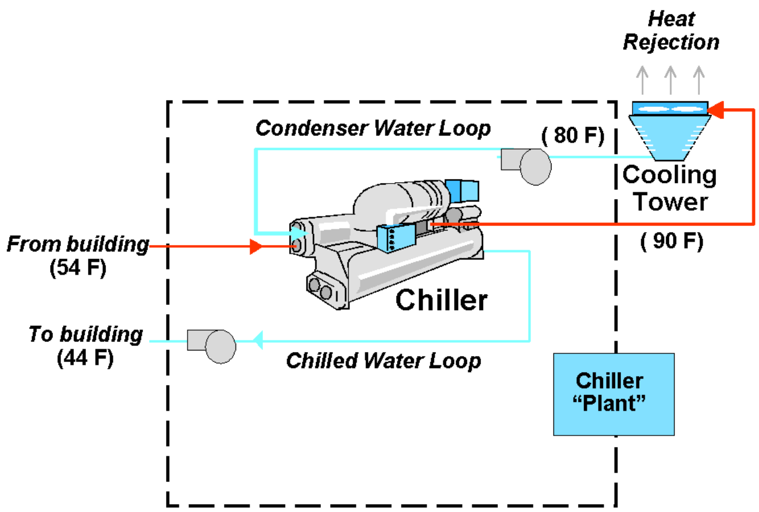

Figure 3-1
Chiller Plant

Electric Chillers

Electric chillers are the principal choice for cooling in large space conditioning systems. In 1992, about 94% of large water chillers shipped in the United States had electric drives, with the balance being primarily gas-fired or gas-engine driven technologies (EPRI 1993a). Electric chillers use a vapor compression refrigeration cycle for transferring heat from the cooling water to the outdoor environment. A diagram for a typical water-cooled electric chiller is shown in Figure 3-2. The chiller includes an electric motor, a refrigeration compressor, a condenser, an evaporator, an expansion device and controls. The electric chiller vapor compression cycle operates in the following manner (numbered items in Figure 3-2 corresponds to the following explanations):

1. The compressor compresses the low-pressure refrigerant vapor to a high-pressure vapor. An electric motor powers the refrigeration compressor.

2. The high-pressure refrigerant vapor is cooled and condensed to a high-pressure liquid in the condenser. The condenser removes heat from the refrigerant and rejects it through a condenser cooling-water loop to the cooling tower.

3. An expansion valve or pressure reducer is used to lower the pressure of the liquid refrigerant that passes into the evaporator.

4. In the evaporator, the low-pressure liquid refrigerant vaporizes, absorbing heat from and chilling the supply water. The low-pressure refrigerant vapor then returns to the compressor inlet.

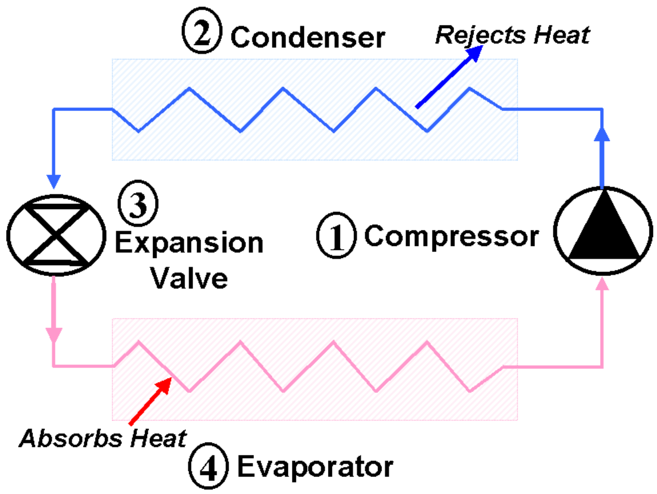

Figure 3-2
Vapor Compression Cycle

Compressor Options

Electric chillers are manufactured with four different types of compressors; centrifugal, screw, reciprocating, and scroll. The cooling capacity, efficiency, noise level and operational characteristics of the chiller collectively influence which type of compressor is used for a particular application. Table 3-1 provides an overall comparison of centrifugal, screw, and reciprocating compressors.

Centrifugal Compressors

Centrifugal compressors are used for most large electric chillers. Centrifugal compressors are turbo-machines, which develop pressure and flow by means of a rotating impeller. Refrigerant vapor enters the compressor near the center of the impeller. The vapor is spun out from the center of the impeller and compressed by centrifugal forces.

Centrifugal compressors may use single-stage compression (with single impellers and speed-increasing gear drives) or multistage compression (with multiple impellers and direct drives). Capacity control is achieved through adjustment of inlet guide vanes or motor speed. Centrifugal compressors are most commonly used for chillers with refrigeration capacities above 300 tons.

Table 3-1
Comparison of Electric Chiller Compressors (EPRI Chiller Handbook, TR-10591-R1)

Characteristic	Centrifugal	Screw	Reciprocating	Scroll
Compressor Operation	turbo-machine	positive-displacement	positive-displacement	positive-displacement
Available Sizes (tons)	80-10,000	40-1250	15-300	20-60
Efficiency (kW/ton) (Water Cooled)	0.49 – 0.81	0.61 – 0.77	0.70 – 0.97	0.80 – 0.90
Turndown	20-40% of full load	10-20% of full load	20-30% of full load	25-30% of full load
Drive Type	• open • semi-hermetic	• open • semi-hermetic • hermetic	• open • semi-hermetic • hermetic	• hermetic
Advantages	• high full-load efficiency • reliable	• small • light weight	• low first cost • parts & service readily available • reliable	• reliable • good part load efficiency
Disadvantages	• surge at low loads • small sizes are expensive to purchase	• low part-load efficiency • lube oil separation required	• low efficiency	• difficult to manufacture

Screw Compressors

Screw compressors are positive-displacement devices available in single-screw or twin-screw designs. The single-screw design consists of a helical main rotor and two intermeshing star or gate rotors. The twin-screw design consists of two inter-meshing helical gears. In both designs the refrigerant vapor is compressed between the tightly sealed, rotating components. Capacity control is achieved through adjustment of either a slide valve or motor speed. Screw compressors are commonly used on chillers with 150- to 400-ton capacities.

Reciprocating Compressors

Reciprocating compressors are positive-displacement devices. The refrigerant is compressed by a number of single-acting pistons operating in cylinders. Designs are available with 1to 12 cylinders. Capacity control is accomplished through individual cylinder unloading and motor speed control. Reciprocating compressors are commonly used on chillers between 50- and 200-ton capacities.

Scroll Compressors

Scroll compressors are positive-displacement devices that are slowly replacing reciprocating compressors. The refrigerant is squeezed between two interlocking scrolls. The scroll compressor design is not new but recent advances in computer-aided manufacturing have reduced their cost of production. Scroll compressors offer better efficiency then reciprocating compressors and accommodate accidental slugs of liquid refrigerant much easier. Scroll compressors are typically manufactured in capacities up to 15 tons, and are combined in multiples to provide chillers with 20- to 80-ton capacities.

Condenser Options

Chiller condensers may be air-cooled or water-cooled. Smaller chillers (up to 250 tons) often use air-cooled condensers rather than cooling towers to reject heat, eliminating the need for a cooling tower and associated costs.

Air-Cooled Condenser

The air-cooled condenser is a refrigerant-to-air heat exchanger. The refrigerant passes through finned tubes while fans blow outdoor air across them. Air-cooled condensers are often used on screw and reciprocating chiller packages up to about 400 tons. Air-cooled condensers may be integrated as part of the chiller package on a skid or remotely located. Air-cooled condensers use motor driven propeller fans to blow air across the condenser.

Water-Cooled Condensers

Water-cooled condensers are usually shell and tube heat exchangers, with the cooling water flowing through the tubes and refrigerant vapor circulating through the shell. Heat removed from the refrigerant by the cooling water is normally rejected by a cooling tower.

Gas Engine-Driven Chillers

A gas engine-driven chiller operates with the same vapor compression refrigeration cycle as an electric chiller. A natural gas-fired internal-combustion engine powers the compressor. With the exception of the gas engine and its ancillary components and controls, gas engine-driven chillers are similar in design and operation to electric chillers.

Gas engine-driven chillers use centrifugal, screw and reciprocating compressors. Gas engine-driven chillers are available from a number of manufacturers in sizes ranging from 15–4000 tons. Depending on chiller size and compressor type, air-cooled or water-cooled packages are offered.

Heat from the engine exhaust can also be recovered for water heating or desiccant regeneration.

Hybrid Chiller

Alturdyne, with the help of the Gas Research Institute, has developed a hybrid gas engine and electric motor driven chiller. Both the engine and the motor sit on the same shaft to drive the compressor. The user can program the chiller to use the electric motor during low cost electric rate periods and switch to the engine when electric rates are high. The units are available in sizes ranging between 50 and 2000 tons.

Gas Engine-Driven Generator-Chiller Sets

Connecting an electric chiller directly to a gas engine-driven generator is an option that provides the efficiency and reliability of an electric chiller with the benefits of using natural gas as the fuel. In this scenario, a building owner may purchase a generator or rent it during the cooling season. The generator's output is connected directly to the chiller to drive the compressor.

Turbine Driven Chillers

Turbine-driven chillers also employ the same vapor compression cycle as electric chillers to produce chilled water. The difference is that a steam-driven turbine is used to power the compressor. The steam can be generated in a boiler (typically fired by gas, oil, coal, or biomass) in order to obtain the necessary steam pressures for driving the turbine. Turbine-driven chillers are generally larger machines that are used in large district cooling applications where both chillers and boilers are needed to meet coincident heating and cooling loads.

Absorption Chillers

Absorption chillers use a series of heat activated chemical processes to remove heat from a chilled water stream. The absorption cycle utilizes a refrigerant (water), which is alternately absorbed and desorbed from the absorbent (typically a salt solution such as lithium bromide). In this process, the refrigerant transfers heat from the chilled water stream to the heat rejection water stream.

Absorption chillers are currently available as single-effect and double-effect. “Effect” (or “stages”) refers to the number of times heat is added during the process to evaporate the refrigerant from the absorbent.

Single-Effect Absorption Chillers

Single-effect absorption chillers are usually indirect-fired, which means they receive heat in the form of steam or hot water from a source outside of the machine. They are not extremely efficient, with typical coefficients of performance (COPs) ranging from 0.6 to 0.7. (The coefficient of performance is defined as the rate of heat removal divided by the rate of energy input. A higher COP indicates a more efficient machine. Typical COPs for electric chillers are 4.0 to 7.0.) The best application for a single-effect absorber is utilizing waste or excess heat from a manufacturing or cogeneration process.

Double-Effect Absorption Chillers

Double-effect absorption chillers are considerably more efficient than single-effect, with COPs in the range of 1.15 to 1.20. These machines may be indirect fired, but they are most often direct-fired, using heat from a burner built into the machine, and eliminating the need for separate equipment to supply heat. During the heating season, a direct-fired absorption chiller can also serve as a heat source for the building's heating system.

Triple-Effect Absorption Chillers

Chiller manufacturers are working to develop triple-effect absorption chillers. They predict efficiencies in the range of 1.5 to 1.70 COP.

Table 3-2
Comparison of Three Chiller Types (EPRI Chiller Handbook, TR-10591-R1)

		Electric Centrifugal	**Gas Engine**	**Absorption *(direct-fired, double-effect)***
Equipment Efficiency Range	(COP) (kW/ton)	7.0-4.0 0.5-0.9	1.20-2.40 —	0.92-1.04 —
Available Size Range	(ton)	70-2250	25-2100	20-1100
Auxiliary Energy[1]	(kW/ton)	0.13	0.15	0.22
Water Consumption[1]	(gph/ton)	3.0	3.3	4.6
Maintenance[1]	($/ton-yr)	15-25	42-95	15-25
Footprint[1]	(ft^2)	122	267	166
Installed Cost[1]	($/ton)	410-630	630-1000	650-1020

1 based on chillers near 500 tons

Heat Recovery Heat Pumps

Heat recovery heat pumps are refrigeration machines configured to produce usable heat rather than cooling. A typical application is to recover heat from a chiller's condenser cooling water to generate hot water for building heating or domestic hot water. These units range in size from under 100 tons to several thousand tons. Heat recovery heat pumps offer inexpensive heat, and the opportunity to downsize or eliminate other heating equipment. The heat pump itself may be slightly more expensive than a similarly sized chiller.

Thermal Energy Storage

Cool thermal storage separates the generation of cooling from its use. Downsized cooling equipment operates during times of low cooling demand to store cooling potential for later use when cooling loads are higher.

A cool storage system reduces operating costs by substituting inexpensive off-peak power for expensive on-peak power. The cost of cool storage capacity is partially offset by reductions in the required size of chillers, cooling towers, and electric service equipment. In some applications, particularly in large plants, incorporating cool storage can reduce the total first cost of the plant. Cool storage can provide backup cooling capacity, extend the capacity of an existing plant, and provide increased flexibility in plant operation. A cool storage system can be sized with reserve cooling capacity to accommodate future load increases, and the excess capacity can be used from day one to reduce plant-operating costs. Ice storage systems can provide chilled water temperatures as low as 2°C (36°F), allowing significant reductions in pump and pipe sizes.

Cool storage systems have specific requirements for design and operation that differ from nonstorage plants. A cool storage system must be sized to meet the total integrated load over its entire storage cycle. The thermal performance must be matched to the expected load profile. The system cannot be sized by its nominal capacity rating. A cool storage system can meet cooling loads from storage, from direct chiller operation, or both. With this flexibility comes the requirement to carefully define how the plant is to be controlled at any given time.

Additional information is available from several EPRI and ASHRAE publications. These publications include:

- EPRI Cool Storage Technology Guide
- EPRI Guide to Successful Implementation of Cool Storage Projects
- EPRI Market Assessment of Thermal Energy Storage
- ASHRAE Design Guide for Cool Thermal Storage
- ASHRAE Successful Cool Storage: From Planning to Operation

Air Distribution in Central Systems

A central system usually has an air-handling unit to condition the air and an air distribution system to transport the air. Also included typically is a means to bring in outdoor air into the system and to exhaust air from the system.

Many variations on the central system concept exist. For example, a central system can have a single zone or multiple zones depending on the heating and cooling requirements of different sections of the building. Occupancy schedule, occupant density, exposure and internal heat gains, and the amount of outdoor air required for individual areas determine the variation in heating or cooling requirements. The volume of supply air and its temperature to each zone can be varied or held constant by the control system.

Typical central systems currently in use are described below.

Constant Air Volume (CAV) Single Zone System

This type of system is typically installed in small office buildings or large interior core spaces with fairly constant loads. A constant volume of air is supplied to the space. A CAV system varies the supply temperature of the air to match the load. Reheat may be required to control humidity. Although used extensively prior to energy crisis of the 70’s, it is not common now.

CAV Single Zone Converted to a Terminal Reheat System

In this system, reheat coils are placed in branch ducts of the air distribution system. The central system supplies are at the coolest temperature required by the zone with the highest cooling load. In those zones not requiring full cooling, the air is reheated by the reheat coils at terminal units to maintain space comfort conditions. This type of system is energy intensive.

Traditional CAV Multizone System

ASHRAE defines a multizone system as an "air-conditioning unit capable of handling variable loads from different sections of a building simultaneously." (ASHRAE, 1991) In this system, the central air-handling unit has both a cooling and a heating coil. For each zone, the two airstreams, one each from cold deck and hot deck, are mixed at the outlet of the central system. This allows for individual space temperature control within each zone. This system can be modified with a bypass path (three-deck multizone) to reduce energy at part-load.

CAV Dual Duct System

ASHRAE defines a dual duct system as a system "that produces conditioned air at two temperatures and humidity levels, to supply air through two independent duct systems to points of usage where mixing may be carried out."(ASHRAE, 1991) First cost of a dual duct system is typically high because of the expense of two distribution ducts for the building and terminal units in each zone.

Variable Air Volume (VAV) System

The VAV systems gained popularity in early 80’s in the industry’s quest for energy efficiency following the energy crisis. A VAV system varies the amount of air it supplies to the space while the supply air temperature does not change. A control box for the space, called a VAV box, varies the amount of air supplied to the space to satisfy the thermostat. As is the case with all systems, the requirement for full heating or full cooling takes place about 20% of the time. (Levenhagen, 1993) The system operates at less than full capacity the rest of the time.

To ensure adequate ventilation air at partial load, some VAV boxes may require reheat of air too cold to be directly supplied to the zone. Reheat is often achieved with either a hot water or an electric heating coil.

Many types of control boxes are available for use in VAV systems. The more common control boxes are:

- Direct modulation at the diffuser
- VAV terminal box
- Non-fan-powered induction box
- Series fan-powered box
- Parallel fan-powered box

Cold Air Distribution

Cold air distribution, in general, is defines as a cooling system that has a leaving air temperature at the cooling coil in the range of 40^{o}F to 51^{o}F (4-10^{o}C). For comfort applications, the supply air is not tempered with reheat prior to distribution into the controlled space.

The benefits of cold air distribution are:

- Better comfort
- Better indoor air quality
- Increase in perceived freshness
- Excellent space humidity control
- Lower construction first cost
- Lower operating costs
- Less energy usage

Cold air with cool storage has three common configurations:

- Cold air distribution with ice storage
- Cold air distribution with chilled water storage
- Cold air distribution with direct chilling

Many variations and configurations can be used. A combination of chilled water, ice, and chillers downstream of storage may be the best option for large buildings and central plant systems. The supply air temperature for a stratified chilled water storage system is limited to 48°F (9° and for an ice system is limited to essentially 40°F (4°C). With freeze point and buoyancy depressants, chilled water and ice can be stored at lower temperatures than the standard 39.2°F (4°C) and 32°F(0°C), respectively. EPRI and equipment manufacturers are continuously developing new products to improve and increase the benefits of both cold air and cool storage.

Benefits of Cold Air Distribution and Cool Storage

The benefits for a cold air distribution and cool storage system go beyond the low construction first cost by achieving long-term operating and maintenance savings and higher levels of indoor air quality.

Initial construction savings are a combination of reduced structural, architectural, and mechanical costs, and a potential increase in net usable space. Realization of these economic benefits requires early acceptance of cold air and cool storage in the planning and concept stages of construction. It is frequently difficult to incorporate these into completed preliminary designs. There are additional first cost requirements due to the components required for a thermal storage system. There may also be additional control, duct insulation, and cold air diffuser costs.

The goal with cold air distribution is to achieve a lower overall project first cost. Case examples and details of how to achieve this goal are included in EPRI's *Cool Storage Total Building Construction Cost Benefits - An Owner's and Architect's Guide*. However, if there are higher first costs, the long-term savings of the operation and maintenance of a cold air distribution and cool storage system should outweigh the additional first cost.

Operational savings will vary for each location, since the savings are dependent on the local electrical rates and the level and quality of maintenance performed. In a properly maintained system, the benefits go beyond cost savings to include occupant and customer satisfaction as a market selling point.

Distributed Systems

Distributed air conditioning systems have multiple, decentralized HVAC units located throughout the space to provide conditioned air relatively close to the equipment’s location. Typically, this equipment directly conditions the air that is supplied to the space.

Unitary Equipment

The most common distributed HVAC system uses unitary air-conditioning equipment, which is defined by ARI as “one or more factory-made assemblies which normally include an evaporator or cooling coil, and may include a heating function as well.” Unitary equipment combines all of the space-conditioning components in a package that is easily installed. The equipment arrives in a single package or as a split system. The unit may include either a fuel fired heating component or a heat pump. All of these options are discussed below.

Central Single-Package Equipment

A central single-package is a piece of unitary equipment with all of the components inside a single case. The encased unit removes exhaust air and provides conditioned air through a single opening. This type of unit is often installed on the roof, in which case it is referred to as a rooftop unit. The unit may also be installed on a concrete pad on the ground adjacent to the building. The equipment will connect directly to the building's ductwork and provide conditioning to the area of the building closest to the unit.

Packaged Terminal Air Conditioners

A Packaged Terminal Air Conditioner (PTAC) is a type of unitary packaged equipment that is installed in a wall penetration, supplying conditioned air to the space and rejecting heat outdoors. This equipment is generally sized to condition a single room, and is commonly used in hotel rooms.

Split Systems

Split system air conditioners are packaged units that are divided into two parts connected by refrigerant lines. The condenser and the compressor are usually located in the outdoor condensing unit. The evaporator is in an air-handling unit providing cooling to a stream of forced air. The outdoor unit may be located nearly anywhere on the roof or around the building. This design requires a considerably larger quantity of refrigerant than a single-package system. Unless the unit is a heat pump, heating must be provided by a separate unit.

Ductless Split Systems

This smaller version of a split system provides a single condenser to reject the heat of one or more evaporators. Each evaporator cools only the room in which it is located. The ductless arrangement does not allow for providing any outside ventilation air . The ductless split system is typically applied where it is not practical or possible to run ductwork.

Heat Pumps

Heat pumps are simplistically described as air conditioners that can run backwards. During the summer, heat pumps move heat from inside the house to the outdoors, like a traditional air conditioner. In the winter, the process is reversed to move heat from the outdoors to inside the building.

Heat pumps are classified as air-source or water-source, referring to the medium with which they exchange heat. Air source heat pumps can be incorporated in almost any of the unitary technologies, including packaged terminal units, rooftop units, and split systems. They are found in diverse applications from residential systems on up to light commercial rooftop units.

Water-source heat pumps operate at higher efficiencies then air-source heat pumps due to the better heat transfer characteristics of water. Their efficiency is also improved because the water source is typically at a more favorable temperature for exchanging heat than ambient air.

The two major classifications of water-source heat pumps are water-loop and geothermal heat pumps, which are described in the following sections.

Water Loop Heat Pumps

Water loop heat pump systems consist of multiple heat pump units arranged to draw heat from or reject heat to a common water loop. These systems may also be referred to as closed-loop internal-source heat pumps or California heat pumps.

Water-loop heat pump systems are especially well-suited to applications that require simultaneous heating and cooling in different areas. For example, the interior areas of many large buildings need air conditioning year-round since they have substantial heat gains from lights, equipment and occupants, and no exterior surfaces through which to lose heat. At the same time, the perimeter areas need heating. The water-loop heat pump system can use the heat from the interior areas to heat the perimeter areas. The heat pumps in the interior reject heat to the water circuit to provide the needed cooling. The heat pumps in the exterior areas remove heat from the water circuit to warm up the space. A boiler provides supplemental heat to the water loop. During the summer, when all areas need cooling, a cooling tower rejects heat from the water-loop to the atmosphere.

Geothermal Heat Pumps

Geothermal heat pumps, or geo-exchange heat pumps, transfer heat to or from the earth. The principal advantage to this approach is the relatively constant earth temperature, which is favorable for high efficiency heat pump operation.

There are several variations of the geothermal heat pump system. The indoor portion may consist of one or two heat pumps, or many water-source heat pump units arranged on a water loop. The geothermal heat exchanger portion may be open-loop or closed-loop. An open-loop heat exchange ruses water drawn from a well or a source of surface water. The water passes once through the heat pump's heat exchanger, and is then rejected to another location such as a different well, a different area in the body of surface water or a new location entirely.

Closed-loop systems continuously circulate the same water through plastic pipe buried underground or in contact with a body of water. Ground heat exchangers are classified as horizontal or vertical. A horizontal ground heat exchanger is buried 4 to 8 feet below the surface, with pipe looping over a large area. A vertical ground heat exchanger consists of a double length of heat exchange pipe inserted in a number of boreholes or wells. Closed loop water heat exchangers have a similar length of pipe that is submersed in a pond, lake, or other body of water.

Dual-Fuel Heat Pumps

A duel-fuel heat pump combines a heat pump and furnace in one package designed to function as a single system. Dual-fuel heat pumps may also be referred to as dual-fuel systems, add-on heat pumps, piggyback heat pumps, all-weather systems, all-fuel systems, or best-fuel systems. The name dual fuel system may also be used to refer to separate heat pump and furnace units serving the same space.

The benefits of a duel fuel heat pump system come from the way the two components offset each other's weaknesses. A standard heat pump provides inexpensive heating during the bulk of the year, but relies on expensive electric resistance to back it up during the coldest days. In a dual-fuel heat pump, the furnace provides supplementary heat rather than electric resistance heaters. The furnace also provides a fast recovery when the thermostat is returned to its normal setting after having been set back for energy savings.. The dual-fuel system also allows the flexibility to switch fuels if utility prices drastically change.

Evaporative Coolers

Evaporative coolers provide air conditioning through the evaporation of water. There are two types of evaporative coolers: direct and indirect. Direct evaporative coolers pass an air stream through a mist of water or a moist pad. The air is simultaneously cooled and humidified. This technology is extremely effective in hot, arid climates like the Southwest U.S. The primary advantage of this technology is that the air conditioning is "free" except for water, fan and pumping costs.

Indirect evaporative cooling uses two air streams. The first air stream is run through an evaporative cooler and then through an air-to-air heat exchanger where it cools a secondary air stream. The secondary air stream is then sent to the space. This provides "free" cooling without adding humidity. Indirect evaporative cooling is less efficient then the direct method due to the additional step of heat exchange. It does have the advantage of providing cooling without increasing humidity.

Direct/indirect evaporative coolers can be combined in a single package to leverage advantages of both systems and extend the climate where these systems can be used effectively.

Dual Path and 100% Make up Air Dehumidification and Air Conditioning

EPRI has developed an advanced 100% make up air and dual path air conditioning system to overcome the limitations of both constant volume and variable air volume (VAV) air conditioning systems. In the dual path approach, the outside air is conditioned separately and independently of the recirculation or return air. The outside air is cooled and dehumidified to low dew point temperatures before it is mixed with the recirculation air and supplied to the space.

The dual-path concept allows good humidity control while avoiding the need to overcool and reheat the supply air. A schematic diagram of the airflow in a dual path system is provided in Figure 3-3.

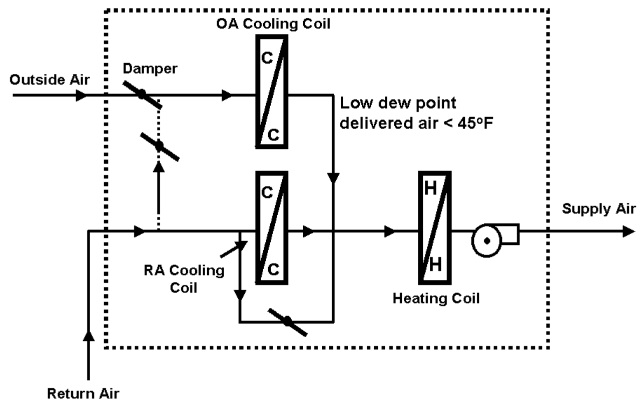

Figure 3-3
Dual Path Dehumidification

Desiccant Dehumidification

A desiccant dehumidification system uses a desiccant material and heat from a gas burner or other source to reduce the humidity in a conditioned space. A desiccant material attracts and holds water vapor through a process known as adsorption. Nearly all materials have some desiccant properties, but certain commercially produced substances have been designed to hold up to 1100% of their dry weight in water vapor. These desiccant materials attract moisture until they reach equilibrium with the surrounding air. To regenerate, or remove the moisture, the material is heated to temperatures ranging between 120ºF and 500ºF.

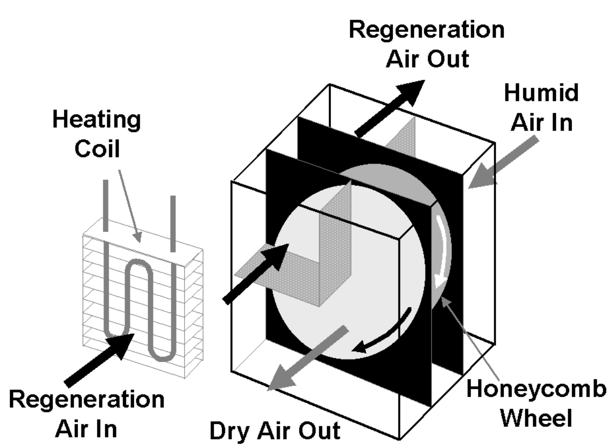

Figure 3-4
Rotary Honeycomb Desiccant Wheel

Commercial desiccants are produced in both solid and liquid form. The solid form is the most commonly used in the HVAC industry. The solid desiccant is impregnated on a substrate that is formed into a honeycombed wheel. The wheel rotates through the humid air stream, picking up moisture. As the wheel continues to rotate it passes through a second air stream, which has been heated to regeneration temperatures. This second air stream removes the moisture from the desiccant material, leaving it very warm and dry. The dried desiccant then rotates back into the first air stream to begin the process again.

The supply air coming from a desiccant is quite warm and dry. If it is to be used for air-conditioning it must be cooled. This is normally accomplished by using an indirect evaporative cooler, a chilled-water cooling coil or a unitary air-conditioning unit. The overall load on the cooling system is not reduced unless hot air after desiccation is cooled by ambient air or indirect evaporative cooler. On the contrary, the total cooling load on chilled water may increase due to combination of the heat of desiccation that is given up by water vapor when it is adsorbed or absorbed and the residual heat of regeneration.

Commercial Unit Sales and Trends

The breakdown of HVAC units sold in the U.S. in 1999 is summarized in Figures Figure 3-5 and Figure 3-6, by unit sales and dollar value respectively. Distributed air conditioning equipment dominates the number of units manufactured as shown in Figure 3-5. Sales of all chiller types comprise less than 1% of U.S. HVAC units sold, but r over 30% of the dollar value, as seen in Figure 3-6.

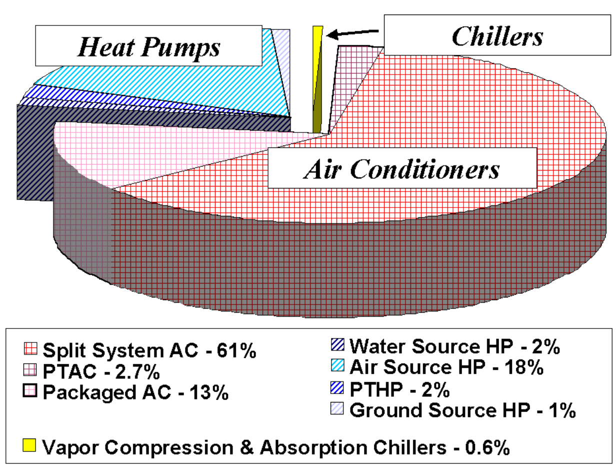

Figure 3-5
Breakdown of HVAC Equipment Sold During 1999 in the U.S. by Units Shipped (Census Bureau, 1999a)

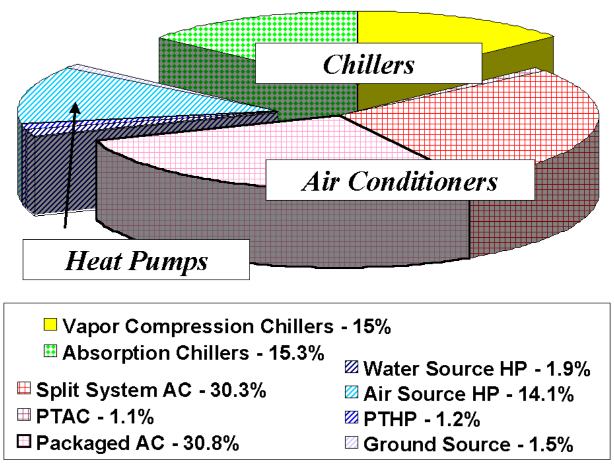

Figure 3-6
Breakdown of HVAC Equipment Sold in the U.S. During 1999 by Shipment Value (Census Bureau, 1999a)

Typical applications of air-conditioning systems are illustrated in Figure 3-7. Buildings under 3 stories, such as shopping malls and small schools, can often be served adequately by rooftop or other packaged units. Medium sized buildings that contain multiple zones, such as an office building or large hotel, are often served by distributed units, such as water loop heat pumps. Once a building surpasses 6 or 7 stories in height, it is impractical to install any system that attempts to move conditioned air throughout the building. This is where the higher first cost of a chiller system is quickly recovered in operating costs. It is much more efficient to pump chilled water throughout a building then to push air. For more information on selection of proper HVAC equipment, refer to EPRI's *Space Conditioning Selection Guide* (TR-103329).

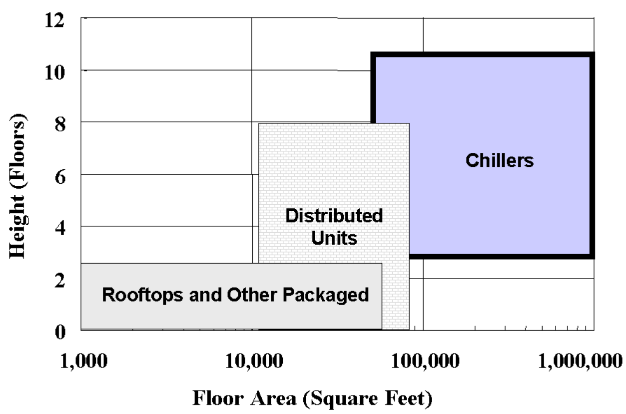

Figure 3-7
Typical Choices of Air-Conditioning Systems

Figures Figure 3-8 through Figure 3-13 summarize U.S. Census Bureau and Air-conditioning and Refrigeration Institute (ARI) information on the yearly sales of unitary air conditioners and chillers. Sales of unitary equipment tend to follow the U.S. construction market, and have been growing by a little over 4% per year as shown in Figure 3-8. Chiller sales increased sharply in the mid-1990's, as shown in Figure 3-9 through Figure 3-13. This increase was largely due to the phaseout of CFC refrigerants CFC-11 and CFC-12, which were the primary refrigerants used in large tonnage chillers. Many facility owners retired their chillers that used the old refrigerants, and purchased new chillers that used new, ozone-friendly refrigerants.

Additional Sources of Information

Additional information is available to electric utility employees and the general public through EPRI and other sources. Appendix A lists EPRI publications relevant to the HVAC industry. In particular, the *Electric Chiller Handbook*, the *Space Conditioning Selection Guide*, the *Heat Pump Manual*; *Second Edition* and the *Residential Space Conditioning Guidebook* provide useful detailed information. EPRI can be found on the web at www.EPRI.com.

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) publishes a series of Handbooks that provide comprehensive technical information on HVAC technology, including equipment, applications, design, and costs. ASHRAE is the preeminent organization in the HVAC industry. Composed of thousands of engineers, it develops many of the codes and standards that govern the HVAC industry. ASHRAE can be found on the web at www.ASHRAE.org.

Statistical information can be obtained from the U.S Census Bureau and the Air-Conditioning and Refrigeration Institute (ARI). The U.S. Census Bureau compiles yearly statistics on sales of major equipment categories. ARI is an organization of HVAC equipment manufacturers. Members report their sales statistics to ARI, which compiles the information and disseminates it back to the members so they can determine their industry share. ARI also releases limited amounts of information to the general public. ARI can be found on the web at www.ARI.org.

A list of manufacturers, government agencies and other organizations is provided in Appendix C. All of these organizations can be sources of additional information.

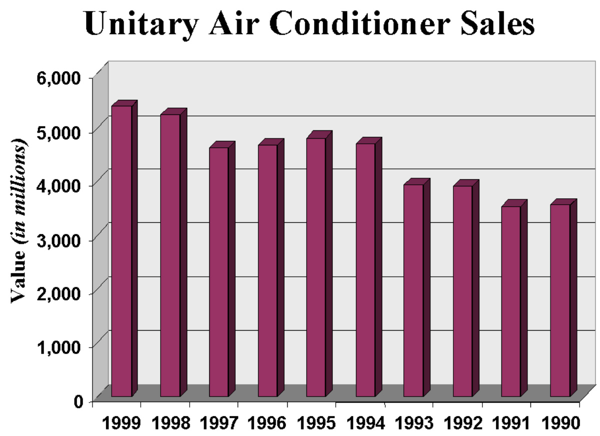

Figure 3-8
Value of Unitary Equipment Sales (Census Bureau, 1999c)

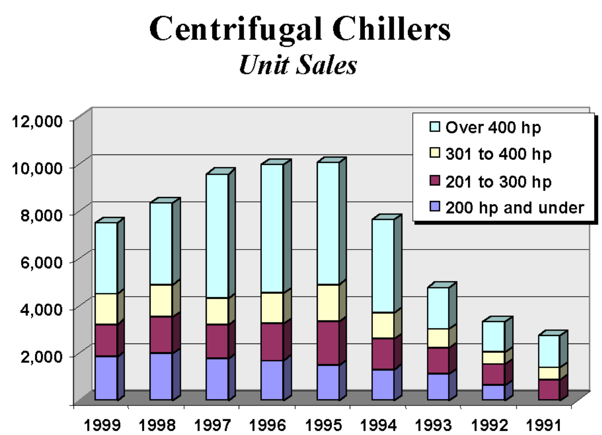

Figure 3-9
Centrifugal Chiller Unit Sales (Census Bureau, 1999c)

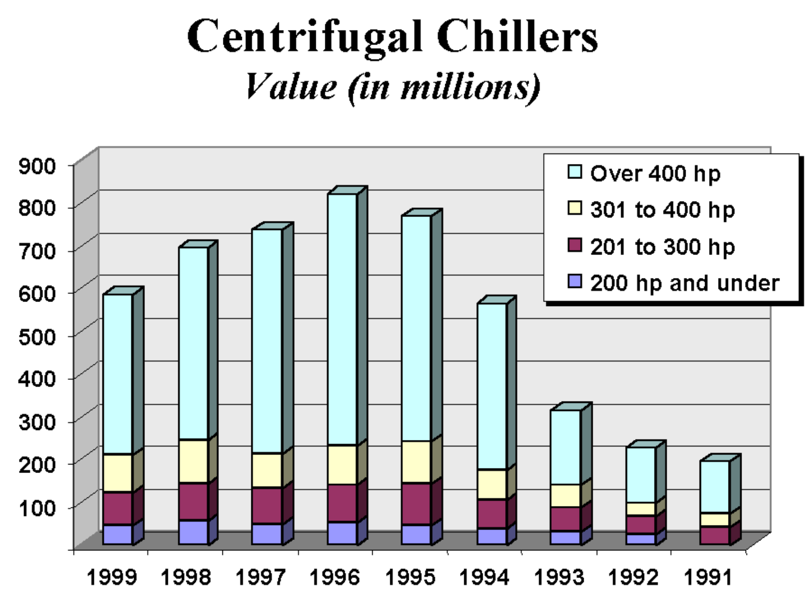

Figure 3-10
Value of Centrifugal Chiller Sales (Census Bureau, 1999c)

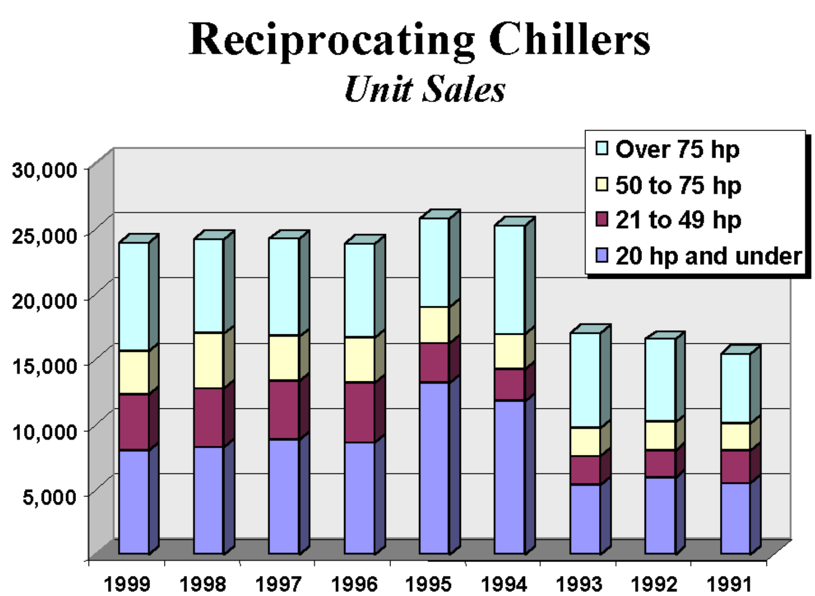

Figure 3-11
Reciprocating Chiller Unit Sales (Census Bureau, 1999c)

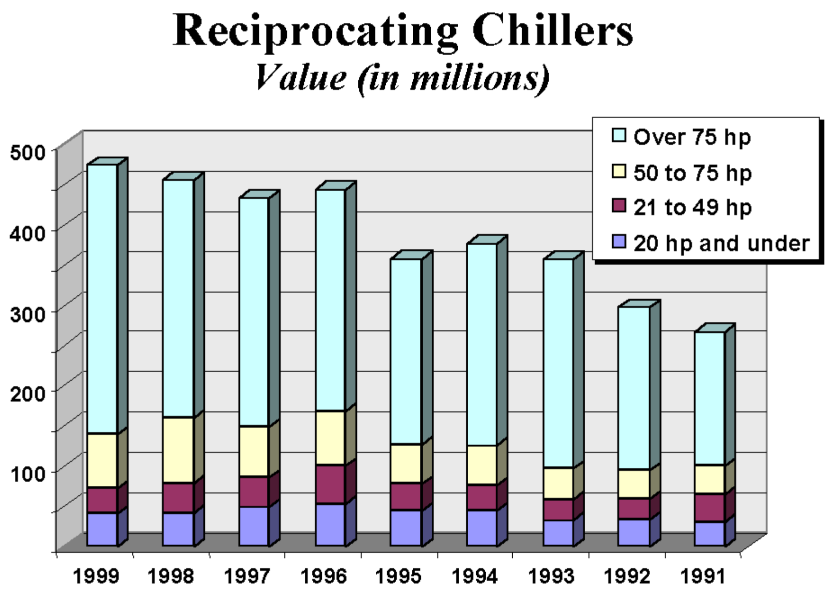

Figure 3-12
Value of Reciprocating Chiller Sales (Census Bureau, 1999c)

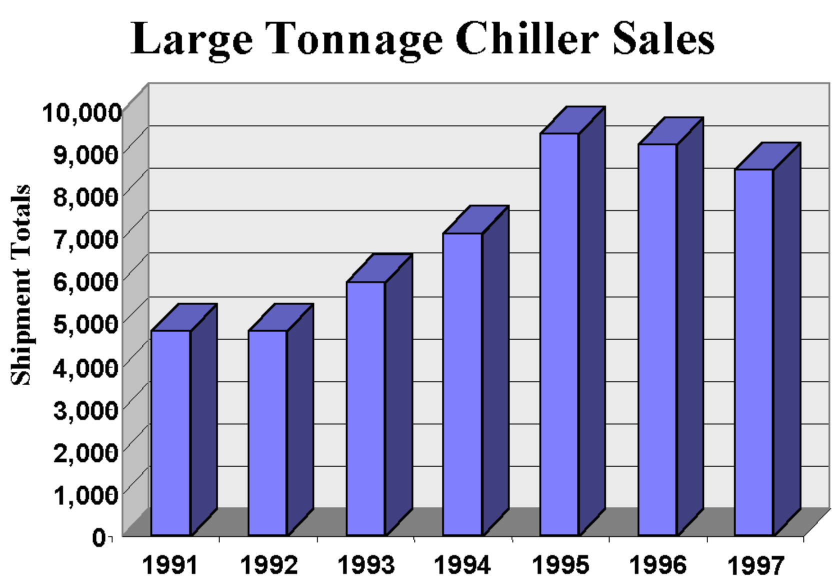

Figure 3-13
Large Tonnage Chiller Sales (ARI, 2000)

4
FACTORS AFFECTING TRENDS IN TECHNOLOGY AND APPLICATIONS

Codes and Standards

ASHRAE Standards

ASHRAE has continued to move forward in the development of a number of standards that pertain to HVAC applications. Two of the most important standards are Standard 90.1 "Energy Standard for Buildings Except Low-Rise Residential Buildings" and Standard 62 "Ventilation for Acceptable Indoor Air Quality." New editions of both of these standards were published in 1999, a decade after the previous versions. Both standards also have been put under the continuous maintenance process that will allow for more timely updates.

As a part of the continuous maintenance process, ASHRAE will consider any proposals to modify the standards in part or in whole. Numerous proposals have already been submitted on both of the standards. If the project committees responsible for the standards deem that a proposal has merit, it will be circulated for public review. If consensus can be reached after the public review process, the proposal will be incorporated into the standard.

ASHRAE has been actively encouraging code agencies to adopt Standard 90.1-1999 by reference. The society has created a Code Interaction Subcommittee to pursue having the Standard adopted as a part of the International Code Council and the National Fire Protection Association.

Standard 62 is in the process of being divided into two components. Proposed Standard 62.1P will be an update of Standard 62-1999 applying to commercial, institutional, and high-rise residential buildings. A public review draft of proposed Standard 62.2P, which applies to low-rise residential buildings, was released in August, 2000. One of the major features of the new draft was a requirement for whole-house mechanical ventilation for all residential buildings under three stories.

ARI Standard 550/590-98

The Air-conditioning Refrigeration Institute has published a new standard for rating chillers. ARI Standard 550/590-98 combines two previously separate Standards: ARI Standard 550-92 for Centrifugal and Rotary Screw Water Chilling Packages, and ARI Standard 590-92 for Positive Displacement Compressor Water Chilling Packages.

The two major changes are in regard to the integrated part load value (IPLV) and the fouling factor adjustment used for evaporators in closed loop water systems. The IPLV rating conditions and part load weightings have been changed to more closely reflect actual operating experience found in the field for a single chiller. The evaporator fouling factor has been based on research work sponsored by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), which shows that the actual fouling of the waterside of evaporators operating in closed circuit water systems experience very minimal degradation in performance over time.

The integrated part load value (IPLV) is a single part load efficiency number for water chillers referenced to the Standard ARI Rating Point. The equation was developed to provide a representation of the average part load efficiency for a chiller—much like the seasonal energy efficiency ratio (SEER) is used to describe the part load efficiency of unitary equipment.

Since it was first developed in 1986, the equation has undergone two changes—each time to make the IPLV more representative of how a chiller might operate over a typical year's period. Extensive computer analysis was used to model chillers applied in various geographic regions and applications and thus reduce the analysis to a single "average" representation.

Because of this, the IPLV may not be representative of a particular job installation. It is best to use a comprehensive analysis that reflects the actual weather data, building load characteristics, number of chillers, operational hours, economizer capabilities, and energy drawn by auxiliaries, such as pumps and cooling towers, when calculating the overall chiller plant system efficiency. Engineers and owners should use caution when applying the new standard. This is necessary because performance may appear to improve from the change in part-load weighting factors, reduction in entering condenser temperatures, and the reduction in cooler waterside fouling allowance. However, the performance of the equipment does not improve, only the rating method has changed. (HPAC, 1999).

Appliance Efficiency Standards

On the governmental level, the Department of Energy has been active in promoting new appliance efficiency standards. The proposed standards for air-conditioning equipment have generated some controversy because of their focus on Seasonal Energy Efficiency Ratio (SEER) levels. While implementing higher SEER levels might lead to lower national energy usage, it does not adequately address the high summertime demand on the nation's electrical grid. Air-conditioning equipment manufacturers can achieve higher SEER levels improving efficiency at part-load and at lower ambient temperatures. However, these improvements do not insure more efficient operation at full load and at higher ambient temperatures. Improvements at these conditions will help reduce peak demand for electricity.

Proposed Catalyst Coating for Texas

In Texas, the Texas Natural Resource Conservation Commission, under pressure from the US Environmental Protection Agency, is considering a requirement for a catalyst coating for central air conditioners and heat pumps. The coating is intended to reduce ground level ozone levels. However its effectiveness in this regard is unproven and the coating may reduce the efficiency of air-conditioning units, thus creating a higher demand upon the electrical grid. The proposal is available at http://www.tnrcc.state.tx.us/oprd/rule_lib/proposals/pc00011j.pdf. A press release from ARI criticizing the proposal can be found at http://www.ari.org/pr/2000/080900texas.html.

Refrigerants

ARI published a new Standard 740-98 on refrigerant recovery and recycling. This new standard was incorporated into the organization's Refrigerant Recovery/Recycling Equipment (RRRE) Certification Program. This standard updated the previous 1995 standard by including requirements for many of the new refrigerants. These included HCFC blends used in replacements for R-12 and R-502 as well as HC blends such as R-404A, R-507, R-407C, and R-410A.

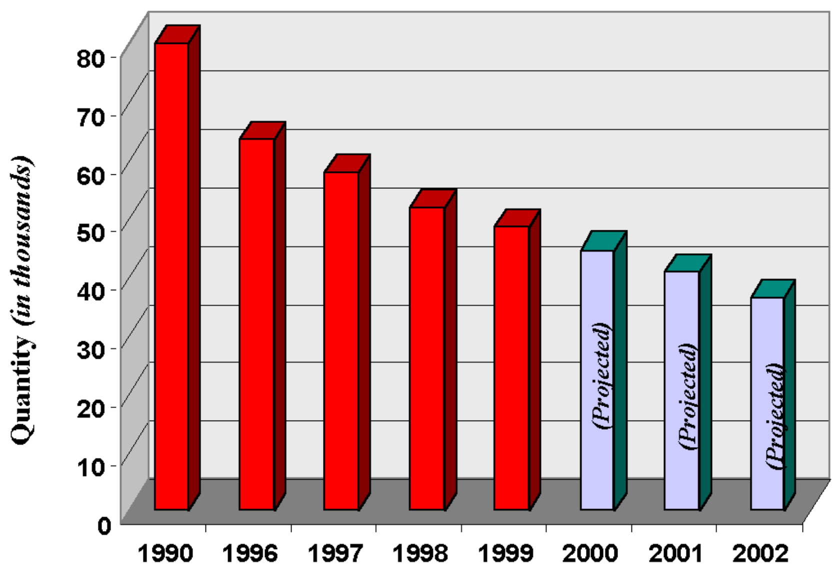

Figure 4-1
Estimates for CFC Based Chillers in Service on January 1st (ARI, 2000)

ARI has also completed a survey regarding the status of the existing chiller marketplace, in terms of the conversion and replacement of CFC chillers. After sizable reductions in the early 1990's, the changeover trend has slowed. Of the estimated 80,000 CFC-using chillers in operation as of 1990, nearly 61% were still utilizing a CFC as the refrigerant. ARI's projections are that the percentage would drop to 56% by the 2001, 51% by 2002, and 46% by 2003.

In the U.S., the industry is searching for replacement refrigerants for the HCFCs that are to be phased out of production, especially HCFC-22. There are two leading candidates at this time - R-407C and R-410a, both blends of HFCs. R-22 machines can be converted to operate on R-407C with little change, but there are efficiency and capacity losses associated with the conversion. At this time, however, the U.S. industry appears to be embracing R-410a as the new choice. Marketed under the name Puron by one manufacturer, R-410a operates more efficiently but at a higher pressure than R-22. This requires redesign of all components, not only compressors but also heat exchangers with thicker walls and other accessories like valves, fittings, etc. that can withstand higher pressures. Manufacturers are currently marketing several residential split systems using R-410a, and McQuay began marketing a screw chiller using R-410a in 1998.

On the other side of the Atlantic, Europeans plan a much faster phaseout of R-22 than the United States, so manufacturers are moving more quickly than their American counterparts. At a recent European trade show, it was apparent that European manufacturers moving towards the use of R-407C. Since R-407C operates at similar pressures to R-22, the equipment originally designed for R-22 did not have to undergo a major redesign. Looking towards the long term future, Europeans are devoting considerable research towards the potential for replacing CFCs, HCFCs, and HFCs with hydrocarbons such as propane or butane, and other natural refrigerants such as carbon dioxide or ammonia. Research into the replacement of R-22 with propane (R-290) has shown very favorable results. (The News, 2000).

Controls and Interoperability Protocols (BACnet vs. LONWORKs)

Since the advent of computer-based supervisory and direct digital control (DDC) systems for commercial and industrial applications, the controls industry has faced the question of how to provide interoperability among different manufacturers' equipment. In the past, when facility owners purchased a control system for their HVAC system, they were locked into a non-competitive purchasing situation. In most cases, the control system could only be expanded and/or modified with proprietary hardware from the original manufacturer. Owners' desire to interface computer control systems from different manufacturers to permit expansion and modification with other vendors' equipment has fostered the movement to develop open systems for commercial and industrial control. The open systems concept allows for the connection of control system components of different manufactures to operate as a single, integrated system in a manner transparent to the user.

In today's commercial market, two data communication protocols have emerged as the leaders for use in building automation and control networks: BACnet, sponsored by ASHRAE, and LONWORKs, sponsored by the Echelon Corporation. Both protocols provide a standard way of representing the functions of any device so they can communicate and operate as a single, integrated system in a manner transparent to the user. There is considerable debate in the industry over which protocol is better. BACnet has the support of ASHRAE, the professional society of HVAC engineers, and seems to be more robust in meeting the needs of the HVAC community. On the other hand, LONWORKs appears to provide more opportunities to link communications from all systems in a facility, such as HVAC, lighting, fire, and security. Either way, both communications protocols provide facility managers with more options for choosing the vendors of their control systems. (HPAC, 2000).

Fault Detection and Diagnostics

Fault Detection and Diagnosis (FDD) is one of the most prevalent areas of research in the HVAC industry today. When considering the vast number of existing and future HVAC system installations, the large hours of operation, and the financial and energy costs to operate, the need for components and systems to perform optimally becomes quite apparent. While the burden for initially efficient systems rests with equipment manufactures, designers, and installers, the goal of FDD systems is to identify unacceptable operation conditions or faults. Detection means simply a 'yes' or 'no' as to whether or not a fault occurs, comparable to a check engine light on a car. Diagnosis attempts to go further to locate the fault and determine its nature, perhaps comparable to a message to check the connection on the spark plug on the second cylinder.

In the past decade, numerous approaches have been proposed for FDD on specific components and building systems as a whole. The majority of these methodologies utilize some means of comparing the current performance to some expected performance through the use of physical (thermodynamic) modeling, less intuitive artificial intelligence (neural network) type modeling, or some combination of the two. Several current research projects are collaborative efforts working to apply these various methodologies to understand and compare their strengths and weaknesses. The results of these projects will then be utilized in the development of the second generation of FDD methodologies for HVAC systems moving the industry closer to wide scale implementation.

Industry Trends

Contractor Consolidation

Numerous utilities have become players in the HVAC contracting industry in recent years, launching their own HVAC service companies or buying existing ones. Consolidators, companies that buy existing contracting businesses and operate them as coordinated networks, have also come onto the scene. These two developments initially raised concern on the part of independent contractors, but the fears that utilities and consolidators would overwhelm the industry have not materialized.

Utilities and consolidators have become important players in the marketplace, but they have not driven the independent contractor to extinction. They do possess the advantage of a more powerful management structure, which can allow for more effective management and marketing.

Consolidation has not always proven to be an easy transition for the contractors that join the large networks. Becoming part of a larger corporate structure has forced them to change some of the ways they do business. It has also led to some instability within companies, but such instability is usually only short-term.

Contractor Certification

There has been a movement in the last few years to develop a national certification program for technicians in the heating, ventilation, air-conditioning, and refrigeration industry. The intention is to give consumers confidence in the level of expertise of their contractor, similar to the SAE certification program available in the automotive industry. Electric utilities are backing this movement to help ensure that qualified technicians have properly installed HVAC equipment.

There are a number of programs available at the moment. The training program currently supported by EPRI and many electric utilities is NATE, North American Technician Excellence, Inc. NATE is an independent, non-profit coalition of industry leaders that provides comprehensive, nationwide testing and certification for HVAC technicians. Nate provides a core exam that covers safety, tools, soft skills, principles of heat transfer and total comfort, and electrical questions. The technician then may receive certification in one of 5 available specialty skills:

- Air Conditioning
- Air Distribution
- Gas Heating
- Heat Pumps
- Oil Heating

Utility Deregulation

Deregulation continues to progress at different rates across the nation. The regulation of utilities, or the lack thereof, is in the hands of the individual states. Many states have done little or nothing, while others have blazed forward with deregulation but failed to see the expected benefits.

The state of California was a deregulation pioneer, and the results there have forced many other states to slow down the pace and take a closer look at deregulation in their jurisdictions. As a result of high demands and a shortage of power, many California customers were faced with higher electric bills this year. The summer high demand in San Diego proved this point most markedly.

Deregulation has led to a new series of changes within the electric utility industry marketplace. Some utilities are divesting themselves of generation while others are actively buying it up. All are trying to position themselves to be in the most financially effective situation. Deregulation has also led, at least indirectly, to a number of large scale mergers within the industry.

Electric utility deregulation is closely followed by several federal agencies, including the Federal Energy Regulatory Commission (FERC) and the Energy Information Administration (EIA). EIA provides a basic reference document on their website, www.EIA.DOE.gov, that provides a comprehensive delineation of the electric power industry in its traditional structure, and describes the industry's transition to a deregulated, competitive environment. They provide routine updates the factors that have contributed to the interest in a competitive market, proposed legislative and regulatory actions, and the steps being taken by the various components of the industry to move towards a competitive environment.

Kyoto Protocol

The Kyoto Protocol is an international agreement to reduce the causes of global warming, which was drafted in Kyoto, Japan, and completed in December 1997. Under this Protocol, the United States would be obligated to a cumulative reduction in its greenhouse gas emissions to 7% below 1990 levels for three greenhouse gases (carbon dioxide, methane, nitrous oxide), and below 1995 levels for three man-made gases (perfluorocarbons, sulfur hexafluoride, hydrofluorocarbons).

The provisions of the Protocol pertain to the use of refrigerants in the air-conditioning industry as well as the generation of electrical power to run air-conditioning equipment. Electrical power plants produce of significant quantities of greenhouse gases. Demand for electricity continues to grow in America. For the United States to significantly reduce greenhouse gas emissions, reductions in energy consumption or improvements in electricity generation will be needed.

The United States signed onto the treaty in November 1998 but Congress has passed several provisions that limit the activities of the United States government in carrying out the goals of the Protocol. Opponents believe that the Protocol puts too much of the burden of fighting global warming on the shoulders of the developed nations in general and the United States in particular.

Current R&D Efforts by Research Organizations

Dual Path and 100% Make up Air Dehumidification and Air Conditioning

EPRI has been one of the driving forces behind the development of dual path air systems. These systems, which condition outdoor air and return air streams separately, provide cost-efficient operation as well as excellent humidity control. EPRI has brought major refinements to this technology. By developing methods to modulate the capacity of the cooling coil and compressor system, the leaving air temperature can be better controlled. Other innovations include more efficient part-load operation and optimizing air flow and coil configuration.

Air systems that deliver 100% outdoor air represent a key component in an overall dual path system. The 100% outdoor air system treats only the outdoor air stream, thereby allowing its design to be optimized for those conditions. Since 1999, EPRI has been working with the manufacturer ClimateMaster to develop water-source prototypes for a water-source 100% outside air heat pump. The objectives of this effort are to refine the system design, incorporate heating capability, upgrade to the most advanced components, and to engineer the unit for manufacturing economy. Prototypes for a 3,000 cfm 100% make up air heat pump are now available for field testing.

21-CR Initiative

The Air-Conditioning and Refrigeration Institute (ARI) is sponsoring a number of research projects whose results could be of major significance to the industry. These projects are a part of ARI's Twenty-First Century Research (21-CR) initiative. This initiative is a private-public sector research collaboration, and its mission is to:

"…identify, prioritize, and undertake precompetitive research that focuses on decreasing energy consumption, increasing indoor environmental quality, and safeguarding the environment."

Some of the projects currently underway are:

- The Efficiency Limits of Water Vapor Compressors Suitable for Air-Conditioning Applications
- Evaluation of the Performance Potential of CO2 as a Refrigerant in Air-to-Air Air Conditioners and Heat Pumps: System Modeling and Analysis
- Evaluating the Ability of Unitary Equipment to Maintain Adequate Space Humidity Levels
- High Performance Heat Exchangers for Air Conditioning and Refrigeration Applications
- Assessing the Commercial Implications for ASHRAE A3 Flammable Refrigerants Used In Air Conditioning and Refrigeration Systems

ASHRAE Research

ASHRAE, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers continues its strong support of research efforts to benefit the HVAC industry. Some of the current projects are:

- Investigation of Methods to Optimize the Environmental Benefits of Ground-Coupled Heat Pumps
- Fault Detection and Diagnostic Requirements and Evaluation Tools For Chillers
- Evaluating the Ability of Unitary Equipment to Maintain Adequate Space Humidity Levels
- Partial Cycling of Stratified Cool Thermal Storage Systems
- Behavior of Ice Slurries Thermal Storage Systems

Gas Technology Institute

GTI, the Gas Technology Institute (formerly the Gas Research Institute and the Institute of Gas Technology) has been working on a number of improved gas-fired chilling units. Working with Tecogen, they developed a 400-ton chiller that uses R-134A as the working fluid. GTI has been working on a number of hybrid applications, incorporating both electric and gas technologies. These include single chiller packages that can be driven by either electric or gas-engine motors as well as cooling systems that contain both electric- and gas-driven components.

New Applications of Current Technology

Remote HVAC Operation

Lennox is offering wireless communication capabilities for some of their rooftop units. This technology will provide a direct, instantaneous alarm to customers' fax machines, pagers, or even e-mail if the unit encounters any problems in operation.

Cooling Tower Ozonation

An alternative method for treating cooling tower water is with ozonation technology. Ozonation is a process of introducing ozone into the water. Ozone is an unstable gas comprising three oxygen atoms (O_3), which is formed by forcing air or pure oxygen through a high-voltage electric field. Ozone has proven to be very effective as a biocide and has been in use for treating wastewater and drinking water since the beginning of the century.

An ozonation system typically includes an air compressor and dryer (to dehumidify the air used to form the ozone), an ozone generator, ozone injectors (to ensure good contact between the ozone and cooling water), and computer-based systems that continuously monitor control system performance. Ozone systems can often be provided as self-contained systems that include all components in a single cabinet.

The use of ozone requires the purchase or lease of additional equipment, but operational and performance benefits can outweigh the capital cost. Benefits include lower labor and maintenance costs, improved cooling-system efficiency, decreased water usage (blowdown reduction), and reduction of chemical costs. Ozone systems do require electricity to operate, but the overall system savings can result in lower overall electricity costs.

Despite it’s proven ability to effectively control bacteria and organisms, several points should be considered when evaluating an ozone system for installation:

- Ozone requires specialized equipment and control systems.
- The use of ozone will not eliminate the need for scale and corrosion inhibitors.
- Ozone may oxidize the chemicals being used as inhibitors; therefore, compatible chemicals may have to be added to the current treatment system.
- Ozone is a corrosive compound that with time causes degradation of plastic piping and rubber seals.

The application of ozonation to cooling towers should be investigated by a qualified professional. Be sure to check the references of any individual or company that proposes to install an ozone system.

A
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B

EPRI PUBLICATIONS

Below is a table of EPRI publications from the last 5 years that are relevant to the HVAC industry. To order any of these publications, contact EPRI Distribution at (800) 313-3774 or (650) 855-2121. EPRI Distribution can also be contacted by mail at:

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Table B-1
EPRI Publications relevant to the HVAC Industry

Publication Title	EPRI Identification Number	Publication Date
100 Percent Make-Up Air Heat Pump Development	WP-114674	12/15/1999
Add-On Heat Pumps: A New Marketing Perspective	TR-109735	12/3/1997
Advanced Dual Path HVAC Systems: For Best Control of Indoor Air Quality and Humidity	BR-109913	12/31/1997
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Residential Desk Book (TM) Version 3.0	AP-114187	11/30/1999
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Residential Heat Pumps: Defending and Growing Market Share	TR-109188	9/30/1997
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Retail Industry Revolution: Small Business Solutions Update, Issue 5, April 1999	MI-113027-OL	3/15/1999
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SST -- Supermarket Simulation Tool Version 2.5	AP-111112-R3	12/1/1999
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Thermal Performance of Soils and Backfills in Horizontal Ground Coupled Heat Pump System Applications	TR-110480	12/31/1997
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Variable Flow Pumping: The Key to Energy Efficiency in Water Loop and Geothermal Heat Pump System Applications	TB-114673	12/15/1999
Ventilation Best Practices Guide	TR-106662	11/1/1996
Widener University and PECO Energy Case Study: An Energy Management System Helps Eliminate the "Ratchet" Charge	MI-107852	7/7/1997
You Won't See the Insider But You'll Feel the Difference -- in Comfort and Cost	BR-108963-R1	7/5/1999

C

CONTACT INFORMATION FOR ORGANIZATIONS RELATED TO THE HVAC INDUSTRY

Table C-1
CONTACT INFORMATION FOR ORGANIZATIONS RELATED TO THE HVAC INDUSTRY

Air-Conditioning & Refrigeration Institute (ARI) 4301 N. Fairfax Drive, Suite 425 Arlington, VA 22203 Phone: (703)524-8800 Fax: (703)528-3816 www.ari.org	American Gas Cooling Center (AGCC) 1515 Wilson Boulevard Arlington, VA 22209 Phone: (703) 841-8411 Fax: (703) 841-8689 www.agcc.org
Air-Conditioning and Refrigeration Technology Institute (ARTI) 4301 North Fairfax Drive, Suite 425 Arlington, VA 22203 Phone: (703) 524-8800 Fax: (703) 528-3816	American National Standards Institute (ANSI) 11 West 42nd Street, 13th Fl. New York, New York, 10036 Phone: (212) 642-4900 Fax: (212)398-0023 www.ansi.org
Air Movement and Control Association International, Inc. (AMCA) 30 West University Drive Arlington Heights, Illinois 60004-1893 Phone: (847) 394-0150 Fax: (847) 253-0088 www.amca.org	The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) 1791 Tullie Circle, N.E. Atlanta, GA 30329 Phone: (404) 636-8400 Fax: (404) 321-5478 Toll-free: (800) 527-4723 (U.S. and Canada only) www.ashrae.org
The Alliance for Responsible Atmospheric Policy 2111 Wilson Boulevard, Suite 850 Arlington, VA 22201 USA Phone: (703) 243-0344 Fax: (703) 243-2874 www.arap.org	American Solar Energy Society (ASES) 2400 Central Avenue, Ste. G-1 Boulder, CO 80301 Phone: (303) 443-3130 Fax: (303) 443-3212 www.ases.org
Alliance to Save Energy 1725 K Street NW, No. 914 Washington, DC 20006-1401 Phone: (202) 857-0666 Fax: (202) 331-9588	Association of Energy Engineers (AEE) 4025 Pleasantdale Rd., Suite 420 Atlanta, GA 30340 Phone: (770) 447-5083 Fax: (770) 446-3969 www.AEEcenter.org

American Council for an Energy-Efficient Economy (ACEEE) 1001 Connecticut Avenue, NW, Suite 801 Washington, D.C. 20036 Phone: (202) 429-8873 www.aceee.org	The Association of Energy Services Professionals International (AESP) 6746 Finamore Circle Lake Worth, FL 33467 Phone: (561) 432-8000 Fax: (561) 432-8074 www.aesp.org
American Gas Association (AGA) 400 N. Capitol Street, N.W. Washington, DC 20001 Phone: (202) 824-7000 Fax: (202) 824-7115 www.aga.org	Building Officials and Code Administrators International (BOCA) 4051 W. Flossmoor Rd. Country Club Hills, IL 60478 Phone: (708) 799-2300 Fax: (708)799-4981 www.bocai.org
California Energy Commission (CEC) 1516 Ninth Street Sacramento, CA 95814-2950 Phone: (916) 654-4207 Fax: (916) 654-4304 www.energy.ca.gov	Consortium for Energy Efficiency (CEE) One State Street, Suite 1400 Boston MA 02109-3507 Phone: (617) 589-3949 Fax: (617) 589-3948 www.ceeformt.org
California Institute for Energy Efficiency (CIEE) One Cyclotron Road Mailstop: 90-3026 Berkeley, CA 94720 Phone: (510) 486-5380 Fax: (510) 486-5929 http://eande.lbl.gov/CIEE/ciee_homepage.html	Council of American Building Officials (CABO) 5203 Leesburg Pike Falls Church, VA 22041 Phone: (703) 931-4535 Fax: (703) 379-1546
Canada Centre for Mineral and Energy Technology (CANMET) 555 Booth Street Ottawa, Ontario K1A 0G1 Canada Phone: (613) 995-4037 Fax: (613) 995-3192	Earth Energy Association 777 North Capitol Street NE, #805 Washington, DC 20002 Phone: (202) 289-0868 Fax: (202) 408-8536
Canadian Electrical Association (CEA) 1 Westmount Square, Suite 1600 Montreal, Quebec, H3Z2P9 Canada Phone: (514) 937-6181 Fax: (514) 937-6498 http://www.pqnet.electrotek.com/pqnet/main/utilpq/utilities/cea.htm	Edison Electric Institute (EEI) 701 Pennsylvania Avenue NW Washington, DC 20004 Phone: (202) 508-5000 Fax: (202) 508-5225 www.eei.org

Canadian Gas Association (CGA) 20 Eglinton Avenue West Suite 1305, P.O. Box 2017 Toronto, Ontario M4R 1K8 Canada Phone: (416) 481-1828 Fax: (416) 481-2625 www.cga.ca	Electric Power Research Institute (EPRI) 3412 Hillview Avenue Palo Alto, California 94304 Phone: (510) 934-4212 www.epri.com
Canadian Gas Research Institute (CGRI) 55 Scarsdale Road Don Mills, Ontario M3B 2R3 Canada Phone: (416) 447-6661 Fax: (416) 447-6757 www.cgri.ca	Energy Efficiency and Renewable Energy Clearinghouse (EREC) P.O. Box 3048 Merrifield, VA 22116 Phone: (800) 363-3732 Fax: (703) 893-0400
Canadian Standards Association (CSA) 178 Rexdale Boulevard Rexdale, Ontario M9W 1R3 Canada Phone: (416) 747-4044 Fax: (416) 747-2475	Energy Efficient Building Association (EEBA) North Central Technical College 1000 Campus Drive Wausau, WI 54401-1899 Phone: (715) 675-6331 Fax: (715) 675-9776
Energy Information Administration (EIA) 1000 Independence Avenue, SW Washington, DC 20585 Phone: (202) 586-8800 www.eia.doe.gov	Institute of Electrical and Electronics Engineers (IEEE) 3 Park Avenue, 17th Floor New York, New York 10016-5997 Phone: (212) 419-7900 Fax: (212) 752-4929 www.ieee.org
HVAC&R Center University of Wisconsin at Madison 949 E. Washington Ave. Suite 2 Madison, WI 53703-2937 Phone: (800) 858-3774 Fax: (608) 262-6209 www.hvacr.wisc.edu	Institute of Gas Technology 1700 South Mount Prospect Road Des Plaines, IL 60018 Phone: (847) 768-0500 Fax: (847) 768-0501 www.igt.org
The Evaporative Cooling Institute (ECI) MSC 3ECI – NMSU P.O. Box 30001 Las Cruces, New Mexico 88003-8001 Phone: (505) 646-4104 Fax: (505) 646-2960 http://solar.nmsu.edu/eci	International Conference of Building Officials (ICBO) 5360 Workman Mill Road Whittier, California 90601-2298 Phone: (310) 699-0541 Fax: (310) 692-3425 www.icbo.org
Florida Solar Energy Center (FSEC) 1679 Clearlake Road Cocoa, Florida 32922 Phone: (321) 638-1000 Fax: (321) 638-1010 http://fsec.ucf.edu/	International District Heating and Cooling Association (IDHCA) 1200 19th Street NW, Suite 300 Washington, DC 20036 Phone: (202) 429-5111 Fax: (202) 223-4579

Gas Appliance Manufacturers Association (GAMA) 2107 Wilson Boulevard, Suite 600 Arlington, Virginia 22201 Phone: (703) 525-7060 Fax: (703) 525-6790 www.gamanet.org	International Energy Agency (IEA) 807 Caddington Avenue Silver Spring, MD 20901 Phone: (301) 681-2826 Fax: (301) 681-2876 www.iea.org
Gas Technology Institute 1700 South Mount Prospect Road Des Plaines, IL 60018-1804 Phone: (847) 768-0710 www.gri.org	International Ground Source Heat Pump Association Oklahoma State University 490 Cordell South Stillwater, OK 74078-8018 Phone: (405) 744-5175 Fax: (405) 744-5283 www.igshpa.okstate.edu
Heating, Refrigeration and Air-Conditioning Institute of Canada (HRAI) 5045 Orbitor Drive, Building 11, Suite 300 Mississauga, Ontario, Canada L4W 4Y4 Phone: (905) 602-4700 Fax: (905) 602-1197 www.hrai.ca	International Organization for Standardization (ISO) 1, rue de Varembé, Case postale 56 CH-1211 Geneva 20, Switzerland Phone: 41-22-749-01-11 Fax: 41-22-733-34-30 www.iso.ch
Lawrence Berkeley National Laboratory 1 Cyclotron Road Berkeley, CA 94720 Phone: (510) 486-5001 Fax: (510) 486-5454 www.lbl.gov	National Renewable Energy Laboratory (NREL) 1617 Cole Blvd Golden, CO 80401-3393 Phone: (303) 275-3000 www.nrel.gov
National Association of Energy Service Companies (NAESCO) 1615 M Street, N.W., Suite 800 Washington, D.C. 20036 Phone: (202) 822-0950 Fax: (202) 822-0955 www.naesco.org	National Technical Information Services (NTIS) U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161 Phone: (703) 487-4650
National Coalition on Indoor Air Quality 1518 K Street NW, Suite 503 Washington, DC 20005 Phone: (202) 628-5336 Fax: (202) 393-5760	Natural Resources Canada (NRCCan) 8th Floor, Section C1 580 Booth Street Ottawa, Ontario K1A 0E4 Canada www.nrcan-rncan.gc.ca

National Conference of States on Building Codes & Standards (NCSBCS) 505 Huntmar Park Drive, Suite 210 Herndon, VA 20170 Phone: (703) 437-0100 Fax: (703) 481-3596 www.ncsbcs.org	Natural Resources Defense Council (NRDC) 40 West 20th Street New York, NY 10011 Phone: (212) 727-2700 Fax: (212) 727-1773 www.nrdc.org
Pacific Northwest Laboratory (PNL) Building Energy Standards Program 2400 Stevens MS K5-16 Richland, WA 99352 Phone: (800) 270-2633 Fax: (509) 375-3614 www.pnl.gov	Oak Ridge National Laboratory P.O. Box 2008 Oak Ridge, TN 37831 Phone: (615) 574-5207 Fax: (615) 574-9338 www.ornl.gov
Radiant Panel Association (RPA) PO Box 717 Loveland, CO 80539-0717 Phone: (970) 613-0100 Fax: (970) 613-0098 www.rpa-info.com	Society of Manufacturing Engineers (SME) One SME Drive Dearborn, MI 48121 Phone: (800) 733-4763 Fax: (313) 271-2861 www.sme.org
The Refrigerating Engineers and Technicians Association (RETA) 4700 W. Lake Avenue Glenview, IL 60025-1485 Phone: (847) 375-4736 Fax: (847)375-6338 www.reta.com	Solar Energy Industries Association (SEIA) 1616 H Street, NW 8th Floor Washington, DC 20006 Phone: (202) 628-7979 Fax: (202) 628-7779 www.seia.org
The Refrigeration Service Engineers Society (RSES) 1666 Rand Road Des Plaines, IL 60016-3552 Phone: (847) 297-6464 Fax: (847) 297-5038 www.rses.org	Standards Council of Canada 270 Albert Street, Suite 200 Ottawa, Ontario K1P 6N7 Canada Phone: (613) 238-3222 Fax: (613) 569-7808 www.scc.ca
Refrigeration Research Foundation 7315 Wisconsin Avenue, 1200 N Bethesda, MD 20814 Phone: (301) 652-5674 Fax: (301) 652-7269	Sustainable Buildings Industry Council (SBIC) 1331 H Street, N.W., Ste. 1000 Washington, DC 20005 Phone: (202) 628-7400 Fax: (202) 393-5043 www.sbicouncil.org
Rocky Mountain Institute (RMI) 1739 Snowmass Creek Road Snowmass, CO 81654-9199 Phone: (970) 927-3851 Fax: (970) 927-4178 www.rmi.org	Underwriters Laboratories, Inc. (UL) 333 Pfingston Road Northbrook, IL 60062 Phone: (708) 272-8800 Fax: (708) 272-8129

Sheetmetal and Air Conditioning Contractors National Association (SMACNA) 4201 Lafayette Center Drive Chantilly, Virginia 20151-1209 Phone: (703) 803-2980 Fax: (703) 803-3732 www.smacna.org	United States Department of Energy (U.S. DOE) 1000 Independence Avenue SW Washington, DC 20585 Phone: (202) 586-6169
U.S. Environmental Protection Agency (EPA) 1200 Pennsylvania Avenue, NW Washington, DC 20460 Phone: (800) 296-1996 www.epa.gov	United states Department of Energy Federal Energy Management Program (FEMP) 1000 Independence Avenue SW Washington, DC 20585 Phone: (800) 566-2877 Fax: (202) 586-3000
United States Occupational Health and Safety Administration (OSHA) 200 Constitution Avenue NW Washington, DC 20210 Phone: (202) 219-8151 Fax: (202) 219-5986	

D
CENSUS BUREAU DATA

The following information is a compilation of statistics from *Refrigeration, Air Conditioning, and Warm Air Heating Equipment* published by the U.S. Census Bureau and issued 1999-1991 starting with MA333M(99)-1. The information has been edited to display information relevant to the residential and commercial HVAC industry. To see the original data, visit the U.S. Census Bureau's website at www.census.gov.

Table D-1
US Census Bureau – Quantity of Shipments

Equipment	1999	1998	1997	1996	1995	1994	1993	1992	1991
Heat transfer equipment (except room and unitary air-conditioners)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Packaged terminal air-conditioners	191,564	185,745	168,084	151,089	117,575	104,495	79,433	66,286	53,567
Packaged terminal heat pumps	155,774	156,132	130,736	112,549	94,843	83,099	57,225	55,438	49,653
Evaporative condensers	2,552	2,715	2,737	2,306	2,353	2,724	2,865	2,145	2,198
100 tons and under	530	556	577	510	526	747	560	419	407
Over 100 tons	2,022	2,159	2,160	1,796	1,827	1,977	2,305	1,726	1,791
Room fan-coil air-conditioning units	335,308	310,345	281,920	263,404	244,174	215,387	262,159	197,785	269,571
Vertical stack	42,758	26,452	15,949	18,319	11,906	24,498	24,510	19,889	26,447
Vertical	163,061	146,423	130,555	120,021	116,498	97,064	133,599	91,076	125,791
Horizontal	129,489	137,470	135,416	125,064	115,770	93,825	104,050	86,820	117,333
Room air induction units	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)
Central station air-handling units (motor-driven fan type)	392,673	381,797	357,603	340,865	336,282	280,053	76,804	71,744	67,772
Draw through	369,889	356,540	332,216	317,418	315,760	258,438	55,418	52,319	48,480
Blow through	7,568	8,617	9,114	8,451	7,980	9,850	8,262	8,158	7,422
Heating and ventilating	15,216	16,640	16,273	14,996	12,542	11,765	13,124	11,267	11,870
Air-cooled refrigerant condensers (remote type)	26,335	25,292	25,688			27,890	23,255	21,939	20,056

Under 30 tons	17,677	17,656	18,194	20,502	23510	22,272	17,649	16,279	15,185
30 to 50 tons	2,656	2,187	2,821	2,019	2074	2,029	2,050	2,003	1,536
Over 50 tons	6,002	5,449	4,673	4,082	3836	3,637	3,556	3,657	3,335
Miscellaneous heat transfer equipment:									
Shell-and-tube, shell-and-coil, shell-and-u-tube, tube-in-tube	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Condensers	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Liquid coolers	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Liquid-suction heat exchangers and refrigerant liquid receivers	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Central system finned coils (air-conditioning and refrigeration type)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Standard steam and steam distributing tube	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Standard water cooling and/or heating and cleanable tube water	(X)	(X)		(X)	(X)	(X)	(X)	(X)	(X)
Volatile refrigerant cooling	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Coil sales by original equipment manufacturers intended for resale or assembly into equipment by other manufacturer (all types)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Copper and aluminum	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Aluminum (only)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Other, including steel and copper	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Factory-assembled, refrigeration type, finned gravity coils, including wetted-	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)

surface dehumidifiers									
Centrifugal liquid chilling packages, hermetic and open types	7,528	8,354	9,579	9,963	10,087	7,661	4,765	3,318	4,646
200 hp and under	1,851	1,965	1,732	1,678	1,487	1,303	1,080	614	(D)
201 to 300 hp	1,361	1,541	1,441	1,557	1,850	1,297	1,140	896	853
301 to 400 hp	1,263	1,377	1,138	1,299	1548	1,112	785	501	507
Over 400 hp	3,053	3,471	5,268	5,429	5,202	3,949	1,760	1,307	1,364
Absorption refrigeration and dehydration systems	5,800	8,647	(D)	(D)		2138	2123		
Reciprocating air and reciprocating water cooled, air-cooled screw, air-cooled scroll, and water- cooled scroll machines	23,910	24,073	24,163	23,776	25,683	25,129	16,983	16,448	15,395
20 hp and under	7,979	8,231	8,740	8,533	13,155	11719	5,346	5,858	5,425
21 to 49 hp	4,234	4,477	4,496	4,605	3046	2,429	2,168	2,148	2,528
50 to 75 hp	3,391	4,197	3,429	3,435	2691	2,709	2,235	2,091	2,093
Over 75 hp	8,306	7,168	7,498	7,203	6791	8,272	7,234	6,351	5,349
Factory-fabricated water cooling towers	9,197	8,859	9,006	9,158	8,948	9,409	9,788	9,613	8,549
Condensing units, refrigeration (complete)	529,779	521,481	465,344	512,135	545,062	542,776	459,490	443,914	399,959
Air-cooled hermetic-type	515,539	500,893	445,741	492,284	526,413	524,021	440,322	430,533	383,931
1 hp and under	421,439	398,877	353,847	400,585	442,416	444,911	365,932	357,412	308,521
15 hp	20,047	19,825	19,181	19,870	18,352	18,801	21,404	18,476	20,642

2 and 25 hp	22,896	24,530	23,863	26,340	23,602	18,540	16,349	15,671	13,985
3 hp	24,533	22,626	21,191	20,704	20,995	22,385	19,038	21,262	20,211
Over 3 hp, but under 15 hp	26,624	35,035	27,659	24,785	21,048	19,384	17,599	18,804	20,572
Water-cooled hermetic-type, under 15 hp	6,967	6,548	6,615	(D)	(D)	6,592	8,405	8,036	9,217
Water or air-cooled hermetic-type	5,628	5,906	4,722	4,794	4,224	4,293	3,430	4,330	5,647
15 hp	2,629	2,544	2,789	1,943	1,793	2,123	1,533	1,942	2,607
20 hp	789	944	689	776	783	876	654	951	1,206
25 hp	380	681	474	605	348	286	291	534	839
30 hp	744	809	344	522	298	425	(D)		
40 hp	1,086	928	426	948	1,002	547	711	903	995
Water or air-cooled open-type (all sizes)	1,645	(D)	(D)	(D)			1,047	1,151	1,164
Room air-conditioners and dehumidifiers	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Electrically operated dehumidifiers, mechanically refrigerated, self-contained	963,428	925,137	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Room air-conditioners	3,906,923	3,223,981	2,838,381	4,453,929	4,278,535	3,265,427	2,234,205	2,490,030	2,285,577
5,999 Btuh and under	985,463	855,326	649,840	985,695	931,033	658,107	422,845	575,542	591,872
6,000 to 6,999 Btuh	209,463	88,419	98,858	288,029	236,127	205,141	192,923	223,721	142,985
7,000 to 7,999 Btuh	279,503	395,704	304,344	544,174	511,719	343,566	157,277	153,114	190,326
8,000 to 8,999 Btuh	403,271	141,450	191,233	276,553	257,206	257,761	212,284	266,300	113,334
9,000 to 9,999 Btuh	91,508	115,675	61,642	96,600	106,321	39,573	55,640	65,032	97722

10,000 to 10,999 Btuh	496,839	437,488	359,399	577,201	525,330	420,696	319,791	304,452	259,112
11,000 to 12,999 Btuh	594,552	542,990	504,149	702,436	762,758	519,028	334,934	337,664	276916
13,000 to 14,999 Btuh	66,871	62,453	69,985	72,656	91,146	66,181	77,873	89,902	95,511
15,000 to 16,999 Btuh	100,946	71,114	99,715	101,365	63,114	51,785	33,646	23,508	23,888
17,000 to 19,999 Btuh	384,999	311,437	302,935	489,019	483,343	414,527	282,407	296,126	299,304
20,000 to 22,999 Btuh	49,468	26,892	22,643	46,530	39,163	35,730	38,760	37,311	56,807
23,000 to 25,999 Btuh	211,109	152,437	143,716	224,297	233,149	210,150	131,960	93,571	110,254
26,000 Btuh and over	32,931	22,596	29,922	49,374	38,126	43,182	29,505	23,787	27,546
Compressors and compressor units 3/ 4/	(X)	(X)	(X)	3,584,521	(X)	(X)	(X)	(X)	(X)
All refrigerants (except ammonia)	25,361,583	23,954,891	23,411,295	26,870,318	39,102,483	34,922,325	29,832,903	28,325,008	21,593,974
Hermetic-type motor compressors	25,294,235	23,885,557	23,333,320	24,063,692	22,484,139	19,653,536	17,018,501	16,801,452	13,694,304
Under 3 hp	19,025,876	18,569,966	17,898,968	18,521,768	17,634,944	15480795	13,241,728	12,963,492	10,680,932
3 to 10 hp	6,160,641	5,212,680	5,263,330	5,386,567	4,722,588	4,077,895	3,694,476	3,757,289	2,918,869
15 hp	30,044	28,384	29,072	27,735	25,851	20,827	20,072	20,447	28,603
20 hp	21,895	20,229	24,034	22,694	23,865	19,608	19,669	17,583	20,077
25 hp	16,931	15,441	17,731	15,770	14,996	12,858	12,684	12,786	15,775
30 hp	10,471	11,112	26,714	22,122	13,682	10,271	8,377	7,845	8,749
40 and 50 hp	15,226	16,111	37,736	34,033	19,384			15,388	14,363
60 hp	4,255	3,890	33,181	24,780	22,484	27,175	17,279	2,689	2,657
75 hp	(D)	(D)	2,554	(D)				1,855	1,970
100 hp and over	(D)	(D)	(D)	(D)	6,345	4,107	4,216	2,078	2,309

Open-type compressors (with or without motor - all sizes)	(D)	68,011	69,494	80,745	73,888	68,888	65,016	73,514	86,591
Screw type	(D)	(D)	(D)	16,902,612	16,544,456	15,268,789	12,749,386	11,450,042	7,813,079
Ammonia refrigerants (all types)	2,860	2,936	2,746	3,066	2,878	2,502	1,930	1,788	1,672
Nonelectric warm air furnaces and humidifiers	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Oil, forced air:									
150,000 Btuh bonnet output and under	134,566	135,114	152,728	167,309	149,315	250,553	238,111	203,160	102,664
150,001 Btuh bonnet output and over	5,903	6,536	6,945	7,080	7,212	8,234	6,889	6,765	102,664
Gas, forced air:									
150,000 Btuh bonnet output and under	2,919,047	3,025,498	2,707,851	3,189,556	2,649,815	2,672,615	2,443,929	2,276,432	1,899,626
150,001 to 400,000 Btuh bonnet output	6,347	14,392	10,470	42,806	(D)	(D)	9,145	3,965	12,128
Over 400,000 Btuh bonnet output	370,584	369,484	398,634	374,118	(D)	(D)	1,555	1,176	1,131
All other nonelectric warm air furnaces (Mostly solid fuel like coal, wood, etc)	1,083	1,489	1,336	601	(D)	1,465	1,069	903	(D)
Humidifiers (attachments to warm air furnaces) (all types), including central systems and self-Humidifiers (attachments to warm air furnaces) (all types), including central systems and self-contained (except portable humidifiers)	656,308	633,800	652,408	626,809	565,004	579,233	544,332	439,873	457,421
Unitary air-conditioners	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)

Single package air-conditioners, with or without evaporator fans, including refrigeration chassis and remote-condenser type	(D)	265,546	241,584	295,064	283535	244,397	206,800	196,312	176,650
Horizontal	253,286	265,546	241,584	258,772	249,494	214730	176,050	171,120	151,698
Under 27,000 Btuh	22,931	22,336	19,408	20,592	24,084	16,354	14,077	13,733	21,212
27,000 to 32,999 Btuh	33,563	31,341	37,454	38,685	44,878	29,578	25,320	23,371	21,840
33,000 to 53,999 Btuh	94,707	94,045	86,704	109,171	90,750	91,680	69,076	65,836	53,146
54,000 to 64,999 Btuh	40,923	51,063	40,296	35,939	37,689	29,511	25,168	26,350	22,702
65,000 to 96,999 Btuh	18,830	21,680	19,157	17,050	16,735	14,844	12,859	12,330	9,945
97,000 to 134,999 Btuh	15,511	16,695	15,060	15,151	15,407	14,149	11,956	12,470	9,546
135,000 to 184,999 Btuh	9,521	10,873	9,477	9,350	8,801	8,208	9,224	8,397	6,066
185,000 to 249,999 Btuh	6,240	6,847	5,358	5,142	4,976	4,993	4,311	4,975	3,919
250,000 to 319,999 Btuh	4,862	5,108	4,499	3,890	3,640	2,882	2,111	1,595	1,206
320,000 to 379,999 Btuh	1,345	1,150	1,017	821	560	601	463	472	510
380,000 Btuh and over	4,853	4,408	3,154	2,981	1,974	1,930	1,485	1,591	1,606
Other than horizontal	(D)	(D)	36,895	36,292	34,041	29,667	30,750	8,927	24,952
Under 54,000 Btuh	(D)	(D)	(D)	(D)		(D)	(D)	16,265	14,719
54,000 to 64,999 Btuh	(D)	4,727	6,474	5,806	31,143	4,855	5,275	4,135	3,785
65,000 to 96,999 Btuh	485	487	568	657	608	603	1,050	1,141	1,432
97,000 to 134,999 Btuh	611	615	639	723	689	661	(D)	1,157	1,609
135,000 to 184,999 Btuh	529	771	678	661	591	781	1104	1,127	1,659
185,000 Btuh and over	(D)	(D)	(D)	(D)	1,010	1,007	1,263	1,367	1,748

Year-round air-conditioners, single package and remote-condenser type (except heat pumps)	648,931	649,786	567,157	573,115	516,003	495,434	426,946	443,438	389,566
Under 33,000 Btuh	140,682	148,741	128,238	137,466	125,685	128,806	96,313	120,664	105,115
33,000 to 38,999 Btuh	120,488	118,405	104,402	111,458	104,987	97,426	104,396	96,388	89,076
39,000 to 43,999 Btuh	35,118	39,511	32,263	36,586	31,230	28,003	24,649	28,658	22,549
44,000 to 53,999 Btuh	74,438	70,850	59,175	57,914	48,722	51,285	48,282	43,537	39,854
54,000 to 64,999 Btuh	103,464	102,907	88,951	87,942	75,212	69,839	63,099	64,271	54,357
65,000 to 134,999 Btuh	112,190	109,653	99,888	91,963	83,388	77,517	53,690	60,039	53,290
135,000 to 184,999 Btuh	31,089	31,447	28,220	26,532	24,790	22,725	21,171	17,170	13,625
185,000 to 249,999 Btuh	15,344	13,890	12,905	12,041	12,123	10,917	8,796	7,388	6,604
250,000 to 319,999 Btuh	7,670	7,080	6,210	5,778	5,964	4,953	3,186	2,238	1,854
320,000 to 379,999 Btuh	2,155	2,015	2,169	1,541	1,024	1,158	1,004	948	1,139
380,000 to 539,999 Btuh	2,201	1,800	1,767	1,523	975	1,308	1,122	998	932
540,000 to 639,999 Btuh	1,470	1,252	1,127	866	554	581	417	343	264
640,000 Btuh and over	2,622	2,235	1,842	1,505	1,349	916	821	796	907
Water source heat pumps (except room air-conditioners)	120,137	120,080	112,052	(D)	109,326	99,321	105,159	99,236	111,745
Split system air-conditioning condensing units	4,335,967	4,465,836	3,810,178	4,261,815	3,441,989	3,385,357	2,623,039	2,763,656	2,455,692
Under 22,000 Btuh	309,824	363,464	306,721	312,325	264,111	249,416	189,620	204,350	227,666
22,000 to 26,999 Btuh	874,204	930,517	796,691	947,829	732,403	694,309	513,472	592,911	518,893
27,000 to 32,999 Btuh	753,539	888,608	764,763	914,015	726,482	679,479	500,991	612,448	495,228
33,000 to 38,999 Btuh	1,074,364	895,784	778,932	878,602	694,783	783,945	614,865	618,360	570,456

39,000 to 43,999 Btuh	378,134	438,753	374,237	412,814	342,832	302,569	220,894	209,533	172,771
44,000 to 53,999 Btuh	505,668	468,134	394,611	407,579	337,343	353,024	297,587	253,753	233,520
54,000 to 64,999 Btuh	373,839	404,316	328,262	328,455	289,291	273,591	237,885	224,094	191,599
65,000 to 96,999 Btuh	26,255	30,364	25,200	23,284	20,533	17,600	17,542	17,610	17,373
97,000 to 134,999 Btuh	18,296	21,411	18,411	16,393	15,470	13,657	13,332	13,653	12,443
135,000 to 184,999 Btuh	9,948	11,244	10,099	8,982	8,460	8,478	8,446	8,167	7,311
185,000 to 249,999 Btuh	5,266	5,989	5,476	4,775	4,130	3,388	3,380	3,541	3,535
250,000 to 319,999 Btuh	1,661	1,899	1,672	1,762	1,629	1,519	1,351	1,451	1,344
320,000 to 379,999 Btuh	1,761	2,051	1,882	1,848	1,557	1,529	1,407	1,384	1,172
380,000 to 539,999 Btuh	1,305	1,475	1,476	1,408	1,258	1,212	1,156	1,101	1,096
540,000 to 639,999 Btuh	604	742	670	668	614	629	434	495	
640,000 Btuh and over	1,299	1,085	1,075	1,076	1,093	1,012	677	805	
Split system air-conditioning coils	3,292,218	3,290,633	2,946,522	3,204,164	2,780,887	2,744,968	2,373,952	2,385,956	2,014,368
With blower	1,516,567	1,521,713	1,341,524	1,322,047	1,216,712	1,180,386	1,020,347	1,076,596	919,587
Without blower	1,775,651	1,768,920	1,604,998	1,882,117	1,564,175	1,564,582	1,353,605	1,309,360	1,094,781
Air source heat pumps (except room air-conditioners)	1,247,863	1,326,736	1,179,930	1,423,503	1,036,767	1,022,908	875,899	909,787	825,160
Single package:									
Under 27,000 Btuh	29,446	42,284	34,564	30,571	24,907	24,868	20,973	25,989	34,341
27,000 to 41,999 Btuh	96,416	146,547	123,822	98,634	73,229	74,934	58,511	61,844	58,056
42,000 to 64,999 Btuh	76,746	94,319	81,897	64,981	48,719	45,892	37,464	37,929	39,670
65,000 Btuh and over	13,028	14,610	12,889	8,982	8,482	8,560	8,430	7,170	6,736

Split system:									
Under 27,000 Btuh	345,534	339,436	299,827	376,042	285,165	264,469	212,159	243,341	211,611
27,000 to 41,999 Btuh	429,294	448,299	414,701	564,405	404,889	408,255	361,108	349,100	321,895
42,000 to 64,999 Btuh	236,697	223,220	198,100	265,378	177,984	184,073	164,972	173,730	146,664
65,000 Btuh and over	20,702	18,021	14,130	14,510	13,392	11,857	12,282	10,684	6,187
Ground and ground water source heat pumps	76,750	(D)	(D)						
Single and split systems:				(NA)					
Under 27,000 Btuh	(D)	(D)	(D)	(NA)					
27,000 to 41,999 Btuh	(D)	(D)	(D)	(NA)					
42,000 to 64,999 Btuh	8,528	(D)	(D)	(NA)					
65,000 Btuh and over	(D)	(D)	(D)	(NA)					

Table D-2
US Census Bureau – Value of Shipments (x $1000)

Equipment	1999	1998	1997	1996	1995	1994	1993	1992	1991
Heat transfer equipment (except room and unitary air-conditioners)	4,548,427	4,493,307	4,245,885	4,267,113	6,169,842	5,802,366	4,951,008	4,117,785	3,925,409
Packaged terminal air-conditioners	109,036	107,771	93,399	84,204	66,246	58,104	46,371	38,420	32,374
Packaged terminal heat pumps	81,498	82,695	70,143	60,848	50,148	43,631	32,807	31,457	28,248
Evaporative condensers	65,598	68,687	67,709	54,033	52,727	49,803	51,056	41,088	38,456
100 tons and under	4,598	4,854	4,753	4,495	4,309	4,269	3,562	3,046	2,903
Over 100 tons	61,000	63,833	62,956	49,538	48,418	45,534	47,494	38,042	35,553
Room fan-coil air-conditioning units	210,249	183,726	154,604	145,069	126,435	109,787	124,937	97,048	119,989
Vertical stack	31,994	20,063	10,901	13,078	8,326	8,484	7,931	8,143	11,015
Vertical	117,549	101,139	83,042	75,567	69,546	63,129	76,908	58,103	69,620
Horizontal	60,706	62,524	60,661	56,424	48,563	38,174	40,098	30,802	39,354
Room air induction units	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)
Central station air-handling units (motor-driven fan type)	650,321	614,865	567,961	528,329	465,598	429,088	389,786	382,544	341,284
Draw through	558,197	532,922	487,298	447,212	400,040	359,437	316,442	308,803	272,204
Blow through	61,046	48,665	54,455	52,712	42,653	46,978	45,520	50,088	39,462
Heating and ventilating	31,078	33,278	26,208	28,405	22,905	22,673	27,824	23,653	29,618
Air-cooled refrigerant condensers (remote type)	78,961	65,095	62,163			57,791	53,096	50,970	44,508

Under 30 tons	15,198	13,578	16,090	18,414	17,782	19,244	17,792	13,682	13,610
30 to 50 tons	11,033	8,104	8,058	7,562	7,673	8,154	7,918	8,278	5,704
Over 50 tons	52,730	43,413	38,015	32,767	31,111	30,535	27,386	29,010	25,194
Miscellaneous heat transfer equipment:									
Shell-and-tube, shell-and-coil, shell-and-u-tube, tube-in-tube	53,435	50,982	51,706	59,268	66,997	64,831	71,237	71,897	66,202
Condensers	26,287	26,085	26,332	28,619	38,664	38,258	40,579	41,516	39,763
Liquid coolers	27,148	24,897	25,374	30,649	28,333	26,573	30,658	30,381	26,439
Liquid-suction heat exchangers and refrigerant liquid receivers	10,944	11,647	(D)	(D)	(D)	(D)	(D)	(D)	(D)
Central system finned coils (air-conditioning and refrigeration type)	84,617	81,537	83,178	90,966	84,724	86,868	80,685	84,840	91,365
Standard steam and steam distributing tube	16,790	17,435	18,645	17,234	14,517	13,876	13,687	17,201	17,699
Standard water cooling and/or heating and cleanable tube water	60,287	53,669		68,093	64,302	66,218	61,445	62,386	65,821
Volatile refrigerant cooling	7,540	10,433	7,446	5,639	5,905	6,774	5,553	5,253	7,845
Coil sales by original equipment manufacturers intended for resale or assembly into equipment by other manufacturer (all types)	460,919	456,883	428,897	404,839	385,729	385,305	321,341	370,772	345,356
Copper and aluminum	323,049	309,794	284,284	281,417	267,258	269,608	210,902	219,346	215,549
Aluminum (only)	70,949	70,427	65,620	52,162	49,349	52,623	51,707	95,608	80,602
Other, including steel and copper	66,921	76,662	78,993	71,260	69,122	63,074	58,732	55,818	49,205
Factory-assembled, refrigeration type, finned gravity coils, including wetted-	16,005	14,923	13,131	15,052	12,823	12,618	11,169	10,610	9,888

surface dehumidifiers									
Centrifugal liquid chilling packages, hermetic and open types	585,507	695,217	737,252	821,440	766,410	562,420	315,112	228,560	337,229
200 hp and under	46,451	55,993	49,358	52,384	46,301	38,328	31,544	23,080	(D)
201 to 300 hp	75,446	86,914	84,161	88,645	98,240	64,774	56,787	44,543	41,726
301 to 400 hp	87,724	102,961	79,650	88,471	97,594	70,290	51,120	31,185	30,172
Over 400 hp	375,886	449,349	524,083	591,940	524,275	389,028	175,661	129,752	125,425
Absorption refrigeration and dehydration systems	86,555	94,355	(D)	(D)		81,815	83,065		
Reciprocating air and reciprocating water cooled, air-cooled screw, air-cooled scroll, and water- cooled scroll machines	473,484	455,858	433,075	443,480	358,065	376,400	356,408	297,635	266,557
20 hp and under	40,649	41,853	49,396	53,102	44,992	44,680	32,474	33,689	30,723
21 to 49 hp	32,206	36,985	36,458	47,221	33,169	31,290	26,199	26,198	33,806
50 to 75 hp	66,215	81,303	63,236	68,022	49,220	49,567	38,101	35,416	36,224
Over 75 hp	334,414	295,717	283,985	275,135	230,684	250,863	259,634	202,332	165,804
Factory-fabricated water cooling towers	169,868	161,608	161,273	162,184	147,365	132,842	109,987	109,878	100,181
Condensing units, refrigeration (complete)	344,013	339,623	317,273	314,882	286,415	277,479	239,720	202,507	210,372
Air-cooled hermetic-type	246,306	222,923	195,205	209,597	198,456	177,624	147,275	148,580	157,060
1 hp and under	118,928	96,966	76,927	94,734	101,627	91,717	68,992	67,261	59,796
15 hp	14,164	14,000	13,257	14,349	13,686	10,845	12,166	10,206	11,916

2 and 25 hp	20,805	20,563	19,646	21,538	16,201	14,996	13,102	12,735	12,592
3 hp	30,279	26,934	25,690	25,185	22,310	21,482	17,794	19,884	21,235
Over 3 hp, but under 15 hp	62,130	64,460	59,685	53,791	44,632	38,584	35,221	41,275	51,521
Water-cooled hermetic-type, under 15 hp	5,324	5,119	5,089	(D)	(D)	4,420	6,286	6,029	5,775
Water or air-cooled hermetic-type	81,016	66,285	71,316	48,768	42,421	55,271	49,089	44,571	44,857
15 hp	44,848	32,269	54,103	27,367	21,782	26,364	19,936	20,002	18,835
20 hp	5,486	5,541	3,689	4,049	4,401	7,861	5,423	6,234	7,085
25 hp	3,399	4,774	3,089	3,762	2,539	2,715	2,793	3,864	5,339
30 hp	7,441	6,621	3,279	5,200	2,771	5,881	(D)		
40 hp	19,842	17,080	7,156	8,390	10,928	12,450	16,625	14,471	13,598
Water or air-cooled open-type (all sizes)	11,367	(D)	(D)	(D)			3,509	3,580	2,680
Room air-conditioners and dehumidifiers	1,225,230	1,098,416	1,020,171	1,495,609	1,359,413	1,105,844	824,477	820,554	811,751
Electrically operated dehumidifiers, mechanically refrigerated, self-contained	141,716	139,306	131,312	163,438	152,269	127,610	107,424	91,819	104,594
Room air-conditioners	1,083,514	959,110	888,859	1,332,171	1,207,144	978,234	717,053	728,735	707,157
5,999 Btuh and under	156,552	158,955	129,527	193,864	173,906	123,571	103,407	114,401	111,203
6,000 to 6,999 Btuh	40,606	19,878	23,859	67,870	54,859	49,348	46,817	51,191	38,847
7,000 to 7,999 Btuh	67,199	97,169	77,048	130,870	111,041	86,826	50,524	34,006	46,337
8,000 to 8,999 Btuh	94,431	38,617	54,586	78,072	70,385	68,318	60,263	72,000	32,062
9,000 to 9,999 Btuh	28,590	36,842	20,589	32,753	35,776	14,758	14,896	18,310	30056

10,000 to 10,999 Btuh	137,427	128,185	110,192	167,151	142,528	115,303	100,261	87,561	77,430
11,000 to 12,999 Btuh	184,118	176,047	170,646	230,906	213,383	162,806	104,629	108,719	93327
13,000 to 14,999 Btuh	28,825	25,824	29,572	30,462	35,712	29,125	27,559	32,276	37,206
15,000 to 16,999 Btuh	38,881	29,119	41,153	39,915	25,429	21,783	17,772	11,160	11,555
17,000 to 19,999 Btuh	148,699	129,980	114,954	195,056	185,039	158,026	112,226	110,273	118,296
20,000 to 22,999 Btuh	21,897	13,405	11,523	18,926	18,951	17,216	16,492	15,705	26,756
23,000 to 25,999 Btuh	93,928	76,911	73,122	108,024	107,345	96,173	50,188	46,129	53,148
26,000 Btuh and over	42,361	28,178	32,088	38,302	32,790	34,981	26,915	27,004	30,934
Compressors and compressor units 3/ 4/	3,034,234	2,814,238	2,795,669	4623341	4,306,689	3,790,885	3,101,174	2,931,398	2,317,053
All refrigerants (except ammonia)	2,922,480	2,699,413	2,696,380	3,089,470	4,210,641	3,710,619	3,037,529	2,850,883	2,264,672
Hermetic-type motor compressors	2,811,968	2,609,154	2,507,259	2,702,973	2,440,446	2,105,384	1,776,724	1,754,970	1,510,455
Under 3 hp	1,354,931	1,330,806	1,306,660	1,361,349	1,294,667	1,115,298	922,341	906,625	813,886
3 to 10 hp	1,125,172	972,330	975,437	974,241	879,630	765,625	688,676	689,054	539,115
15 hp	30,920	32,902	33,864	32,627	30,374	26,060	24,977	24,461	25,362
20 hp	33,370	31,669	36,162	34,557	34,742	28,086	28,763	24,818	22,608
25 hp	27,227	25,747	29,399	26,093	24,948	21,104	21,319	20,352	22,501
30 hp	27,039	27,873	31,047	29,499	24,181	20,185	18,919	16,326	14,547
40 and 50 hp	51,406	50,609	64,825	58,707	49,307			39,126	36,550
60 hp	16,913	14,498	20,130	17,803	15,018	52,486	47,307	8,931	8,887
75 hp	(D)	(D)	9,735	(D)				7,838	8,090
100 hp and over	(D)	(D)	(D)	(D)	87,579	76,540	24,422	17,439	18,909

Open-type compressors (with or without motor - all sizes)	(D)	69,253	58,754	71,294	55,378	36,429	33,447	39,075	48,362
Screw type	(D)	(D)	(D)	1,806,776	1,714,817	1,605,235	1,227,358	1,056,831	705,855
Ammonia refrigerants (all types)	111,754	114,825	99,289	108,554	96,048	80,266	63,645	80,515	52,381
Nonelectric warm air furnaces and humidifiers	1,564,269	1,606,949	1,558,425	1,678,999	1,522,335	1,523,354	1,334,215	1,216,095	957,333
Oil, forced air:									
150,000 Btuh bonnet output and under	98,897	95,197	106,031	114,027	100,775	137,470	129,838	99,479	60,626
150,001 Btuh bonnet output and over	7,680	9,070	10,215	9,425	9,664	11,142	10,130	8,590	60,626
Gas, forced air:									
150,000 Btuh bonnet output and under	1,216,333	1,260,708	1,197,014	1,314,405	1,165,592	1,163,775	1,096,230	1,027,946	810,821
150,001 to 400,000 Btuh bonnet output	13,523	18,256	7,313	10,844	(D)	20,837	14,131	11,222	13,046
Over 400,000 Btuh bonnet output	156,448	156,059	165,486	158,700	(D)	124,936	23,849	18,943	18,850
All other nonelectric warm air furnaces (Mostly solid fuel like coal, wood, etc)	1,654	2,160	2,072	1,087	(D)	1,847	1,430	1,249	(D)
Humidifiers (attachments to warm air furnaces) (all types), including central systems and self-Humidifiers (attachments to warm air furnaces) (all types), including central systems and self-contained (except portable humidifiers)	69,734	65,499	70,294	70,511	65,850	63,347	58,607	48,666	48,155
Unitary air-conditioners	5,386,341	5,247,751	4,614,616	4,670,915	4,807,452	4,688,524	3,936,501	3,913,435	3,532,970

Single package air-conditioners, with or without evaporator fans, including refrigeration chassis and remote-condenser type	(D)	617,025	520,927	604,492	513,385	496,425	420,035	371,488	336,067
Horizontal	633,594	617,025	520,927	521,704	431,020	411,352	341,845	311,326	268,876
Under 27,000 Btuh	25,978	25,085	21,567	20,711	19,112	16,722	14,757	11,035	14,268
27,000 to 32,999 Btuh	36,653	33,032	42,943	40,493	35,775	32,329	26,229	18,963	17,141
33,000 to 53,999 Btuh	91,381	90,878	80,617	96,108	82,291	79,162	61,296	52,287	44,293
54,000 to 64,999 Btuh	57,235	64,429	51,216	47,206	42,089	38,862	35,362	30,818	28,138
65,000 to 96,999 Btuh	48,265	51,726	45,092	41,939	37,750	34,555	30,914	25,310	20,777
97,000 to 134,999 Btuh	52,861	54,600	50,470	49,674	45,769	41,718	33,195	35,993	27,601
135,000 to 184,999 Btuh	43,500	47,152	40,527	42,086	35,652	34,569	38,670	37,269	26,284
185,000 to 249,999 Btuh	46,817	46,599	37,595	35,608	36,669	35,077	27,048	31,977	25,686
250,000 to 319,999 Btuh	40,982	40,970	35,724	34,607	30,621	26,995	20,895	16,045	12,770
320,000 to 379,999 Btuh	21,016	16,540	13,792	13,575	8,432	10,015	6,856	6,917	6,967
380,000 Btuh and over	168,906	146,014	101,384	99,697	56,860	61,348	46,623	44,712	44,951
Other than horizontal	(D)	(D)	83,630	82,788	82,365	85,073	78,190	39,924	67,191
Under 54,000 Btuh	(D)	(D)	(D)	(D)		(D)	(D)	20,238	18,192
54,000 to 64,999 Btuh	(D)	11,951	15,537	15,009	47,672	11,057	10,987	8,527	8,295
65,000 to 96,999 Btuh	1,852	1,822	2,028	2,273	2,192	2,248	3,274	3,585	4,322
97,000 to 134,999 Btuh	2,921	2,994	2,895	3,117	3,149	3,033	(D)	4,454	5,994
135,000 to 184,999 Btuh	3,621	5,110	4,422	4,209	3,668	5,126	5,479	5,568	8,195
185,000 Btuh and over	(D)	(D)	(D)	(D)	25,684	29,433	27,644	17,790	22,193

Year-round air-conditioners, single package and remote-condenser type (except heat pumps)	1,543,564	1,429,261	1,280,158	1,192,159	1,098,062	1,028,579	842,423	824,592	757,013
Under 33,000 Btuh	130,756	135,484	119,690	118,989	118,341	128,566	96,407	109,889	97,731
33,000 to 38,999 Btuh	132,085	125,277	110,164	115,313	110,318	101,267	104,569	92,009	89,904
39,000 to 43,999 Btuh	38,665	42,878	34,572	38,570	35,126	31,481	25,952	37,790	24,030
44,000 to 53,999 Btuh	98,072	92,234	78,174	74,210	64,478	67,753	58,383	52,157	50,783
54,000 to 64,999 Btuh	180,439	160,052	138,043	132,665	116,193	109,120	93,443	93,883	82,832
65,000 to 134,999 Btuh	327,655	313,294	286,559	260,522	244,675	220,660	150,457	173,937	157,769
135,000 to 184,999 Btuh	159,719	155,363	144,300	130,761	131,975	118,950	108,200	88,067	70,859
185,000 to 249,999 Btuh	123,634	109,275	104,329	93,716	93,623	85,921	68,160	58,337	50,897
250,000 to 319,999 Btuh	72,734	66,828	59,440	53,652	62,098	51,525	35,515	26,106	23,709
320,000 to 379,999 Btuh	34,154	30,049	32,668	22,101	17,723	20,633	16,068	13,842	17,332
380,000 to 539,999 Btuh	43,394	35,238	33,891	28,380	21,063	27,377	23,543	20,370	20,452
540,000 to 639,999 Btuh	50,137	43,198	39,923	35,864	20,229	19,544	14,968	12,858	11,087
640,000 Btuh and over	152,120	120,091	98,405	87,416	62,220	45,782	46,758	45,347	59,628
Water source heat pumps (except room air-conditioners)	133,971	129,668	116,280	(D)	120,378	105,771	111,513	101,621	102,424
Split system air-conditioning condensing units	2,138,899	2,168,059	1,879,622	2,035,244	1,653,676	1,648,339	1,348,018	1,378,934	1,217,019
Under 22,000 Btuh	98,523	114,849	97,524	99,258	83,156	76,888	62,871	64,352	73,386
22,000 to 26,999 Btuh	301,289	317,102	272,568	311,905	255,287	238,751	187,615	208,676	171,845
27,000 to 32,999 Btuh	306,805	354,077	309,400	367,264	300,764	274,825	213,481	252,260	198,266
33,000 to 38,999 Btuh	470,800	401,393	356,410	395,551	299,427	356,132	291,495	283,548	263,080

39,000 to 43,999 Btuh	201,883	232,181	202,181	222,018	184,654	161,761	121,681	116,617	100,117
44,000 to 53,999 Btuh	298,008	275,339	234,770	242,799	200,738	210,077	178,268	158,190	142,458
54,000 to 64,999 Btuh	259,275	275,513	227,685	228,003	175,783	189,607	164,711	160,706	139,641
65,000 to 96,999 Btuh	34,002	38,874	32,878	30,730	27,024	23,362	23,447	25,675	25,279
97,000 to 134,999 Btuh	34,870	39,347	34,885	31,217	29,301	25,842	25,060	25,603	24,253
135,000 to 184,999 Btuh	51,092	32,993	29,839	26,860	24,981	25,546	24,533	23,948	21,376
185,000 to 249,999 Btuh	22,147	24,734	22,796	20,671	17,723	14,240	13,784	14,488	14,395
250,000 to 319,999 Btuh	9,482	10,458	9,244	9,758	9,206	8,311	7,122	7,967	7,430
320,000 to 379,999 Btuh	11,304	13,137	11,898	12,034	10,204	9,811	9,017	8,897	7,538
380,000 to 539,999 Btuh	11,662	12,789	13,155	12,461	11,342	10,539	9,527	9,305	9,432
540,000 to 639,999 Btuh	6,792	7,912	7,313	7,237	6,552	6,590	4,492	5,311	
640,000 Btuh and over	20,965	17,361	17,076	17,478	17,534	16,057	10,914	13,391	
Split system air-conditioning coils	663,239	666,305	616,439	592,513	519,471	519,481	465,036	466,764	408,891
With blower	431,908	435,716	389,252	366,882	324,868	322,903	290,244	299,993	255,099
Without blower	231,331	230,589	227,187	225,631	194,603	196,578	174,792	166,771	153,792
Air source heat pumps (except room air-conditioners)	997,059	1,053,837	917,152	1,114,276	790,146	778,375	686,641	670,322	626,306
Single package:									
Under 27,000 Btuh	25,592	33,343	26,217	25,756	21,030	20,392	17,631	21,483	26,215
27,000 to 41,999 Btuh	108,295	139,897	112,290	100,356	75,979	75,149	59,291	57,860	57,057
42,000 to 64,999 Btuh	104,940	119,504	98,310	84,428	60,381	57,590	48,429	44,640	49,988
65,000 Btuh and over	46,917	50,884	44,162	35,067	34,729	32,426	29,960	36,920	27,017

Split system:									
Under 27,000 Btuh	170,857	168,415	145,805	193,959	140,463	130,536	110,325	109,878	102,970
27,000 to 41,999 Btuh	291,356	306,067	282,096	397,002	273,913	278,692	248,326	235,441	215,130
42,000 to 64,999 Btuh	213,653	202,904	177,201	246,872	156,733	159,454	147,138	142,401	131,384
65,000 Btuh and over	35,449	32,823	31,071	30,836	26,918	24,136	25,541	21,699	16,545
Ground and ground water source heat pumps	105,006	(D)	(D)						
Single and split systems:				(NA)					
Under 27,000 Btuh	(D)	(D)	(D)	(NA)					
27,000 to 41,999 Btuh	(D)	(D)	(D)	(NA)					
42,000 to 64,999 Btuh	11,274	(D)	(D)	(NA)					
65,000 Btuh and over	(D)	(D)	(D)	(NA)					

Targets:

Residential and Commercial Business Development

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