CHAPTER 5

DECENTRALIZED COOLING AND HEATING

PACKAGED UNIT SYSTEMS are applied to almost all classes of buildings. They are especially suitable for smaller projects with no central plant where low initial cost and simplified installation are important. These units are installed in office buildings, shopping centers, manufacturing plants, hotels, motels, schools, medical facilities, nursing homes, and other multiple-occupancy dwellings. They are also suited to air conditioning existing buildings with limited life or income potential. Applications also include facilities requiring specialized high performance levels, such as computer rooms and research laboratories.

SYSTEM CHARACTERISTICS

These systems are characterized by several separate air-conditioning units, each with an integral refrigeration cycle. The components are factory designed and assembled into a package that includes fans, filters, heating coil, cooling coil, refrigerant compressor(s), refrigerant-side controls, air-side controls, and condenser. The equipment is manufactured in various configurations to meet a wide range of applications. Examples include window air conditioners, through-the-wall room air conditioners, unitary air conditioners for indoor and outdoor locations, air-source heat pumps, and water-source heat pumps. Specialized packages for computer rooms, hospitals, and classrooms are also available.

Commercial grade unitary equipment packages are available only in pre-established increments of capacity with set performance parameters, such as the sensible heat ratio at a given room condition or the cubic feet of air per minute per ton of refrigeration. Components are matched and assembled to achieve specific performance objectives. These limitations make the manufacture of low cost, quality-controlled, factory-tested products practical. For a particular kind and capacity of unit, performance characteristics vary among manufacturers. All characteristics should be carefully assessed to ensure that the equipment performs as needed for the application. Several trade associations have developed standards by which manufacturers may test and rate their equipment. Chapter 45 and Chapter 46 describe the equipment used in multiple-packaged unitary systems and the pertinent industry standards.

Large commercial/industrial grade equipment can be custom designed by the factory to meet specific design conditions and job requirements. This equipment carries a higher first cost and is not readily available in smaller sizes.

Self-contained units can use multiple compressors to control refrigeration capacity. For variable air volume systems, compressors are turned on or off or unloaded to maintain the discharge air temperature. As airflow is decreased, the temperature of the air leaving the unit can often be reset upward so that a minimum ventilation rate can be maintained. Resetting the discharge air temperature is a way of demand limiting the unit, thus saving energy.

Although the equipment can be applied as a single unit, this chapter covers the application of multiple units to form a complete air-conditioning system for a building. Multiple, packaged-unit systems for perimeter spaces are frequently combined with a central all-air or floor-by-floor system. These combinations can provide better humidity control, air purity, and ventilation than packaged units alone. Air-handling systems may also serve interior building spaces that cannot be conditioned by wall or window-mounted units.

Advantages of Packaged Systems

- Heating and cooling capability can be provided at all times, independent of the mode of operation of other spaces in the building.
- Manufacturer-matched components have certified ratings and performance data.
- Assembly by a manufacturer helps ensure better quality control and reliability.
- Manufacturer instructions and multiple-unit arrangements simplify the installation through repetition of tasks.
- Only one unit conditioner and one zone of temperature control are affected if equipment malfunctions.
- System is readily available.
- One manufacturer is responsible for the final equipment package.
- For improved energy control, equipment serving vacant spaces can be turned off locally or from a central point, without affecting occupied spaces.
- System operation is simple. Trained operators are not required.
- Less mechanical and electrical room space is required than with central systems.
- Initial cost is usually low.
- Equipment can be installed to condition one space at a time as a building is completed, remodeled, or as individual areas are occupied, with favorable initial investment.
- Energy can be metered directly to each tenant.

Disadvantages of Packaged Systems

- Limited performance options may be available because airflow, cooling coil size, and condenser size are fixed.
- A larger total building installed cooling capacity is usually required because the diversity factors used for moving cooling needs do not apply to dedicated packages.
- Temperature and humidity control may be less stable especially with mechanical cooling at very low loads.
- Standard commercial units are not generally suited for large percentages of outside air or for close humidity control. Custom equipment or special purpose equipment such as packaged units for computer rooms or large custom units may be required.
- Energy use is usually greater than for central systems, if efficiency of the unitary equipment is less than that of the combined central system components.
- Low cost cooling by outdoor air economizers is not always available.
- Air distribution control may be limited.
- Operating sound levels can be high.
- Ventilation capabilities are fixed by equipment design.

The preparation of this chapter is assigned to TC 9.1, Large Building Air-Conditioning Systems.

- Overall appearance can be unappealing.
- Air filtration options may be limited.
- Discharge temperature varies because control is either on or off or in steps.
- Maintenance may be difficult because of the many pieces of equipment and their location.

ECONOMIZERS

Air-Side Economizers

The air-side economizer takes advantage of cool outdoor air to either assist mechanical cooling or, if the outdoor air is cool enough, provide total cooling. It requires a mixing box designed to allow 100% of the air to be drawn from outside. It can be field-installed accessory that includes an outdoor air damper, relief damper, return air damper, filters, actuator, and linkage. Controls are usually a factory-installed option.

Self-contained units usually do not include return air fans. A variable-volume relief fan must be installed with the air-side economizer. The relief fan is off and discharge dampers are closed when the air-side economizer is inactive.

Advantages of Air-Side Economizers

- Substantially reduces compressor, cooling tower, and condenser water pump energy requirements.
- Has a lower air-side pressure drop than a water-side economizer.
- Reduces tower makeup water and related water treatment.

Disadvantages of Air-Side Economizers

- In systems with larger return air static pressure requirements, return fans or exhaust fans are needed to properly exhaust building air and intake outside air.
- If the unit's leaving air temperature is also reset up during the air-side economizer cycle, humidity control problems may occur and the fan may use more energy.
- Humidification may be required during winter operation.

Water-Side Economizer

The water-side economizer is another option for reducing energy use. ASHRAE *Standard* 90.1 addresses its application. The water-side economizer consists of a water coil located in the self-contained unit upstream of the direct-expansion cooling coil. All economizer control valves, piping between the economizer coil, and the condenser and economizer control wiring can be factory installed (Figure 1).

The water-side economizer takes advantage of the low cooling tower or evaporative condenser water temperature to (1) either precool the entering air, (2) assist mechanical cooling, or, (3) if the cooling water is cold enough, provide total system cooling. If the economizer is unable to maintain the supply air set point for variable-air-volume units or zone set point for constant-volume units, factory-mounted controls integrate economizer and compressor operation to meet cooling requirements.

Cooling water flow is controlled by two valves (Figure 1), one at the economizer coil inlet (A) and one in the bypass loop to the condenser (B). Two control methods are common—constant water flow and variable water flow.

Constant water flow control allows constant condenser water flow during unit operation. The two control valves are factory wired for complementary control, where one valve is driven open while the other is driven closed. This keeps water flow through the unit relatively constant.

Variable modulating control allows variable condenser water flow during unit operation. The valve in the bypass loop (B) is an on-off valve and is closed when the economizer is enabled. Water flow through the economizer coil is modulated by valve A, thus allowing variable cooling water flow. As the cooling load increases,

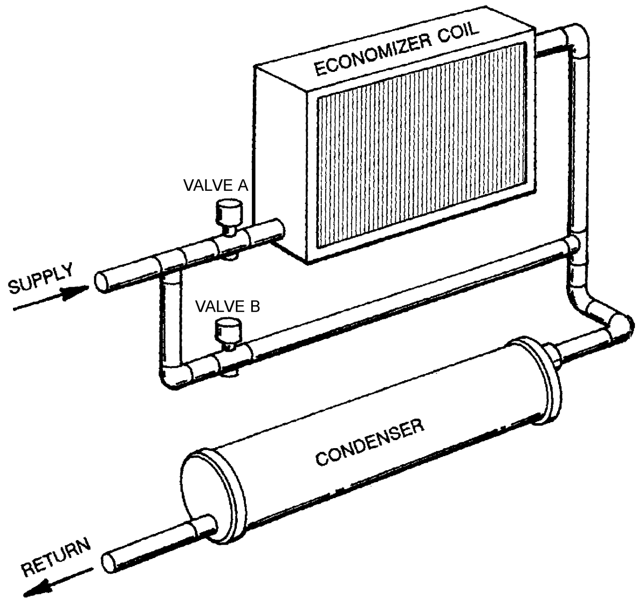

Fig. 1 Water-Side Economizer and Valves

valve A opens, increasing water flow through the economizer coil. If the economizer is unable to satisfy the cooling requirements, factory-mounted controls integrate economizer and compressor operation. In this operating mode, valve A is fully open. When the self-contained unit is not in the cooling mode, both valves are closed. Reducing or eliminating cooling water flow reduces pumping energy.

Advantages of Water-Side Economizers

- Reduces compressor energy by precooling entering air. Often the building load can be completely satisfied with an entering condenser water temperature of less than 55°F. Because the wet-bulb temperature is always less than or equal to the dry-bulb temperature, a lower discharge air temperature is often times available.
- Building humidification may not be required if return air contains sufficient humidity to satisfy the winter requirement.
- No external wall penetration is required for exhaust or outdoor air ducts.
- Mechanical equipment rooms can be centrally located in a building.
- Controls are less complex than for air-side economizers, because they often reside inside the packaged unit.
- Coil can be mechanically cleaned.
- More net usable floor area is available because large fresh air and relief air ducts are unnecessary.

Disadvantages of Water-Side Economizers

- Cooling tower water treatment cost is greater.
- Air-side pressure drop may be increased.
- Condenser water pump may see slightly higher pressure.
- Cooling tower must be designed for winter operation.
- The increased operation (including winter operation) required of the cooling tower may reduce its life.

THROUGH-THE-WALL AND WINDOW-MOUNTED AIR CONDITIONERS AND HEAT PUMPS

A window air conditioner (air-cooled room conditioner), which is further described in Chapter 46, is designed to cool or heat individual room spaces. Window units are used where low initial cost, quick installation, and other operating or performance criteria outweigh the advantages of more sophisticated systems. Room units are also available in through-the-wall sleeve mountings. Sleeve-installed units are popular in low-cost apartments, motels, and homes.

Window units may be used as auxiliaries to a central heating or cooling system or to condition selected spaces when the central system is shut down. In such applications, these units usually serve only part of the spaces conditioned by the basic system. Both the basic system and the window units should be sized to cool the space adequately without the other operating.

A through-the-wall air-cooled room air conditioner is designed to cool or heat individual room spaces. Design and manufacturing parameters vary widely. Specifications range from appliance grade through heavy-duty commercial grade, the latter known as packaged terminal air conditioners (ARI *Standard* 310). With proper maintenance, manufacturers project a life expectancy of 10 to 15 years for these units.

Advantages

- Initial cost is generally less than for a central system adapted to heat or cool each room under the control of the room occupants.
- Because no energy is needed to transfer air or chilled water from mechanical equipment rooms, the energy consumption may be lower than for central systems. However, this advantage may be offset by the lower efficiency of this type of equipment.
- Building space is conserved because ductwork and mechanical rooms are not required.
- Installation is simple. It usually only requires a hole in the wall or displacement of a window to mount the unit and connection to electrical power.
- Generally, the system is well-suited to spaces requiring many zones of individual temperature control.
- Designers can specify electric, hydronic, or steam heat or use an air-to-air heat pump design.
- Service can be quickly restored by replacing a defective chassis with a spare.

Disadvantages

- Equipment life is relatively short, typically 10 years; window units are built to appliance standards, rather than building equipment standards.
- May have relatively high energy use.
- Requires outside air; thus, cannot be used for interior rooms. Packaged terminal air conditioners must be installed on the perimeter of the building.
- The louver and wall box must stop wind-driven rain from collecting in the wall box and leaking into the building. The wall box should drain to the outside.
- Condensate removal can cause dripping on walls, balconies, or sidewalks.
- Temperature control is usually two-position, which causes swings in room temperature.
- Air distribution control is limited.
- Ventilation capabilities are fixed by equipment design.
- Overall appearance can be unappealing.
- Air filtration options are limited.
- Humidification, when required, must be provided by separate equipment.
- Noise levels vary considerably and are not generally suitable for critical applications.
- Routine unit maintenance is required to maintain capacity. Condenser and cooling coils must be cleaned, and filters must be changed regularly.

Design Considerations

Units are usually furnished with individual electric controls. However, when several units are used in a single space, the controls should be interlocked to prevent simultaneous heating and cooling. In commercial applications (e.g., motels), centrally operated switches can de-energize units in unoccupied rooms.

A through-the-wall or window-mounted air-conditioning unit incorporates a complete air-cooled refrigeration and air-handling system in an individual package. Each room is an individual occupant-controlled zone. Cooled or warmed air is discharged in response to thermostatic control to meet room requirements. The section on Controls describes how controls allow the use of individual room systems during off-schedule hours, but automatically return all systems to normal schedule use.

Each packaged terminal air conditioner has a self-contained, air-cooled direct-expansion cooling system; a heating system (electric, hot water, or steam); and controls. Two general configurations are shown—Figure 2 shows a wall box, an outdoor louver, heater section, cooling chassis, and cabinet enclosure; Figure 3 shows a combination wall sleeve cabinet, plus combination heating and cooling chassis with outdoor louver.

A through-the-wall air conditioner or heat pump system is installed in buildings requiring many temperature control zones such as (1) office buildings, (2) motels and hotels, (3) apartments and dormitories, (4) schools and other education buildings, and (5) areas of nursing homes or hospitals where air recirculation is allowed.

These units can be used for renovation of existing buildings, because existing heating systems can still be used. The equipment

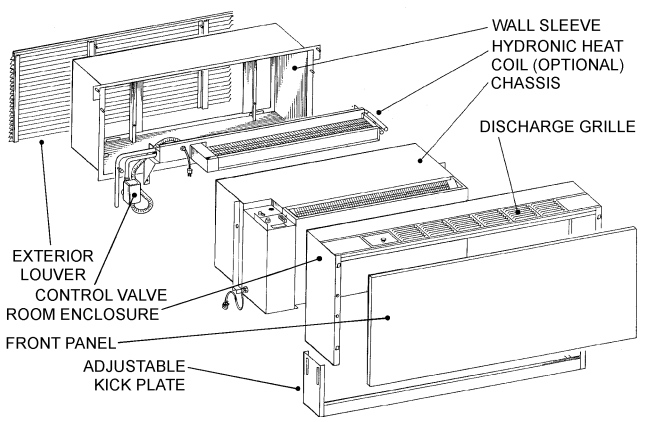

Fig. 2 Packaged Terminal Air Conditioner with Heating Section Separate from Cooling Chassis

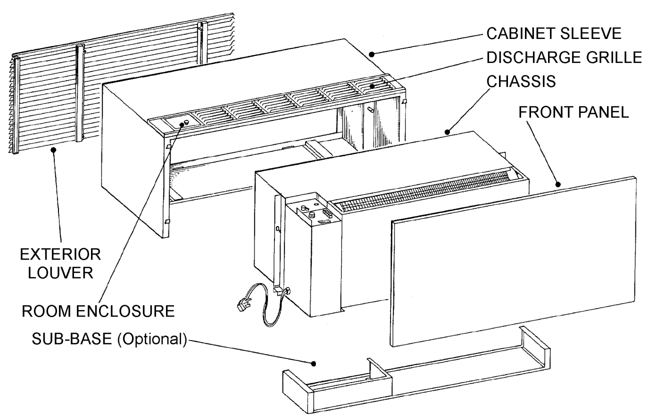

Fig. 3 Packaged Terminal Air Conditioner with Combination Heating and Cooling Chassis

can be used in both low- and high-rise buildings. In buildings where a stack effect is present, use should be limited to those areas that have dependable ventilation and a tight wall of separation between the interior and exterior.

Room air conditioners are often used in parts of buildings primarily conditioned by other systems, especially where spaces to be conditioned are (1) physically isolated from the rest of the building and (2) occupied on a different time schedule (e.g., clergy offices in a church and ticket offices in a theater).

Ventilation air through each terminal may be inadequate in many situation, particularly in high-rise structures because of the stack effect. Chapter 26 of the *ASHRAE Handbook—Fundamentals* explains combined wind and stack effects. Electrically operated outdoor air dampers, which close automatically when the equipment is stopped, reduce heat losses in winter.

Refrigeration Equipment

Room air conditioners are generally supplied with hermetic reciprocating, or scroll compressors. Capillary tubes are used in place of expansion valves in most units.

Some room air conditioners have only one motor to drive both the evaporator and condenser fans. The unit circulates air through the condenser coil whenever the evaporator fan is running, even during the heating season. The annual energy consumption of a unit with a single motor is generally higher than one with a separate motor, even when energy efficiency ratio (coefficient of performance) is the same for both. The year-round continuous flow of air through the condenser increases dirt accumulation on the coil and other components, which increases maintenance costs and reduces equipment life.

Because through-the-wall conditioners are seldom installed with drains, they require a positive and reliable means of condensate disposal. Conditioners are available that spray the condensate in a fine mist over the condenser coil. These units dispose of more condensate than can be developed without any drip, splash, or spray. In heat pumps, provision must be made for disposal of condensate generated from the outside coil during the defrost cycle.

Many air-cooled room conditioners experience evaporator icing and become ineffective when the outdoor temperature falls below about 65°F. Units that ice at a lower outdoor temperature may be required to handle the added load created by the high lighting levels and high solar radiation found in contemporary buildings.

Heating Equipment

The air-to-air heat pump cycle described in Chapter 45 of this volume is available in through-the-wall room air conditioners. Application considerations are quite similar to conventional units without the heat pump cycle, which is used for space heating when the outdoor temperature is above 35 to 40°F. Electric resistance elements supply heating below this level and during defrost cycles.

The prime advantage of the heat pump cycle is that it reduces the annual energy consumption for heating. Savings in heat energy over conventional electric heating ranges from 10 to 60%, depending on the climate.

Controls

All controls for through-the-wall air conditioners are included as a part of the conditioner. The following control configurations are available:

Thermostat Control. Thermostats are either unit mounted or remote wall mounted.

Guest Room Control for Motels and Hotels. This has provisions for starting and stopping the equipment from a central point.

Office Building and School Controls. These controls (for occupancies of less than 24 h) start and stop the equipment at preset times with a time clock. The conditioners operate normally with the unit thermostat until the preset cutoff time. After this point, each conditioner has its own reset control, which allows the occupant of the conditioned space to reset the conditioner for either cooling or heating, as required.

Master/Slave Control. This type of control is used when multiple conditioners are operated by the same thermostat.

Emergency Standby Control. Standby control allows a conditioner to operate during an emergency, such as a power failure, so that the roomside blowers can operate to provide heating. Units must be specially wired to allow operation on emergency generator circuits.

Acoustics

The noise from these units may be objectionable and should be checked to ensure it meets sound level requirements.

INTERCONNECTED ROOM-BY-ROOM SYSTEMS

Multiple-unit systems generally use single-zone unitary air conditioners with a unit for each zone (Figure 4). Zoning is determined by (1) cooling and heating loads, (2) occupancy considerations, (3) flexibility requirements, (4) appearance considerations, and (5) equipment and duct space availability. Multiple-unit systems are popular for office buildings, manufacturing plants, shopping centers, department stores, and apartment buildings. Unitary self-contained units are excellent for renovation.

A common condensing and heat source loop connects all units together. Heat pumped into the loop by units in the cooling mode can be reclaimed by units in a heat pump heating mode. During moderate weather and in buildings with high diversity in cooling and heating loads, these systems will tend to balance the building load. Heat from warm areas are in effect moved to cooler areas of the building. This minimizes the amount of auxiliary loop heating and cooling required. Figure 5 shows a typical unit with some commonly used components.

Advantages

- Installation is simple. Equipment is readily available in sizes that allow easy handling.
- Relocation of units to other spaces or buildings is practical, if necessary.

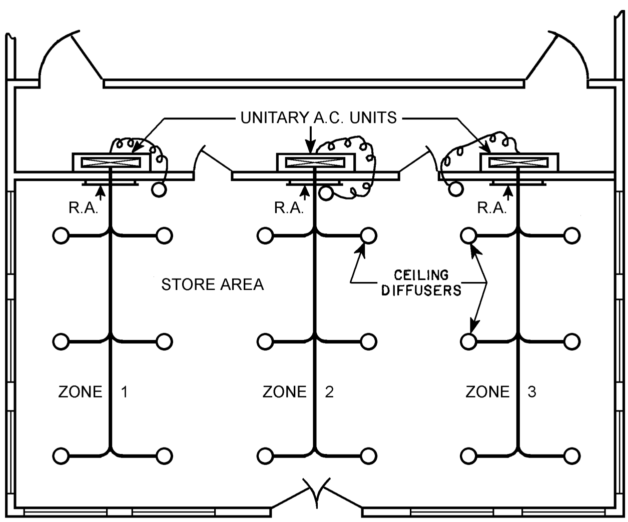

Fig. 4 Multiple Packaged Units

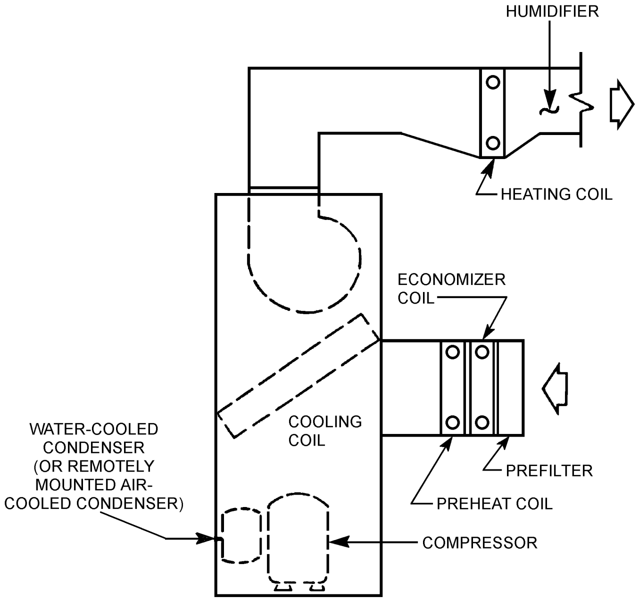

Fig. 5 Unitary Packaged Unit with Accessories

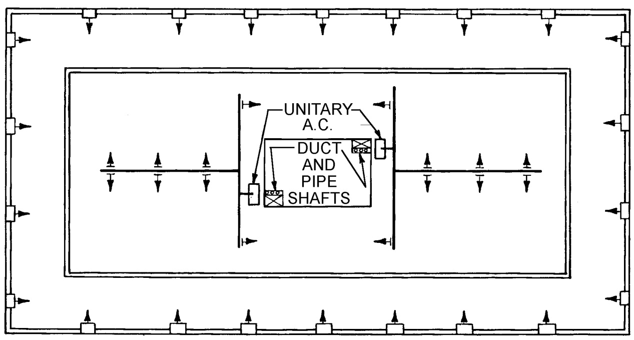

Fig. 6 Multiroom, Multistory Office Building with Unitary Core and Through-the-Wall Perimeter Air Conditioners

- Units are available with complete, self-contained control systems that include variable volume control, economizer cycle, night set-back, and morning warm-up.
- Easy access to equipment facilitates routine maintenance.

Disadvantages

- Fans may have limited static pressure ratings.
- Integral air-cooled units must be located along outside walls.
- Multiple units and equipment closets or rooms may occupy rentable floor space.
- Close proximity to building occupants may create noise problems.
- Discharge temperature may vary too much because of on-off or step control.

Design Considerations

Unitary systems can be used throughout a building or to supplement perimeter area packaged terminal units (Figure 6). Because core areas frequently have little or no heat loss, unitary equipment with water-cooled condensers can be applied with water-source heat pumps serving the perimeter.

In this multiple-unit system, one unit may be used to precondition outside air for a group of units (Figure 7). This all-outdoor air

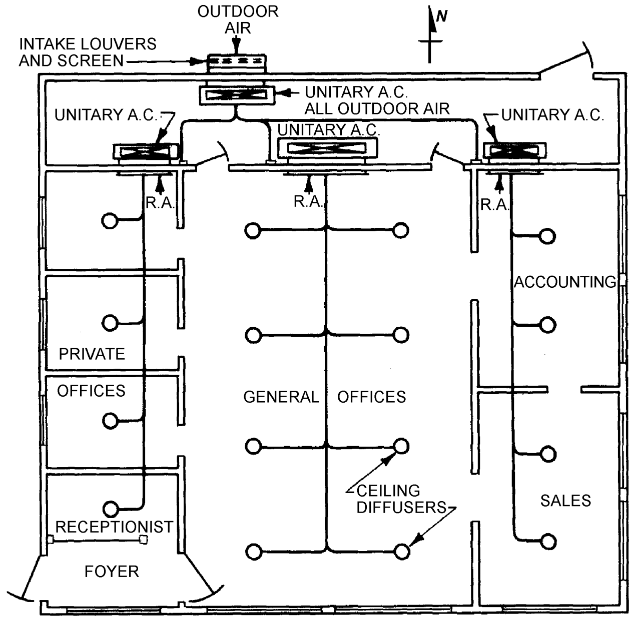

Fig. 7 Multiple-Packaged Units with Separate Outdoor Air Makeup Unit

unit prevents hot, humid air from entering the conditioned space under periods of light load. The outdoor unit should have sufficient capacity to cool the required ventilation air from outdoor design conditions to interior design dew point. Zone units are then sized to handle only the internal load for their particular area.

Special-purpose unitary equipment is frequently used to cool, dehumidify, humidify, and reheat to maintain close control of space temperature and humidity in computer areas. Chapter 17 of the *ASHRAE Handbook—Applications* has more information.

Refrigeration Equipment

Compressors are usually hermetic, reciprocating, or scroll compressors. Capillary tubes are used for expansion. Condensers are water cooled and connected to a central loop. A cooling tower or fluid cooler supplies supplemental cooling to the central loop as required.

Heating Equipment

The heating cycle on interconnected systems primarily uses an air-to-water heat pump. Supplemental heat to the loop is supplied with a central boiler

Controls

Units under 20 tons of cooling are typically constant-volume units. Variable-air-volume distribution is accomplished with a bypass damper that allows excess supply air to bypass to the return air duct. The bypass damper ensures constant airflow across the direct-expansion cooling coil to avoid coil freeze-up due to low air flow. The damper is usually controlled by the supply duct pressure.

Economizer Cycle. When the outdoor temperature permits, energy use can be reduced in many locales by cooling with outdoor air in lieu of mechanical refrigeration. Units must be located close to an outside wall or outside air duct shafts. Where this is not possible, it may be practical to add an economizer cooling coil adjacent to the preheat coil (Figure 5). Cold water is obtained by cooling the condenser water through a winterized cooling tower. Chapter 36 has further details.

Acoustics

Because these units are typically located near the occupied space, they can have a significant effect on acoustics. The designer must study both the airflow breakout path and the unit's radiated sound power when selecting wall and ceiling construction surrounding the unit. Locating units over non-critical work spaces such as restrooms or storage areas around the equipment room helps reduce noise in the occupied space.

RESIDENTIAL AND LIGHT-COMMERCIAL SPLIT SYSTEMS

A split system consists of an indoor unit with air distribution and temperature control with either a water-cooled condenser, integral air-cooled condenser, or remote air-cooled condenser. These units are commonly used in single-story or low-rise buildings, and residential applications where condenser water is not readily available. Commercial split systems are well-suited to office environments with variable occupancy schedules.

The indoor equipment is generally installed in service areas adjacent to the conditioned space. When a single unit is required, the indoor unit and its related ductwork constitute a central air system, as described in Chapter 4.

Typical components of a split-system air conditioner include an indoor unit with evaporator coils, economizer coils, heating coils, filters, valves, and a condensing unit with the compressors and condenser coils.

Advantages

- Unitary split-system units (Figure 8) allow air-handling equipment to be placed close to the air-conditioning load, which allows ample air distribution to the air-conditioned space with a minimum amount of ductwork and fan power.
- Heat rejection through a remote air-cooled condenser allows the final heat rejector to be located remote from the air-conditioned space.
- A floor-by-floor arrangement can offer reduced fan power consumption because the air handlers are located close to the air-conditioned space.
- Large vertical duct shafts and fire dampers are eliminated.
- Commercial split systems generally reduce mechanical room area. Equipment is generally located in the building interior near elevators and other service areas and does not interfere with the building perimeter.

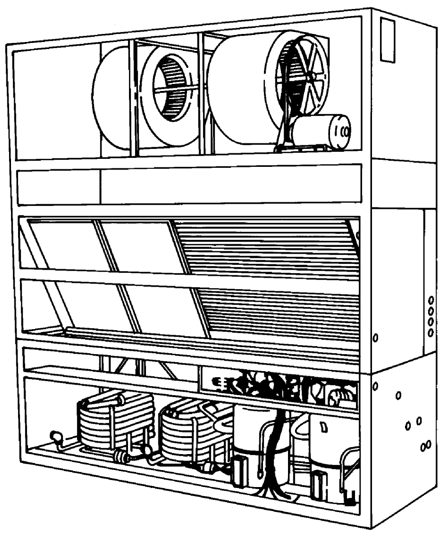

Fig. 8 Vertical Self-Contained Unit

Disadvantages

- The close proximity of the air handler to the air-conditioned space requires special attention to unit inlet and outlet airflow and to building acoustics around the unit.
- Ducting ventilation air to the unit and removing condensate from the cooling coil should be considered. Separate outdoor air systems are commonly applied in conjunction with the split system.
- A unit that uses an air-side economizer must be located near an outside wall or outdoor air shaft. Split-system units do not generally include return air fans.
- A separate method of handling and controlling relief air must be incorporated if required.

Design Considerations

Building characteristics that favor split systems include

- Multiple floors or zones
- Renovation work
- Historic structures
- Multiple tenants per floor with variable schedules
- Common return air paths

The modest space requirements of split-system equipment make it an excellent choice for renovations or for providing air conditioning to previously non-air-conditioned, historic structures. Control is usually one- or two-step cool and one- or two-step or modulating heat. Variable-air-volume operation is possible with a supply air bypass. Some commercial units are capable of airflow modulation with additional cooling modulation with a hot gas bypass.

Commercial split-system equipment can incorporate an integral water-side economizer coil and controls, thus allowing an interior location. In this configuration, the outdoor air shaft is reduced to meet only ventilation and space pressurization requirements.

Refrigeration Equipment

Compressors supplied on these units are usually hermetic or semihermetic reciprocating or scroll compressors. Smaller units have capillary tubes while larger units system have thermostatic expansion valves. Larger systems may also use multiple- or two-speed compressors. Compressors are usually located in the remote condensing unit instead of with the indoor equipment.

Heating Equipment

Heating systems available include electric resistance, indirect fired gas, or air-to-air heat pumps. Larger systems may also have available hot water or steam heating coils.

Controls

Commercial split-system units are available as constant-volume equipment for use in atriums, public areas, and industrial applications. Unit options include fan modulation and variable-air-volume control. When applied with variable-air-volume terminals, commercial split systems provide excellent comfort and individual zone control.

Acoustics

As with any unit with components in the occupied space, acoustics are a concern. Many commercial split-system units include a factory-engineered acoustical discharge plenum, which facilitates a smooth supply air discharge from the equipment room. This allows lower fan power and lower sound power levels. This discharge arrangement also reduces the size of the equipment room.

COMMERCIAL SELF-CONTAINED (FLOOR-BY-FLOOR) SYSTEMS

Commercial, self-contained systems provide central air distribution, refrigeration, and system control on a zone or floor-by-floor basis. Typical components include compressors, water cooled condensers, evaporator coils, economizer coils, heating coils, filters, valves, and controls (Figure 9). To complete the system, a building needs cooling towers and condenser water pumps.

Advantages

- Units are well-suited for office environments with variable occupancy schedules.
- The floor-by-floor arrangement can offer reduced fan power consumption.
- Large vertical duct shafts and fire dampers are eliminated.
- Electrical wiring, condenser water piping, and condensate removal are centrally located.
- Commercial self-contained systems generally require less mechanical room area.
- Equipment is generally located in the building interior near elevators and other service areas and does not interfere with the building perimeter.
- Integral water-side economizer coil and controls allow an interior equipment location and eliminate large outdoor air and exhaust ducts and relief fans.
- This equipment integrates refrigeration, air-handling, and controls into a factory package, thus eliminating many field integration problems.
- An acoustical discharge plenum allows lower fan power and lower sound power levels.
- Cost of operating cooling equipment after normal building hours is reduced by operating only units in occupied areas.

Disadvantages

- Units must be located near an outside wall or outdoor air shaft to incorporate an air-side economizer.
- A separate relief air system and controls must be incorporated if an air-side economizer is used.

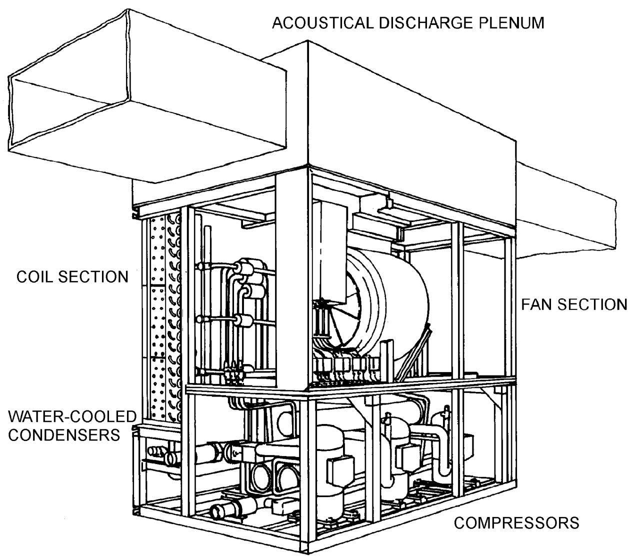

Fig. 9 Commercial Self-Contained Unit with Discharge Plenum

- Close proximity to building occupants requires careful analysis of space acoustics.
- Filter options may be limited.
- Discharge temperature varies because of on-off or step control.

Design Considerations

Commercial self-contained units can serve either variable-air-volume or constant-volume systems. These units contain one or two fans—either forward curved (FC), backward inclined (BI), or airfoil (AF)—inside the cabinet. The fans are commonly configured in a draw-through arrangement.

The size and diversity of the zones served often dictate which system is optimal. For comfort applications, variable-air-volume self-contained units coupled with terminal boxes or fan powered terminal boxes are popular for their energy savings, individual zone control, and acoustic benefits. Constant-volume self-contained units have a low installation cost and are often used in non-comfort or industrial air-conditioning applications or in single-zone comfort applications.

Unit airflow is reduced in response to terminal boxes closing. Several common methods used to modulate the airflow delivered by the fan to match system requirements include inlet guide vanes, fan speed control, inlet/discharge dampers, and multiple speed fan motors.

Appropriate outside air and exhaust fans and dampers work in conjunction with the self-contained unit. Their operation must be coordinated with the unit operation to maintain design air exchange and building pressurization.

Refrigeration Equipment

Self-contained units may control capacity with multiple compressors. For variable-air-volume systems, compressors are turned on or off or unloaded to maintain discharge air temperature. Hot gas bypass is many time incorporated to provide additional capacity control. As system airflow decreases, the temperature of air leaving the unit is often reset upward so that a minimum ventilation rate can be maintained. Resetting the discharge air temperature limits the unit's demand, thus saving energy. However, the increased air temperature and volume will increase fan energy. Thermostatic or electronic expansion valves are used on these systems.

Heating Equipment

In many applications, heating is handled by perimeter radiation, heating installed in the terminal boxes or other such systems when floor by floor units are used. If heating is incorporated in these units it is usually provided by hot water coils or electric resistance heat.

Controls

Self-contained units typically have built-in capacity controls for refrigeration, economizers, and fans. Although units under 15 tons of cooling tend to have basic on-off/automatic controls, many larger systems have sophisticated microprocessor controls that monitor and take action based on local or remote programming. These controls provide for stand-alone operation, or they can be tied to a building automation system.

A building automation system allows for more sophisticated unit control by time-of-day scheduling, optimal start/stop, duty cycling, demand limiting, custom programming, etc. This control can keep the units operating at their peak efficiency by alerting the operator to conditions that could cause substandard performance.

The unit's control panel can sequence the modulating valves and dampers of an economizer. A water-side economizer is located upstream of the evaporator coil, and when condenser water temperature is lower than entering air temperature to the unit, water flow is directed through the economizer coil to either partially or fully meet building load. If the coil alone cannot meet design requirements, but the entering condenser water temperature remains cool enough to provide some useful precooling, the control panel can keep the economizer coil active as stages of compressors are activated. When entering condenser water exceeds entering air temperature to the unit, the coil is valved off, and water is circulated through the unit's condensers only.

Typically, in an air-side economizer an enthalpy switch or dry-bulb temperature energizes the unit to bring in outside air as the first stage of cooling. An outside air damper modulates the flow to meet a design temperature, and when outside air can no longer provide sufficient cooling, compressors are energized.

A temperature input to the control panel, either from a discharge air sensor or a zone sensor, provides information for integrated economizer and compressor control. Supply air temperature reset is commonly applied to variable-air-volume systems.

In addition to capacity controls, units have safety features for the refrigerant-side, air-side, and electrical systems. Refrigeration protection controls typically consist of high and low refrigerant pressure sensors and temperature sensors wired into a common control panel. The controller then cycles compressors on and off or activates hot-gas bypass to meet system requirements.

Constant-volume units typically have high-pressure cut-out controls, which protect the unit and ductwork from high static pressure. Variable-air-volume units typically have some type of static pressure probe inserted in the discharge duct downstream of the unit. As terminal boxes close, the control modulates airflow to meet the set point, which is determined by calculating the static pressure required to deliver design airflow to a zone farthest from the unit.

Acoustics

Because self-contained units are typically located near occupied space, their performance can significantly affect tenant comfort. Units of less than 15 tons of cooling are often placed inside a closet with a discharge grille penetrating the common wall to the occupied space. Larger units have their own equipment room and duct system. Three common sound paths to consider are:

- Fan inlet and compressor sound which radiates through the unit casing to enter the space through the separating wall.
- Fan discharge sound is airborne through the supply duct and enters the space through duct breakout and diffusers.
- Airborne fan inlet sound finds its way to the space through the return air ducts.

Discharge air transition off the self-contained unit is often accomplished with a plenum located on top of the unit. This plenum facilitates multiple duct discharges that reduce the amount of airflow over a single occupied space adjacent to the equipment room (Figure 9). Reducing the airflow in one direction reduces the sound that breaks out from the discharge duct. Several feet of internally lined round duct immediately off the discharge plenum significantly reduces noise levels in adjacent areas.

In addition to the airflow breakout path, the system designer must study unit radiated sound power when determining equipment room wall and door construction. A unit's air-side inlet typically has the highest radiated sound. The inlet space and return air ducts should be located away from the critically occupied area to reduce the effect of this sound path.

Selecting a fan that operates near its peak efficiency point helps in the design of quiet systems. Fans are typically dominant in the first three octave bands, and selections at high static pressures or near the fan's surge region should be avoided.

Units may be isolated from the structure with neoprene pads or spring isolators. Manufacturers often isolate the fan and compressors internally, which generally reduces external isolation requirements.

COMMERCIAL OUTDOOR PACKAGED EQUIPMENT

Outdoor packaged equipment consists of a complete system that includes unitary equipment, ducted air distribution, and temperature control. The equipment is generally mounted on the roof, but it can also be mounted at grade level. Rooftop units are designed as central station equipment for single-zone, multizone, and variable-air-volume applications.

Advantages

- The location of equipment allows for shorter duct runs, reduced duct space requirements, and lower initial cost.
- Installation is simplified.
- Valuable building space for mechanical equipment is conserved.
- Suitable for floor-by-floor control in low-rise office buildings.

Disadvantages

- Maintenance or servicing of outdoor units is sometimes difficult.
- Frequent removal of panels for access may destroy the weatherproofing of the unit, causing electrical component failure, rusting, and water leakage.
- Corrosion of casings is a potential problem. Many manufacturers prevent rusting with galvanized or vinyl coatings and other protective measures.
- Equipment life is reduced by outdoor installation.
- Depending on building construction, sound levels and transmitted vibration may be excessive.

Design Considerations

Centering the rooftop unit over the conditioned space results in reduced fan power, ducting, and wiring. Avoid installation directly above spaces where noise level is critical.

All outdoor ductwork should be insulated. In addition, the ductwork should be (1) sealed to prevent condensation in the insulation during the heating season and (2) weatherproofed to keep it from getting wet.

Use multiple single-zone, not multizone, units where feasible. For large areas such as manufacturing plants, warehouses, gymnasiums, and so forth, single-zone units are less expensive and provide protection against total system failure.

Use units with return air fans whenever return air static pressure loss exceeds 0.5 in. of water or the unit introduces a large percentage of outdoor air via an economizer.

Units are also available with relief fans for use with an economizer in lieu of continuously running a return fan. Relief fans can be initiated by static pressure control.

In a rooftop application, the air handler is outdoors and needs to be weatherproofed against rain, snow, and, in some areas, sand. In cold climates, fuel oil does not atomize and must be warmed to burn properly. Hot water or steam heating coils and piping must be protected against freezing. In some areas, enclosures are needed to maintain units effectively during inclement weather. A permanent safe access to the roof, as well as a roof walkway to protect against roof damage, are essential.

Accessories such as economizers, special filters, and humidifiers are available. Factory-installed and wired economizer packages are also available. Other options offered are return and exhaust fans, variable volume controls with hot-gas bypass or other form of coil frost protection, smoke and fire detectors, portable external service enclosures, special filters, and microprocessor-based controls with various control options.

Rooftop units are generally mounted using integral frames or lightweight steel structures. Integral support frames are designed by the manufacturer to connect to the base of the unit. No duct openings are required for supply and return ducts. The completed installation must adequately drain condensed water. Lightweight steel structures allow the unit to be installed above the roof using separate, flashed duct openings. Any condensed water can be drained through the roof drains.

Refrigeration Equipment

The compressors in large systems are reciprocating, screw or scroll compressors. Chapter 34 has information about compressors and Chapter 41 and Chapter 43 of the *ASHRAE Handbook—Refrigeration* discusses refrigeration equipment, including the general size ranges of available equipment. Air-cooled or evaporative condensers are built integral to the equipment.

Air-cooled condensers pass outdoor air over a dry coil to condense the refrigerant. This results in a higher condensing temperature and, thus, a larger power input at peak conditions. However, this peak time may be relatively short over a 24-hour period. The air-cooled condenser is popular in small reciprocating systems because of its low maintenance requirements.

Evaporative condensers pass air over coils sprayed with water, thus taking advantage of adiabatic saturation to lower the condensing temperature. As with the cooling tower, freeze prevention and close control of water treatment are required for successful operation. The lower power consumption of the refrigeration system and the much smaller footprint from the use of the evaporative versus the air-cooled condenser are gained at the expense of the cost of the water used and increased maintenance costs.

Heating Equipment

Natural gas, propane, oil, electricity, hot water, steam, and refrigerant gas heating options are available.

Controls

Multiple outdoor units are usually the single-zone, constant-volume, or variable-air-volume units. Zoning for temperature control determines the number of units; each zone has a unit. The zones are determined by the cooling and heating loads for the space served, occupancy, allowable roof loads, flexibility requirements, appearance, duct size limitations, and equipment size availability. Multiple units are installed in manufacturing plants, warehouses, schools, shopping centers, office buildings, and department stores. These units also serve core areas of buildings whose perimeter spaces are served by packaged terminal air conditioners. These systems are usually applied to low-rise buildings of one or two floors, but have been used for conditioning multistory buildings as well.

Most operating and safety controls are provided by the equipment manufacturer. Although remote monitoring panels are optional, they are recommended to allow operating personnel to monitor performance.

Acoustics

Most unitary equipment is available with limited separate vibration isolation of the rotating equipment. Isolation of the entire unit casing is not always required; however care should be taken when mounting on lightweight structures.

Outdoor noise from unitary equipment should be reduced to a minimum. Sound power levels at all property lines must be evaluated. Airborne noise can be attenuated by silencers in the supply and return air ducts or by acoustically lined ductwork. Avoid installation directly above spaces where noise level is critical.

INDUSTRIAL/COMMERCIAL CUSTOM PACKAGED SYSTEMS

An outdoor unitary equipment system can be designed to cool or heat an entire building. On large projects and highly demanding systems, the additional cost of a custom packaged unit can be justified. These systems offer a large degree of flexibility and can be configured to satisfy almost any requirement. Special features such as heat recovery, service vestibules, boiler, chillers and space for other mechanical equipment can be designed into the unit.

The equipment is generally mounted on the roof, but it can also be mounted at grade level. Units usually ship in multiple pieces and require field assembly on the roof.

These units can be designed as central station equipment for single-zone, multizone, and variable-air-volume applications. Multiple, separate air handlers can be incorporated into a single unit.

Advantages

- Equipment location allows for shorter duct runs, reduced duct space requirements, lower installed cost, and ease of service access.
- Construction costs are offset toward the end of the project because the unit can be one of the last items installed.
- Field labor costs are reduced because most components are assembled and tested in a controlled factory environment.
- A single source has responsibility for the design and operation of all major mechanical systems in a building.
- Installation is simplified.
- Valuable building space for mechanical equipment is conserved.

Disadvantages

- Higher first cost than commercial equipment.
- Unit design must be coordinated with structural design because it represents a significant building structural load.
- Overall appearance can be unappealing.
- Maintenance or servicing of outdoor units is sometimes more difficult.
- Corrosion of casings is a potential problem. Many manufacturers prevent rusting with galvanized or vinyl coatings and other protective measures.
- Equipment life is reduced by outdoor installation.
- Depending on building construction, sound levels and transmitted vibration may be excessive.

Design Considerations

Centering the rooftop unit over the conditioned space results in reduced fan power, ducting, and wiring. Avoid installation directly above spaces where noise level is critical.

All outdoor ductwork should be insulated. In addition, the ductwork should be (1) sealed to prevent condensation in the insulation during the heating season and (2) weatherproofed to keep it from getting wet.

Use units with return air fans whenever return air static pressure loss exceeds 0.5 in. of water or the unit introduces a large percentage of outdoor air via an economizer.

Units are also available with relief fans for use with an economizer in lieu of continuously running a return fan. Relief fans can be initiated by static pressure control.

In a rooftop application, the air handler is outdoors and must be of a weatherproof design. In cold climates, fuel oil does not atomize and must be warmed to burn properly. Hot water or steam heating coils and piping must be protected against freezing. A permanent safe access to the roof, as well as a roof walkway to protect against roof damage, is essential.

Accessories such as economizers, special filters, and humidifiers are available. Factory-installed and wired economizer packages are also available. Other options offered are return and exhaust fans, variable volume controls with hot-gas bypass or other form of coil frost protection, smoke and fire detectors, portable external service enclosures, special filters, and microprocessor-based controls with various control options.

These units are generally mounted using integral support frames or steel structures. Integral support frames are designed by the manufacturer to connect to the base of the unit. The installation must allow any condensed water to drain. Lightweight steel structures allow the unit to be installed above the roof using separate, flashed duct openings. Any condensed water can be drained through the roof drains.

Because each unit is custom designed to a the specific application, it may be desirable to require additional witnessed factory testing to insure the performance and quality of the final product.

Refrigeration Equipment

The major types of refrigeration equipment used in large systems are hermetic and semihermetic reciprocating, screw, and scroll compressors. See Chapter 34 for information about compressors and Chapter 41 and Chapter 43 of the *ASHRAE Handbook—Refrigeration* for further discussion of refrigeration equipment, including the general size ranges of available equipment.

Air-cooled or evaporative condensers are built integral to the equipment. Air-cooled condensers pass outdoor air over a dry coil to condense the refrigerant. This results in a higher condensing temperature and, thus, a larger power input at peak condition; however, over 24 hours this peak time may be relatively short. The major advantage of air-cooled condensers are the low maintenance requirements.

Evaporative condensers pass air over coils sprayed with water, thus taking advantage of adiabatic saturation to lower the condensing temperature. As with the cooling tower, freeze prevention and close control of water treatment are required for successful operation. The lower power consumption of the refrigeration system and the much smaller footprint from the use of the evaporative versus the air-cooled condenser are gained at the expense of the cost of the water used and increased maintenance costs.

Heating Equipment

Natural gas, propane, oil, electricity, hot water, steam, and refrigerant gas heating options are available. These can be incorporated directly into the air-handling sections or a separate pre-piped boiler and circulating systems can be used.

Controls

The equipment manufacturer provides all operating and safety controls. Although remote monitoring panels are optional, they are recommended to permit operating personnel to monitor performance.

Acoustics

This equipment is available with several (optional) degrees of internal vibration isolation of the rotating equipment. Isolation of the entire unit casing is rarely required; however, care should be taken when mounting on lightweight structures. If external isolation is required, it should be coordinated with the unit manufacture to insure proper separation of internal verse external isolation deflection.

Outdoor noise from unitary equipment should be reduced to a minimum. Sound power levels at all property lines must be evaluated. Special attenuated condenser sections are available where required. Airborne noise can be attenuated by silencers in the supply and return air ducts or by acoustically lined ductwork. Avoid installation directly above spaces where noise is critical.

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