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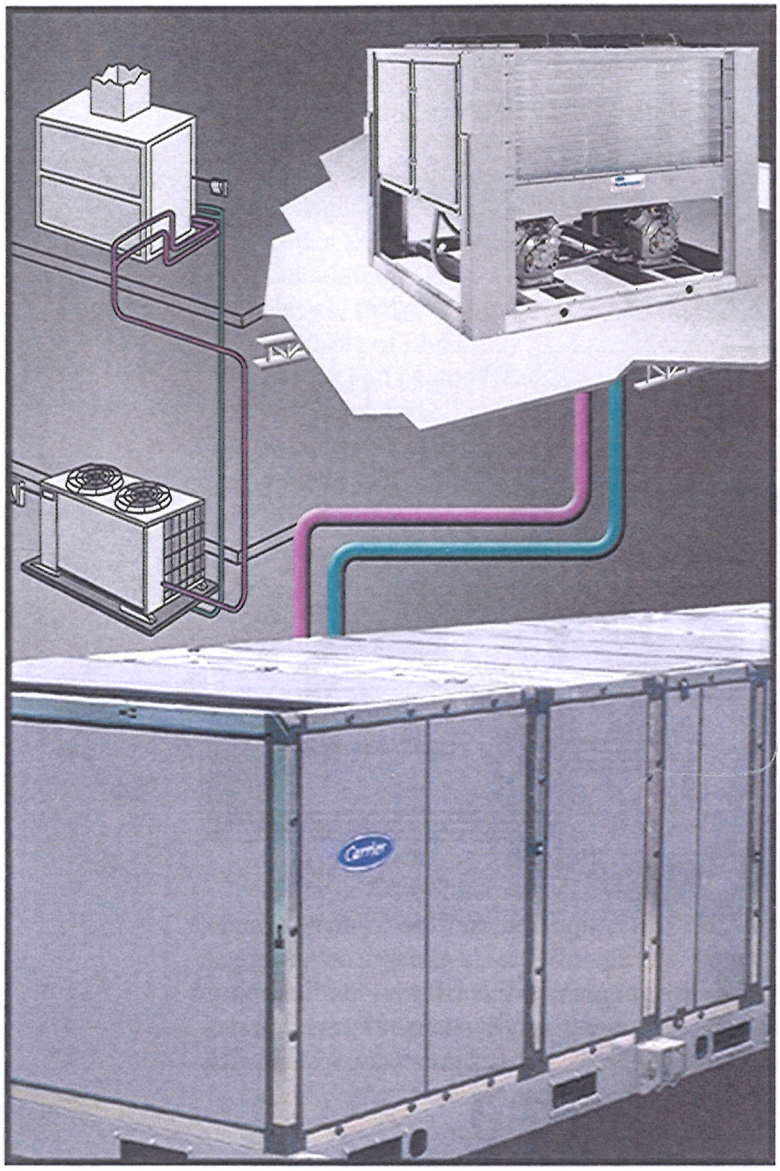


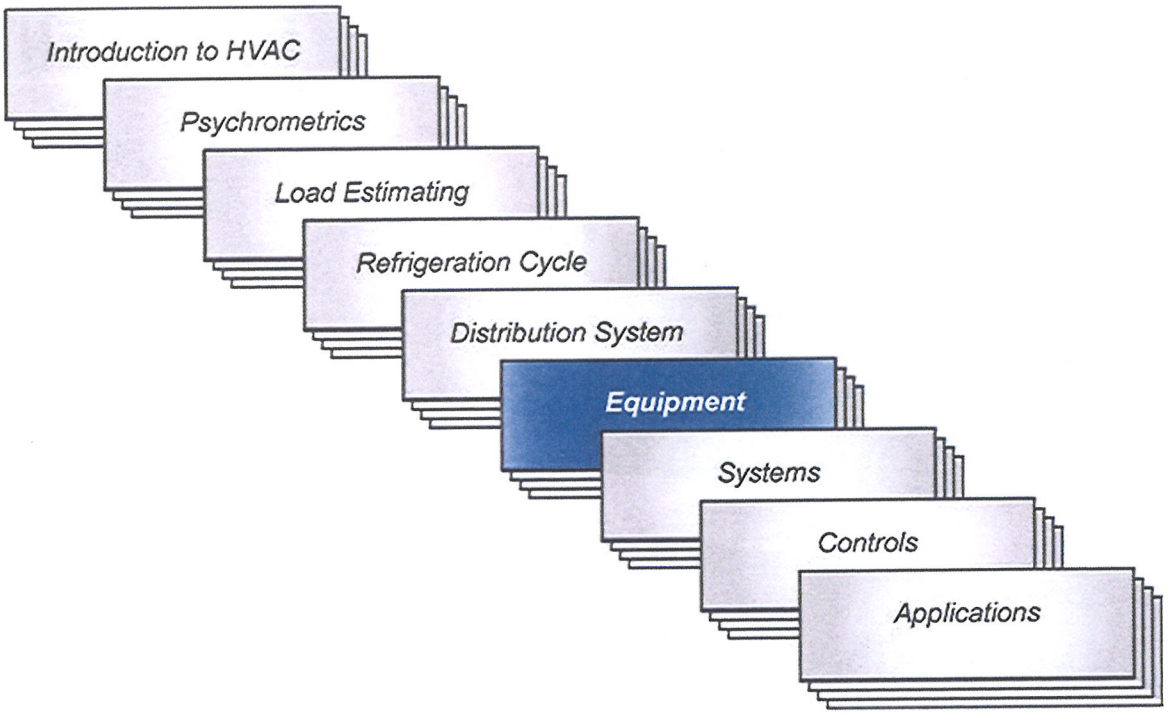
COMMERCIAL HVAC PACKAGED EQUIPMENT

Split Systems

Technical Development Program

Technical Development Programs (TDP) are modules of technical training on HVAC theory, system design, equipment selection and application topics. They are targeted at engineers and designers who wish to develop their knowledge in this field to effectively design, specify, sell or apply HVAC equipment in commercial applications.

Although TDP topics have been developed as stand-alone modules, there are logical groupings of topics. The modules within each group begin at an introductory level and progress to advanced levels. The breadth of this offering allows for customization into a complete HVAC curriculum – from a complete HVAC design course at an introductory-level or to an advanced-level design course. Advanced-level modules assume prerequisite knowledge and do not review basic concepts.



Spilt systems are one of the major categories of HVAC equipment, and the primary system type used in residential air conditioning. Split systems are classified as a unitary, or packaged unit; and, as such, have many of the benefits of packaged equipment while offering the flexibility associated with applied products. This module will describe what split systems are, the components of the system and accessories frequently used. It will show the designer how systems are applied, explain common installation issues, and describe how to select a system.

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Introduction

A system designer must be able to choose the system that will best fit the application. To do this, the designer must thoroughly understand each system, its benefits, and the components that make up the system.

A split system is a direct expansion (DX) air conditioning or heat pump system that has an evaporator, fan, compressor, and condenser section where one or more of the components are separated and connected by refrigerant piping. In most residential and commercial applications, the compressor and condenser are combined into a single piece of equipment called a condensing unit. Refrigerant piping and control wiring connects the system components and is field-installed to meet the physical requirements of each individual application.

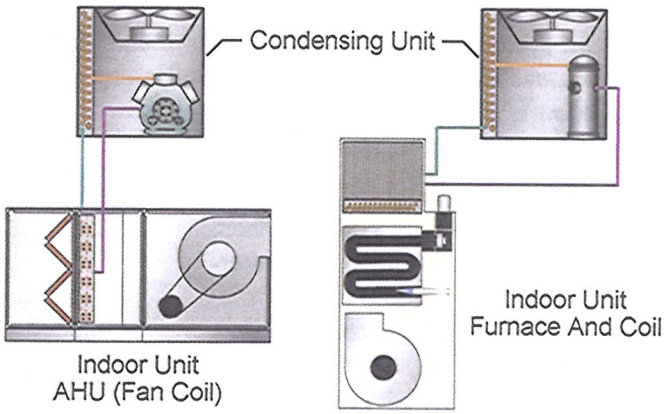


Figure 1

Split System Components

Split Systems

Provide the benefits of factory-designed and selected components with the design flexibility associated with applied products.

Split systems are a popular way to cool buildings, from residential and small commercial applications to large commercial applications. Split systems range in size from less than one ton in small applications to above 120 tons in larger applications. When utilized in a multi-unit design, very large commercial buildings can be handled with split systems. Split systems include cooling only applications, air source heat pumps, and process applications. They may be equipped with electric heat, hydronic heat, or steam heat. Split systems may also be combined with furnace systems to provide cooling and heating.

Split systems provide the opportunity to utilize packaged products in an applied manner. This means that factory-assembled products may be applied in factory-approved combinations to provide an engineered system that most closely meets the need of the application. There are many benefits to split systems, including this flexibility, and they will be discussed in detail.

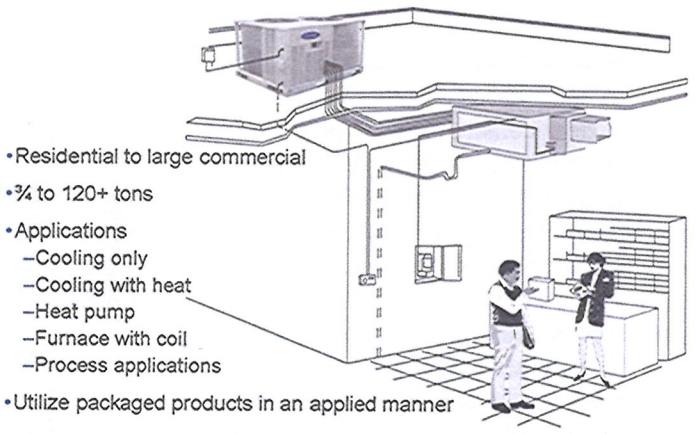


Figure 2

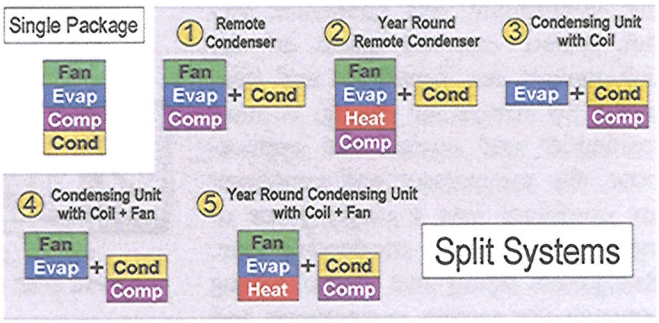
Split Systems

Definitions and Descriptions

The term "packaged" covers a wide range of factory-assembled products from room air conditioners to large tonnage water chillers. For purposes of this TDP, packaged is defined as those products that fall within the unitary air conditioner category. The Air Conditioning and Refrigeration Institute (ARI) defines the unitary air conditioner as one or more factory made assemblies that normally include an evaporator or cooling coil, an air moving device or fan, a compressor, and a condenser.

Split systems are defined as those systems that have more than one factory-made assembly, such as a packaged air handler and a condensing unit. These separate units may be placed indoors or outdoors, depending on the requirements of the application.

ARI has five basic categories of split systems. For split systems, there are options for air-cooled, water-cooled, and evaporative-cooled systems. As shown here, there are many different ways of separating the four unit components to develop a split system. As you can see, split systems have a wide variety of combinations, which provide a high degree of flexibility.



- 5 ARI cooling split system categories
- ARI has categories for air, evaporative or water-cooled
- Plus 4 ARI heat pump categories (not shown)

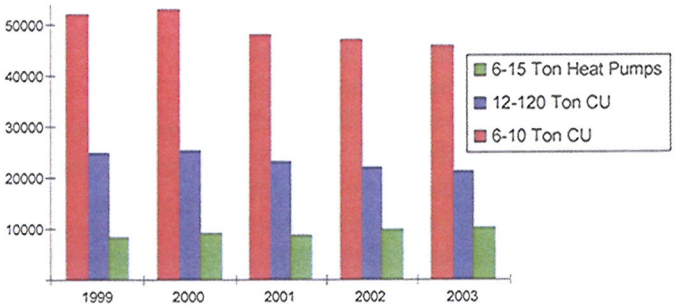
Figure 3

ARI Definition of Packages

Common Use of Split Systems

The split system industry is a mature market that has been relatively stable for many years, with typical year-after-year variations in volume being quite small. The exception to this has been the heat pump segment of the market. This segment has grown significantly in recent years as more attention is given to energy costs and comparisons are made to more traditional fossil fuel heating methods.

The split system industry is more often used in the replacement market than in new construction. It is generally accepted that at least 50 percent of the split system business is replacement, and some markets say it may be as high as 80 percent. Rooftop units are used more often in new construction because of their low first cost in comparison to split systems; only one unit needs to be installed and only one electrical service needs to be provided.



- Stable, mature market
- Heat pump growing
- Replacement vs. new construction

Figure 4

Recent Market Statistics

Advantages of Split Systems

The key advantage in using split systems is their flexibility. This flexibility allows many possible solutions to application challenges. Typically, splits are applied when one or more specific needs must be addressed. These needs include aesthetics, space utilization, duct requirements, and performance and zoning needs.

Flexibility

- Aesthetics
- Space utilization
- Duct design
- Performance
- Zoning



Figure 5

The key advantage of split systems is their flexibility.

Aesthetics is a significant factor in choosing split systems for an application. For example, a restaurant with a large skylight in the dining area would not be an appropriate application for a rooftop unit, but a split system condensing unit could be hidden behind the building. Splits are popular with churches for the same reason. The air handler may be located anywhere in the building, within refrigerant line limitations. The condensing unit may be located outdoors where it may be concealed, thereby contributing to the building's aesthetics, rather than detracting from it. For structures greater than two stories in height, the cost of ductwork may override the initial first cost advantage of a rooftop unit. With a split system, you may place the evaporator very close to or in the conditioned space, thereby greatly reducing ductwork cost. This also allows a building to be zoned on a floor-by-floor basis, eliminating the need for a large vertical duct chase. The split system also eliminates the need for large penetrations in the roof or exterior walls that are required with other packaged products. The performance aspect relates to the ability to mix and match components in order to engineer a system that is exactly right for the application. For example, a split system using an up-sized indoor unit can more closely match the requirements of an application that has a higher sensible load than a typical rooftop. Conversely, up-sizing the outdoor unit provides a system with greater latent performance.

Split System Basics

There are many types of systems available for a project, so why are split systems selected for a given application? With the various ways of dividing split system components, when is one selected over another? To answer these questions, a system designer should understand the components of a split system and the limits of their application.

A split system is

a direct expansion air conditioning system that has an evaporator, fan, compressor, and condenser section where one or more of the components is separated and connected by refrigerant piping.

As discussed previously, a split system is comprised of two or more packaged assemblies. These assemblies are interconnected with refrigerant piping and wiring, and they comprise the air conditioning system. The most common split system is made up of two assemblies, the outdoor unit, and the indoor unit. The outdoor unit is a condensing unit or heat pump and the indoor unit is a coil/fan combination, for example a packaged air handler. Another type of split system is the "triple split" in which the compressor and condenser are separated components. In this presentation, we will concentrate on the two-unit style split system.

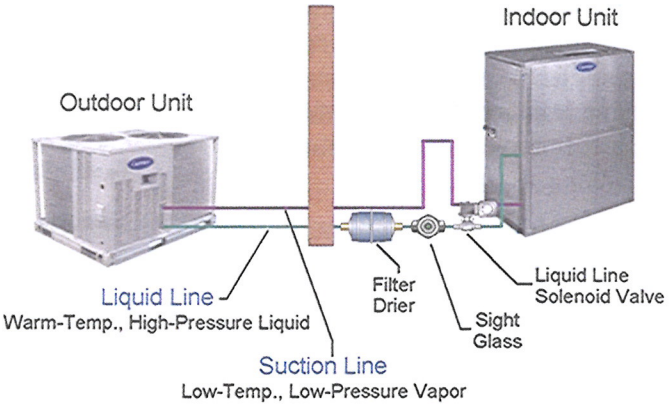


Figure 6

Basic Split System

Mix and Match Components

The flexibility advantage of the split system is a result of the designer's ability to mix and match assemblies, within manufacturer's guidelines. The most common combination of outdoor and indoor units would be assemblies that have the same capacity, e.g., a 10-ton outdoor unit combined with a 10-ton indoor unit. However, the designer may be able to match a 10-ton outdoor unit with the next size larger indoor unit, e.g., a 12½-ton indoor unit. This combination will typically provide higher airflows and higher sensible heat ratios. Alternatively, the designer may be able to match a 7½-ton outdoor unit with a 6-ton indoor unit. This combination will typically provide better latent performance. Always consult the manufacturer's recommendations regarding the limitations on mix-matching indoor and outdoor assemblies. In most cases, mix matching of heat pump assemblies is NOT allowed.

Mix Matching

is typically NOT permitted with heat pump assemblies.

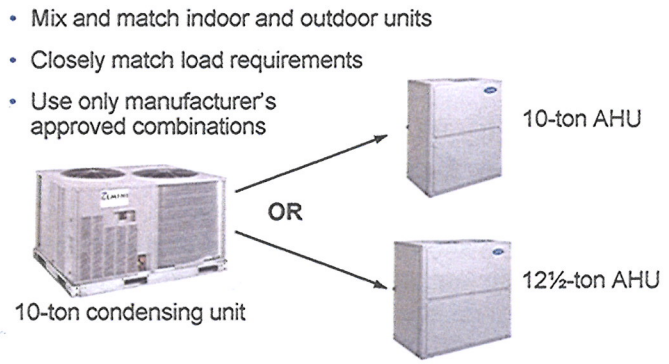


Figure 7

Split systems provide the flexibility to mix and match assemblies.

- smaller OU capacity is still OK to use our won't damage compressor

Residential and Duct Free Systems

Two additional variations of the split system concept are the residential style and the duct-free type. Residential split systems typically utilize an air-cooled condensing unit or heat pump matched with either a fan coil or an indoor coil assembly. In general, residential systems are defined as systems less than five tons. However, this does not mean that residential systems are less sophisticated. Some residential products use variable speed and highly-refined control technology

Duct-free systems, as their name implies, utilize indoor units that are placed in the conditioned space, thereby eliminating the need for ducts. Again, these systems can be sophisticated air conditioning units.

Both types of systems are frequently used in many commercial applications for smaller spaces and special application requirements.



Figure 8

Residential and Duct-Free Split Systems

Typical Split System – Outdoor Unit

As mentioned previously, the outdoor unit of a two-assembly style split system is a condensing unit. A condensing unit is comprised of a compressor, a condenser, and a control system. The control system for a condensing unit includes an interface with space temperature controls and safety circuits, as well as to the control of the indoor unit. The controls for a condensing unit may be as simple as single-stage thermostat or a more complex programmable controller.

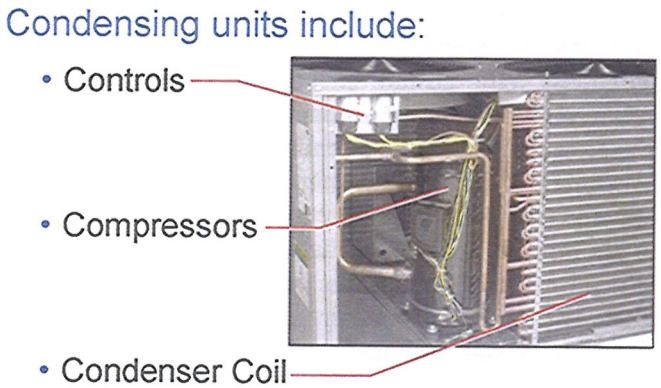


Figure 9

Condensing Unit

Condensing units smaller than 10 tons will typically have only one compressor. Larger tonnage condensing units may have one or more compressors with 40 tons generally being the largest single compressor unit. The condenser in most condensing units is air-cooled. However, water-cooled condensing units are also available.

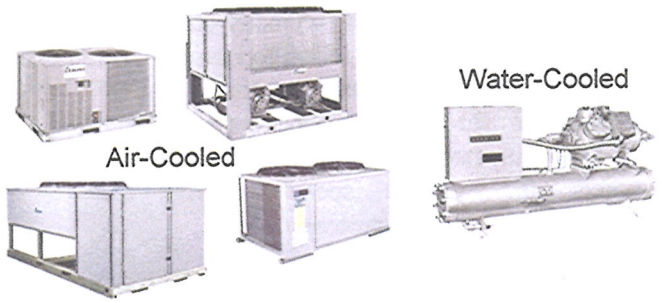


Figure 10

Typical Condensing Units

Typical Split System – Indoor Unit

The indoor unit in most commercial applications will be an air handler. This air handler may be a packaged air handler or it may be a built-up type, also known as a central station air handler. Central station air handlers can be further classified into three types: factory-assembled, custom air handlers, and field-erected air handlers. In factory-assembled air handlers, a wide range of pre-engineered components is available for selection. They are factory-assembled in a number of defined configurations. With custom air handlers, within certain limits, the components are selected and factory assembled for a specific project. The components of field-erected air handlers are selected for the project, and the air handler is field-constructed around the components. All three types of air handlers are used with split systems.

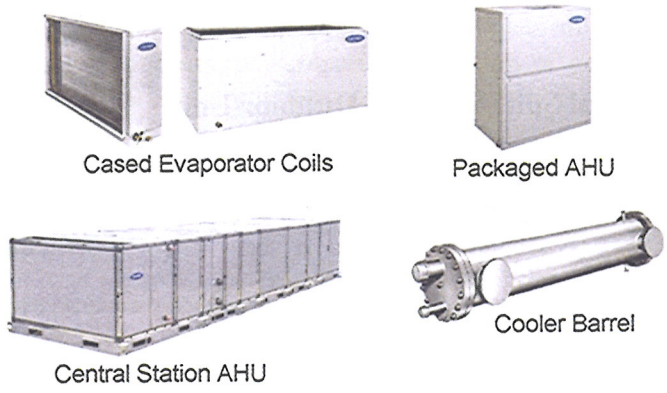


Figure 11

Indoor Units

Residential split systems and some commercial systems will use a cased evaporator coil as the indoor unit. In these applications, some other device, such as the fan in a furnace, provides the air movement.

An air-cooled chiller may also be constructed by matching a split-system condensing unit with a cooler barrel (i.e. evaporator). However, a packaged air-cooled chiller may be a better choice when available as the cooler and condensing sections are already pre-selected. The cooler barrel can be remote mounted in some cases.

Heat Pump Systems

The typical systems described previously may be defined as cooling-only systems. Split systems may also be heat pump systems. The most common heat pump system is an air-to-air heat pump arrangement.

These heat pump systems employ special indoor and outdoor units that are designed to function as either an evaporator or condenser. Typically, the coils used are larger than a comparably sized cooling-only unit. In addition, the metering devices are different in order to accomplish both heating and cooling. When a heat pump unit is in cooling mode, it functions in the same manner as a cooling-only unit; the outdoor coil is the condenser and the indoor coil is the evaporator. However, when the unit is in heating mode, a 4-way valve is used to reverse the cycle; the outdoor coil is now the evaporator and the indoor coil is the condenser. In this way, heat is removed from the outdoor air and transferred to the indoor air.

Heat pump system components are designed and tested as matched pairs and must only be applied according to the manufacturer's recommendations.

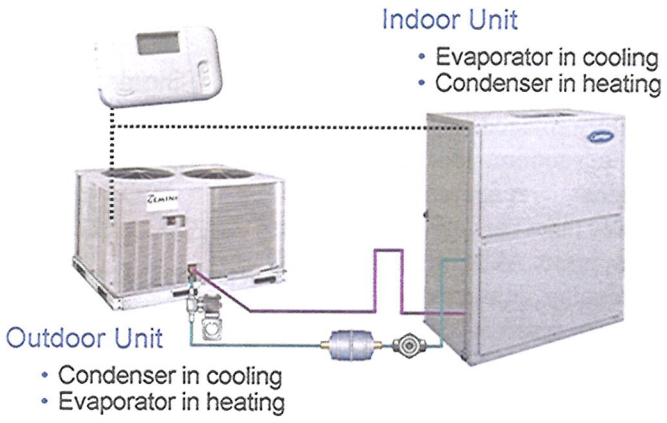


Figure 12

Heat Pump Split System

Refrigerant Circuits

The number of refrigerant circuits, single or dual, may also classify split systems. This definition is most often applied to the condensing unit. 10-ton and smaller condensing units are typically single circuit. Most single-circuit condensing units have only one compressor, however, specially designed dual-compressor single circuit systems are available. A single circuit system may be identified by the single liquid line and single suction line connecting the outdoor unit to the indoor unit. Single circuit systems are the simplest systems and in many cases are the least costly to install. Dual circuit condensing units have two independent refrigerant circuits and at least two compressors. Dual circuit systems utilize two liquid lines and two suction lines between the indoor and outdoor units. The primary advantage of dual circuit systems is redundancy. If one compressor fails, the other circuit will continue to operate and provide 50 percent of the nominal capacity.

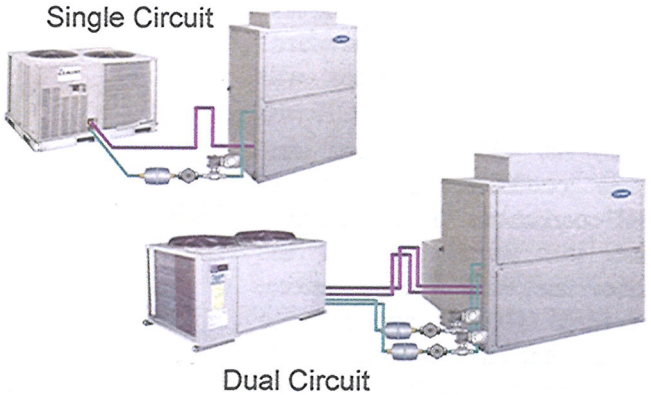


Figure 13

Refrigerant Circuits

Refrigerant Circuits – Indoor Unit

Indoor units may also be referred to as single or dual circuit, meaning the refrigerant either flows through the coil in a single path or splits into two paths. Single circuit coils typically have one TXV/distributor assembly and dual circuit coils will have two TXV/distributor assemblies. A single-circuit condensing unit may be connected to a single or dual-circuit indoor unit. However, a dual-circuit condensing unit must only be connected to a dual-circuit indoor unit due to compressor oil management. Dual-circuit condensing units have at least two compressors.

In any properly operating refrigeration system, a small portion of the compressor oil is constantly moving throughout the system. The key to compressor oil management is that the oil leaving the compressor through the discharge side must be continually replaced by oil returning on the suction side. Dual independent refrigerant circuits ensure that the oil that leaves compressor A of a dual-circuit condensing unit may only return to compressor A. If a dual circuit-condensing unit were applied to a single-circuit indoor unit by manifolding the refrigerant lines, the ability to manage the compressor oil would be lost.

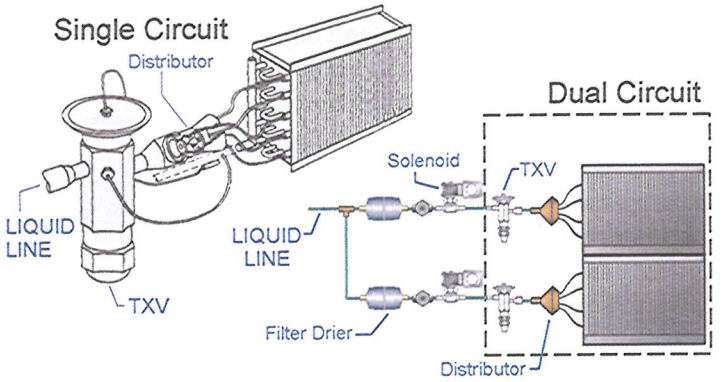


Figure 14

Indoor Unit, Refrigerant Circuits

Codes and Standards

System designers should be aware of a number of codes and standards. These include ARI and ASHRAE standards that have been incorporated into building codes. The Air Conditioning and Refrigeration Institute (ARI) standards primarily define performance-testing methods.

The standard applicable to split systems depends upon the capacity of the system, expressed in Btuh. For example, ARI Standard 340/360 applies to air-cooled split systems with a capacity greater than 65,000 Btuh and less than 250,000 Btuh. This standard defines that the equipment will be tested at 80° F db/67° F wb return air, 95° F outdoor air. These conditions are known as ARI conditions. Since performance is a function of both the indoor and outdoor performance, Standard 340/360 applies to a system, such as a combination of an indoor and an outdoor unit.

Standard #	Applies to	Capacity Range
210/240	Unitary Air Conditioners	<65,000 Btuh
	Air Source Unitary Heat Pumps (Air-Cooled)	<65,000 Btuh
340/360	Unitary Air Conditioners	65,000 to <250,000 Btuh
	Air Source Unitary Heat Pumps (Air-Cooled)	65,000 to <250,000 Btuh
365	Air Conditioning Condensing Units	>135,000 to <250,000

Figure 15

ARI Standards influencing Split Systems

Typically, manufacturers submit data to ARI stating that a given split system has been tested according to the applicable ARI standard and they verify the performance value in Btuh and the Energy Efficiency Ratio (EER). This data is listed by ARI and is available to the system designers through ARI. In the case of Standard 340/360, listed systems are subject to performance verification by ARI. To verify performance, ARI may, at any time, randomly select from a manufacturer's inventory listed units or combinations. These units are sent to an independent laboratory for performance testing. The equipment performance must match the listed values within 5 percent. Figure 15 lists the ARI standards applicable to split systems.

Calculating EER

Since EER is used to comply with standards, it is important to understand how it is calculated. The formula is: EER equals capacity (expressed in Btuh) divided by the total power input (expressed in Watts). EER is expressed as a pure number with the units of measure (Btuh/Watts) are normally left off. A higher EER number represents a higher efficiency. The simple formula noted here is suitable for a stand-alone condensing unit and listed combinations of indoor units. For example, the published capacity of a 25-ton condensing unit operating at 95° F outdoor air and 45° F saturated suction temperature (ARI conditions) is 290 MBtuh. The power input equals compressor power plus the total power required by the condenser fan motors. The published compressor power at the conditions noted is 22.8 kW. The condenser fan motors require a total of 3.1 kW.

$$EER = \frac{\text{Capacity (Btuh)}}{\text{Total Power Input (Watts)}}$$

Example 25-ton condensing unit @ ARI conditions

$$EER = \frac{\text{Capacity (Btuh)}}{\text{Total Power Input (Watts)}}$$

$$EER = \frac{290\ \text{MBtuh}}{(22.8 + 3.1)\ \text{kW}}$$

$$EER = \frac{290}{25.9}$$

$$EER = 11.2$$

Figure 16

Calculating EER

Therefore, the EER of this 25-ton condensing unit operating at ARI conditions is:

EER= 290 MBtuh / (22.8 + 3.1) kW

EER = 290 / 25.9

EER = 11.2

Net vs. Gross Capacity

It is slightly more complicated to calculate EER for a system, which is not a listed combination. ARI published data is for a system combination at the specific ARI rating conditions. The calculation procedure is different when a condensing unit rating or a point other than the ARI rating is used.

The formula for a system is: EER equals net cooling capacity (Btuh)/ total power input. Remember that the operating conditions will affect capacity; therefore, they also affect the EER. The ARI condition for a commercial split system is defined as 80° F db and 67° F wb return air temperature, 95° F outdoor air. First, the difference in gross capacity versus net capacity must be addressed. The capacity value published by most manufacturers is the gross capacity; that is, the amount of heat removed by the evaporator coil. However, the indoor fan motor (IFM) adds heat to the system which means the actual cooling to the space is less. Net capacity during cooling mode is defined as the gross capacity minus the indoor fan heat. The first step in determining the system EER is to calculate the net cooling capacity. To do this, you need to know the heat added by the IFM. Typically, manufacturer's data will provide the brake horsepower (bhp) requirements of the IFM operating at given airflow (cfm) and resistance (static pressure). The ARI standard defines the minimum external resistance based on the size of the unit.

$$\text{System EER} = \frac{\text{Net Capacity (Btuh)}}{\text{Total Power Input}}$$

$$\text{Net Capacity} = \text{Gross Capacity} - \text{IFM Heat}$$

ARI Minimum External Resistance Table	
Standard Ratings MBtuh	**Minimum External Resistance Inches of Water**
135 - 210	0.35
211 - 280	0.40
281 - 350	0.45
351 - 400	0.55
401 - 500	0.65
501 and over	0.75

Figure 17

Net vs. Gross Capacity

Example of bhp

As an example, lets look at a 25-ton packaged air handler operating at 10,000 cfm with 0.44 in. wg of external static. Interpolating from the published data, between 0.4 and 0.6 in. wg external pressure, the bhp requirement is 4.0 bhp.

AHU Size	Airflow cfm	External Static Pressure (in. wg)							
		0.0		0.2		0.4		0.6	
		rpm	bhp	rpm	bhp	rpm	bhp	rpm	bhp
028	10,000	615	3.12	641	3.36	692	3.87	743	4.41

Interpolate to derive bhp for 0.44 in. wg

bhp @ 0.44 in. wg = 4.0 bhp

Figure 18

Demonstration of the bhp required for specific levels of external static pressure.

Indoor Fan Motor Heat

IFM heat equals the bhp (from the published data) multiplied by 746 (Watts/hp), divided by the motor efficiency. If motor efficiency is not known, 0.83 is a good assumption. This equation will provide the IFM heat expressed in Watts. To convert to Btuh, multiply the result by 3.414 (Btuh/ Watt) to express the IFM heat in Btuh.

$$\text{IFM Heat} = \frac{(\text{bhp} * 746)}{\text{Motor Efficiency}}$$

$$\text{IFM Heat} = \frac{(4.00 * 746)}{0.83}$$

$$\text{IFM Heat} = 3{,}595 \text{ Watts}$$

$$3{,}595 \text{ Watts} * \frac{3.414 \text{ Btuh}}{\text{Watts}} = 12{,}274 \text{ Btuh}$$

Figure 19

Indoor Fan Motor Heat

Net Capacity

Now we can determine the net capacity during the cooling mode. The manufacturer's data indicates that the gross capacity of the example air handler at the conditions noted is 294 MBtuh. To calculate net capacity:

Net Capacity = Gross Capacity – IFM Heat

Net Capacity = 294 MBtuh – 12.274 MBtuh

Net Capacity = 282 MBtuh

In heating mode

net capacity includes the addition of fan motor heat.

Total Power Input

To calculate the total power input, add all of the electrical inputs of the system, the compressor(s) plus the IFM, plus the outdoor fan motor(s) (OFM). If you do not have the power value for the OFM, it may be calculated if OFM motor horsepower is known.

$$\text{OFM power per motor} = \frac{(\text{bhp} * 746)}{\text{Motor Efficiency}}$$

Now calculate Total Power Input using data from previous slides

Total Power Input = Compressor power + IFM power + OFM power

Total Power Input = 22.8 kW + 3.6 kW + 3.1 kW

Total Power Input = 29.5 kW

Figure 20

Total Power Input

System EER

Now you can calculate system EER of our example 25-ton system.

System EER for the 25-ton example system:

$$\text{System EER} = \frac{\text{Net Cooling Capacity}}{\text{Total Power Input}}$$

$$\text{System EER} = \frac{282 \text{ MBtuh}}{29.5 \text{ kW}}$$

$$\text{System EER} = 9.6$$

Figure 21

System EER

SEER

The Seasonal Energy Efficiency Ratio (SEER) is similar to EER in that it defines the energy efficiency of a unit or system in the cooling mode. SEER only applies to units that operate on single-phase power and have a capacity of 5 tons or less. SEER differs from EER in a couple of ways. First, SEER considers the fact that the fan motor(s) and compressor cycle, therefore, the

energy usage is not constant. Secondly, SEER is calculated using three operating conditions plus a cycle test. Net capacity is determined at the ARI rating point, 80° F db, 67° F wb and 95° F outdoor air. Then ratings at two points: 80° F db, 67° F wb return air temperature, 82° F outdoor air; and 80° F db 57° F wb return air temperature, 82° F outdoor air. The later condition is used with a cyclic test to determine seasonal energy efficiency. SEER provides a means to evaluate performance at two seasonally different conditions, one high humidity and one low humidity. Calculating SEER involves laboratory testing to record the power and capacity measurements. Therefore, SEER information is provided by the manufacturer and cannot be calculated in the field.

Applies to:
- Single phase power only
- Capacity less than 60 MBtuh

Calculated at three conditions and cycle test:
- 80/67° F return air, 95° F outdoor air
- 80/67° F return air, 82° F outdoor air
- 80/57° F return air, 82° F outdoor air
- 80/57° F cycle test, 82° F outdoor air

Requires laboratory testing and is not calculated in the field.

Figure 22

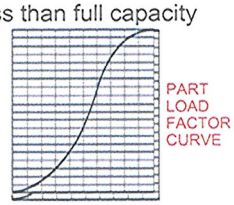
Calculating Seasonal Energy Efficiency Ratio (SEER)

IPLV

Integrated Part Load Value (IPLV) is used to evaluate the efficiency of a unit or system operating in the cooling mode at less than full capacity. IPLV is only applicable to equipment that has more than one stage of capacity, for example, equipment with multiple compressors or a single compressor unit with unloading. IPLV is a weighted average of the EER calculated at each stage of capacity of the unit. A unit that has a small number of steps of capacity will have a higher IPLV than one with many steps of capacity, all other factors being equal. It is important to understand that a unit with a higher number of steps of capacity will have the ability to more closely match the cooling load of the application and, therefore, is more efficient. Unless the unit will be operating at 100 percent capacity at all times, a unit with a higher IPLV is preferred.

FOR ALL 3 ∅ AND WATER-COOLED UNITS AND AIR-COOLED UNITS ABOVE 60 MBH CAPACITY

- Evaluate equipment efficiency at less than full capacity
- Applicable only to equipment with more than one stage of capacity
- Weighted average of EER at each capacity step



- Equipment with greater number of capacity steps can more closely match the load requirements of the space
- Unless equipment is always operated at 100% capacity, a higher IPLV is preferred

Figure 23

Integrated Part Load Value (IPLV)

Note, IPLV is commonly expressed as EER (Btuh/Watt) for packaged equipment and as kW/ton for chillers. There is a fixed relationship between kW/ton and EER (EER = 12/(kW/ton)). This relationship shows that EER increases as kW/ton decreases, and vice versa. Therefore, a "better" IPLV is shown as a lower value when the units are kW/ton, and, a "better" IPLV is a higher value when the units are expressed in terms of EER.

COP

Coefficient of Performance (COP) is a value used to measure a unit's efficiency while operating in the heating mode and applies to heat pumps that operate on three-phase power. Since the compressor and indoor fan motor heat provide a positive benefit in heat pumps, their power is included in the heating calculation as a benefit. A higher COP value represents a more efficient heat pump.

- Applies to heat pumps that operate on 3-phase power only
- Measures efficiency while operating in the heating mode
- A higher COP indicates a more efficient heat pump

$$COP = \frac{\text{Net Capacity (Watts)}}{\text{Total Power Input (Watts)}}$$

Figure 24

Coefficient of Performance (COP)

COP = net capacity (Watts)/total power input (Watts)

Net capacity now includes the supply fan heat

Net capacity = gross compressor capacity + supply fan heat

Total Power Input = supply fan (Watts) + compressor(s) (Watts) + OFM motor(s) (Watts)

Heating performance varies as the outdoor temperature drops and when the temperature is below freezing and defrost is required. Defrost energy decreases the usable energy for space heating. To account for this, heat pump ratings are calculated at two points: high temperature at 70° F db and 60° F wb indoor and 47° F db and 43° F wb outdoor, and low temperature at 70° F db and 60° F wb indoor and 17° F db and 15° F wb outdoor.

HSPF

Heating Seasonal Performance Factor (HSPF) is used to measure the efficiency of heat pumps that operate on single-phase power and have a cooling capacity of less than 5.5 tons. HSPF is similar to SEER in that it represents the seasonally adjusted heating efficiency of a heat pump. A higher HSPF value represents a higher efficiency heat pump. Also, like the SEER, the measurement and calculation technique dictates that the testing can only be done in a laboratory. The impacts of defrost and supplemental heaters are factored into these calculations as well.

HSPF:

- Applies to heat pumps that operate on single phase power and have a cooling capacity of < 5.5 tons only
- Is similar to SEER in that it measures the seasonally adjusted efficiency of a heat pump
- Accounts for defrost and required electric heat
- A higher HSPF is a more efficient heat pump

Figure 25

Heating Seasonal Performance Factor (HSPF)

Building Energy Codes

Building codes regulate the building and the products used in them. Their primary purpose is to assure the safety of the building occupants. However, after the energy crunch of the 1970s, building performance standards started to become a provision of building codes. This activity has continued and today, energy requirements are a part of nearly every building code. One important point about building codes is that they establish minimum levels. Buildings may be built to levels that are more stringent but not less. Several ASHRAE standards have become incorporated into code requirements.

Many codes rely on ASHRAE 90.1 that sets minimum efficiency requirements.

Air-Cooled Split System Requirements

- Performance requirements

< 65,000 Btuh	10.0 SEER 1Ø
≥ 65,000 – < 135,000 Btuh	10.3 EER
≥ 135,000 – < 240,000 Btuh	9.7 EER
≥ 240,000 – < 760,000 Btuh	9.5 EER / 9.7 IPLV
≥ 760,000 Btuh	9.2 EER / 9.4 IPLV

- Control requirements
- Motor hp limits
- Economizer requirements
- Heat pump requirements

Figure 26

Energy codes establish air-cooled split system minimum performance requirements.

ASHRAE 90.1,Energy Standard for Buildings except Low-Rise Residential Buildings, has become the benchmark for energy codes. At the very basic level, you may consider ASHRAE Standard 90.1 as defining minimum energy efficiency standards for a variety of devices, including air conditioning equipment. As this standard applies to split systems, it defines the minimum EER, IPLV, and COP of systems, or, in some cases individual units, such as large condensing units. It also has a number of other provisions that affect the design of split systems. These provisions include requirements on the control system, limits on the indoor fan motor horsepower, requirements on the use of an economizer and requirements on heat pumps. Additional information on these requirements can be found in Sections 6.2 and 6.3 of the Standard.

A key factor when comparing efficiency values of split systems is to ensure that you are comparing apples to apples. For example, when comparing two brands, do the values reflect the total of the indoor and outdoor units? If both values represent the system efficiency, are the airflow and static pressure values for the indoor unit the same? If not, the comparison is not valid.

Indoor Air Quality and Sustainable Design

As was the case with energy, requirements have been written into building codes that set minimum standards for ventilation and control of conditions that can lead to poor indoor air quality. ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality*, is the industry guideline defining ventilation requirements for a variety of commercial applications.

- IAQ – ASHRAE 62
  - Limits maximum humidity to less than 65%
  - Indoor unit condensate control
  - Indoor unit ventilation capability
- Sustainable Design – LEED™
  - Require meeting ASHRAE 90.1 efficiency and ASHRAE 62 IAQ features
  - Optimized energy performance and IAQ

Split System mix and match provides better humidity control and flexibility to meet these requirements

Figure 27

IAQ and Sustainable Design

This standard has tables that set minimum ventilation airflows based on the type of building, the usage of the space, the number of people, and the space area. It also contains a number of provisions that influence the use of split systems. One of these requirements is to control the chance of mold growth. Humidity in the space must be kept below 65 percent. ASHRAE Standard 62 addresses moisture by limiting the allowable relative humidity in an occupied space to 65 percent or less at either of the following two design conditions:

- Peak outdoor dew point design conditions and peak indoor design latent load, or
- Lowest space sensible heat ratio expected to occur and the concurrent (simultaneous) outdoor conditions.

ASHRAE Standard 62 also notes that the load on a space may be significantly different at outdoor dew point design conditions than at outdoor dry bulb design conditions. It is important to design the system to handle the worst-case scenario, which may be the dew point design condition. The Standard also requires the design minimum outdoor air intake airflow to be greater than the design maximum exhaust airflow. In other words, the total building must be pressurized, understanding that certain spaces within the building may be at a negative pressure condition.

Ventilation requirements in split system applications may be handled in a variety of ways. The ventilation may be addressed directly in the split system by equipping the indoor section with a mixing box or economizer section. The ventilation needs may also be addressed by dedicated outdoor air system that is independent of the split system.

Split systems can offer a distinct advantage in dealing with these requirements. When spaces have high latent requirements because of the activity in the space or large amounts of humid outdoor air, humidity control can be a challenge. As indicated before, split systems allow a variety of system matches and the use of DX allows lower coil temperatures, which can result in much better humidity control.

Provisions must also be made for ventilation air ducted to each unit, which can impact the location of the indoor air handler. In addition, requirements for control of condensate within the air handler dictate the use of condensate pans with no standing water, double-wall construction, surfaces downstream of the coil protected from condensate damage and other IAQ protection measures. These measures may influence the air handler selected or the options required.

While energy efficiency and IAQ have dealt with setting a minimum performance standard for units, there is interest today in programs that promote achieving a superior level of energy performance and IAQ. These efforts are commonly called sustainable design, green buildings, or by the most common certifier of these buildings, LEED™ (Leadership in Energy and Environmental Design). These programs are aimed at driving building design to achieve the maximum economical performance and minimal environmental impact. The LEED™ program requires meeting all the requirements of the ASHRAE 90.1 Energy Standard and the ASHRAE 62 requirements of the Ventilation Standard. It then uses these standards as a benchmark to measure how much performance has been improved. Split systems, with the ability to closely match the load requirements and offer superior part load control, are worthy of consideration for projects seeking high levels of indoor air quality and LEED™ certification.

Systems and Components

Rules of Thumb

There are a number of "rules of thumb" regarding split systems. These rules should be considered a guide, not always the final authority. For example, historically, the nominal condition, rule of thumb regarding airflow has been defined as 400 cfm/ton. The range is typically considered to be 300 cfm/ton on the low side up to a maximum of 500 cfm/ton. Therefore, the data for a 10-ton packaged air handler will include performance and fan information across a range of 3000 to 5000 cfm. As guidelines change regarding the amount of outdoor air required in many applications, it is causing the "rule of thumb" to shift downward. It is not uncommon today to see systems designed at 350 cfm/ton.

As addressed before, split systems offer the flexibility of matching different air handlers to a condensing unit. A good rule of thumb to follow is one size up and one size down is acceptable in the air handler match. Other options may be available but would need investigation by the manufacturer.

Rules of Thumb are considered to be guidelines only

- Airflow:
  - 400 cfm per nominal ton
  - Range of 300 to 500 cfm per ton
  - Today, 350 cfm per ton may be more appropriate
- Mix and Match:
  - Nominal and one size up, sometimes one size down, others depend (consult the manufacturer)
- Line Length:
  - Keep them at 100 ft or less

Figure 28

Rules of Thumb

One other quick rule to keep in mind is to limit the measured line length between the indoor and the outdoor units to 100 feet or less. While units are often capable of much greater distances, this is a good guideline in terms of selecting locations for the indoor and outdoor units.

Operating Limits

There are a number of parameters that define the proper operating envelope for a split system. These include:

- Maximum outdoor air temperature 115° F
- Minimum return air temperature 55° F
- Maximum return air temperature 95° F
- Saturated suction temperature range 25 - 55° F
- Maximum discharge temperature 275° F
- Minimum discharge superheat 60° F

Saturated suction temperature

in typical operation, falls in the 40 - 50° F range for air conditioning duty.

If the equipment is a heat pump, two additional parameters are considered:

- Maximum outdoor air operating temperature in heating 75° F
- Minimum outdoor air operating temperature in heating -20° F

Although a heat pump can safely operate at very low temperatures, it should be understood that a heat pump does not operate efficiently at low temperatures. Therefore, heat pump systems may employ supplemental heating systems, most commonly electric heaters in the indoor units. In some applications, building codes set the need for heaters and the size of the heaters.

It is incumbent upon the designer to make sure that the equipment selected will operate within these limitations throughout the operating envelope of the application.

Outdoor Units

Let's discuss some of the variables found in outdoor units, or more generically, condensing units. Obviously, one variable is size, or capacity. As described earlier, residential condensing units typically have a nominal capacity range of 1½ tons to 5 tons. Commercial condensing units range in size from a nominal 6 tons to 120 tons and greater. Another variable is the type of compressor. Typically, condensing units with a nominal capacity of 10 tons or less use hermetic type compressors, with scroll compressors being the most common today. This choice provides a reasonably priced compressor that meets the relatively simple need of a small split system.

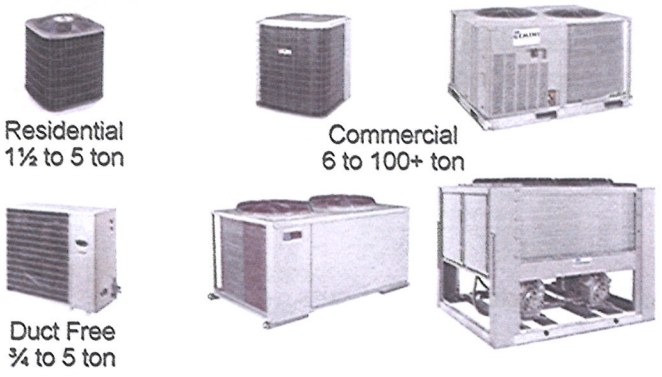


Figure 29

Outdoor Unit

Semi-Hermetic Compressors

10-ton and larger condensing units may be equipped with reciprocating semi-hermetic compressors. The semi-hermetic compressor offers the flexibility of a repairable compressor vs. replacement being the only option with a failed hermetic compressor. More importantly, reciprocating semi-hermetic compressors offer the capability of capacity control through cylinder unloading. This provides a means for a relatively large single-compressor condensing unit to adjust its capacity to meet the load requirements of the application. For example, a 40-ton semi-hermetic compressor may have 3 stages of capacity, 100 percent, 67 percent, and 33 percent. In other words, this 40-ton compressor may operate at 40 tons, 27 tons, or 13 tons, depending on the needs of the application.

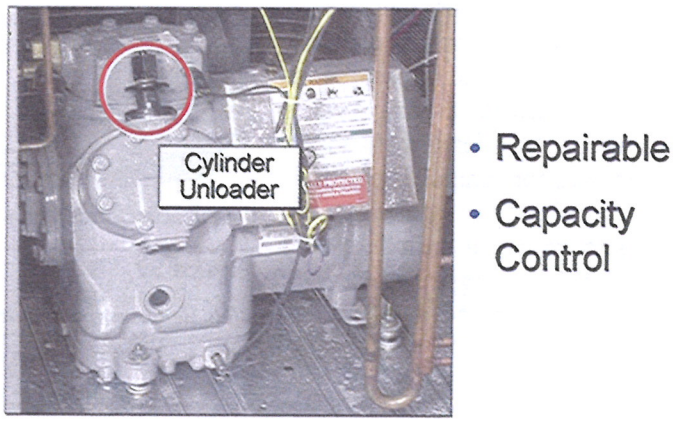


Figure 30

Semi-Hermetic Compressor

Multiple Compressors

Condensing units may also be equipped with more than one compressor. Typically, multiple compressor condensing units have a nominal capacity of 10 tons or larger. Many multiple compressor condensing units are dual circuit units. The use of multiple compressors provides another means of capacity control, i.e., by turning compressors on and off, the total capacity of the condensing unit may be changed. It is possible to have multiple compressors manifolded together on a single circuit, however this requires special consideration by the equipment designer in the area of compressor oil management.

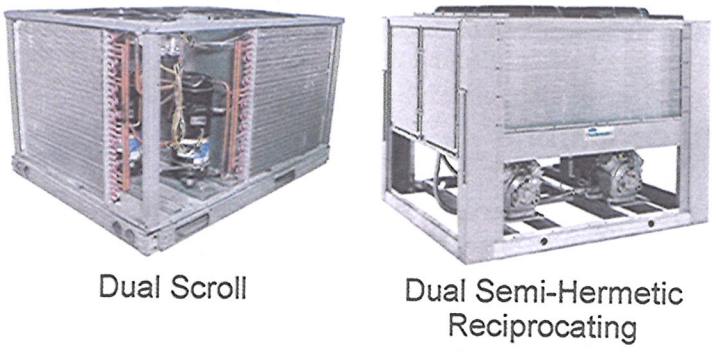


Figure 31

Multiple Compressors

Multiple Condensing Units

Another variation of the multiple compressor concept is the use of multiple condensing units. It is possible to use two, single-circuit, condensing units connected to a dual circuit air handler. This method provides a means of capacity control by staging the condensing units. It also provides a system in which the outdoor sections are completely independent, which in some applications may be an important additional level of redundancy. There is also an advantage in that one unit may be serviced while the other is operating. For critical applications, this provides a means of having at least 50 percent capacity while maintenance is performed on the other outdoor units. The disadvantages include: dual electrical services must be installed, two units must be rigged, two pads (mountings) must be provided, etc.

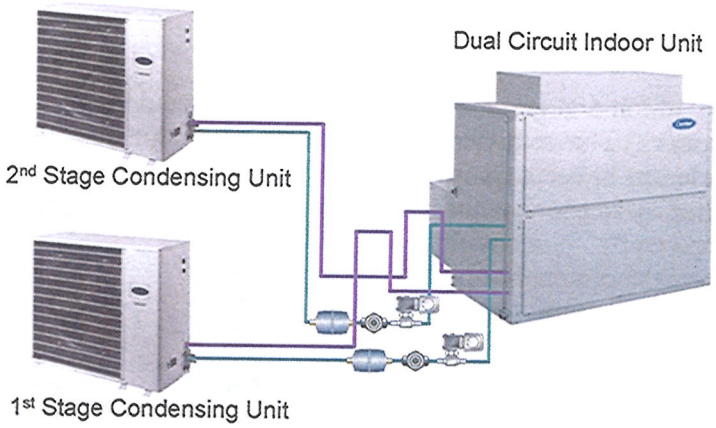


Figure 32

Multiple Condensing Units

Hot Gas Bypass

Hot gas bypass (HGBP) is a piping arrangement that is designed to protect the system in low load conditions. Specifically, HGBP will limit the minimum evaporator temperature in low load conditions to prevent coil icing. A HGBP system is not a form of capacity control, however, it is sometimes applied in that manner. For example, a condensing unit that is equipped with a single scroll compressor does not have any means of capacity control. Therefore, the designer, to protect the system in low load conditions, may specify HGBP. An HGBP system is composed of a hot gas valve, a solenoid valve, a connection point to inject the hot gas, and interconnecting piping and control wiring. The hot gas must be injected at the indoor unit evaporator coil, between the TXV and the distributor. If the indoor unit does not have a hot gas connection, an auxiliary side connection must be installed. Do not inject hot gas directly into the suction line because compressor overheating may result. If the system is equipped with a multi-step thermostat, the hot gas solenoid should be active only in the minimum stage of cooling.

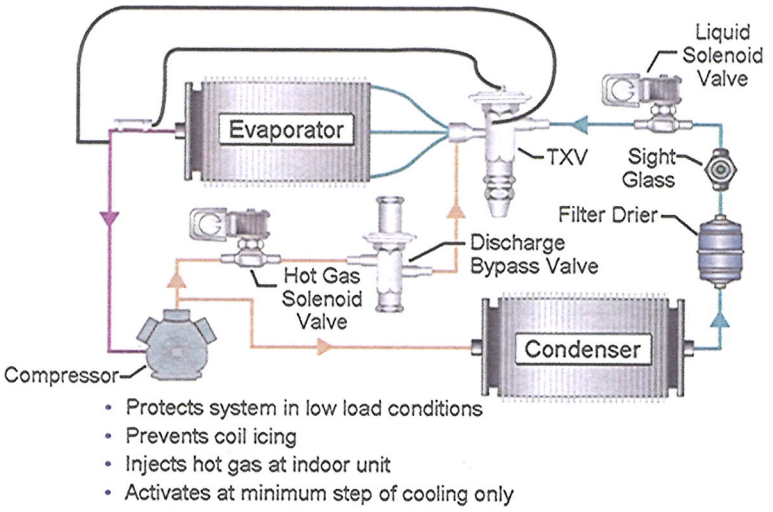


Figure 33

Hot Gas Bypass

Alternative Condensing Unit Solutions

There may be applications where it is desired to install the outdoor unit, the condensing unit, indoors. In these cases, it is necessary to make special provisions to remove heat from the space in which the condensing unit is located. The typical air-cooled condensing unit utilizes propeller type fans, which are designed to operate against very low static. Therefore, ducting the condenser air is not a viable option.

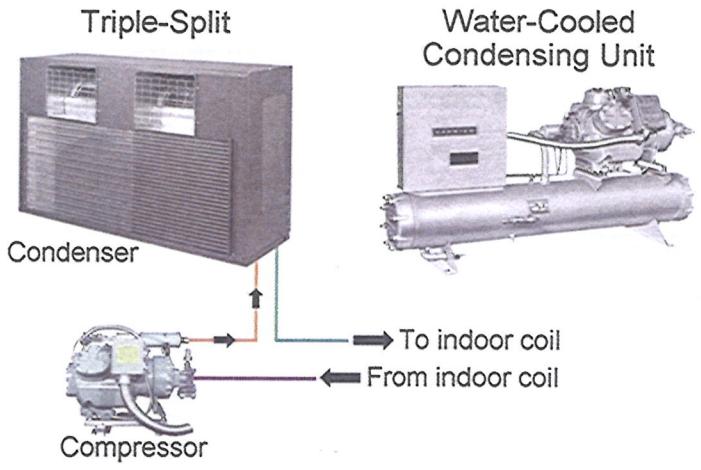


Figure 34

Alternative Condensing Unit Solutions

The potential options include use of:

- a specialty condensing unit equipped with fans capable of being ducted
- a water-cooled condensing unit
- an air-cooled indoor self-contained unit
- a triple split in which the separate compressor and fan coil are indoors and the air-cooled condenser is outdoors using propeller fans or indoors using centrifugal fans.

Heat Pump Outdoor Unit

The outdoor unit in an air-to-air heat pump system is a special adaptation of an air-cooled condensing unit. In addition to the components found in a condensing unit, the heat pump will also have a reversing valve and normally will include a suction accumulator. The reversing valve, or 4-way valve, provides the means to reconfigure the refrigerant flow path in order for the outdoor unit to be the condenser in cooling and the evaporator in heating. The accumulator is a protective device that prevents liquid refrigerant from reaching the compressor, thereby preventing damage that could result.

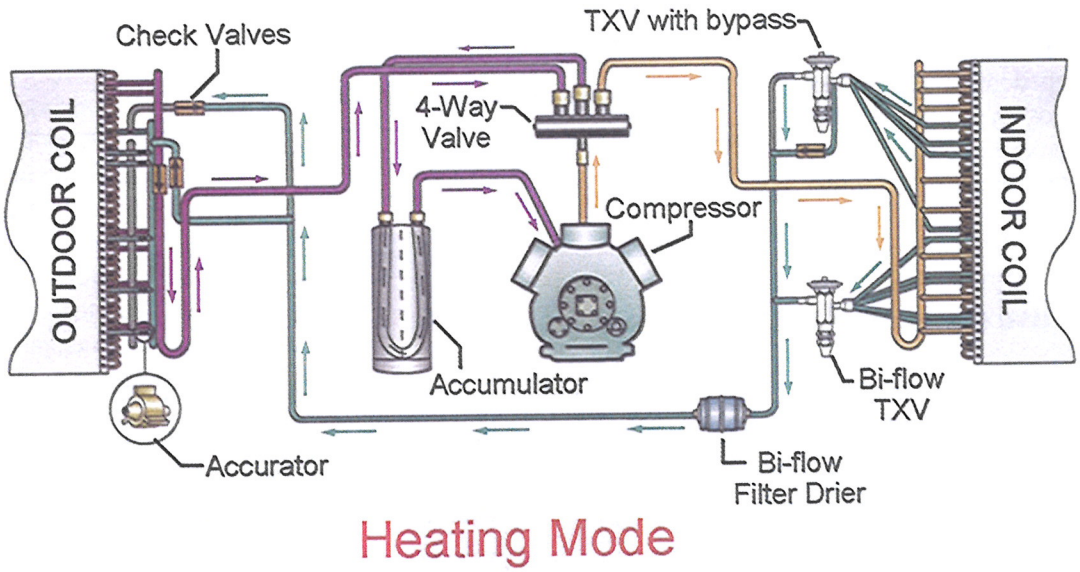


Figure 35

Heat Pump in Heating Mode

The design of the outdoor coil in a heat pump also receives special attention. In order for the coil to operate effectively as both a condenser and an evaporator, the coil must be designed and tested to work in conjunction with a particular indoor unit (coil). For this reason, heat pumps are provided as a system only, an outdoor unit matched with an indoor unit. It is not possible to mix and match indoor and outdoor units in a heat pump application unless the combination has been tested.

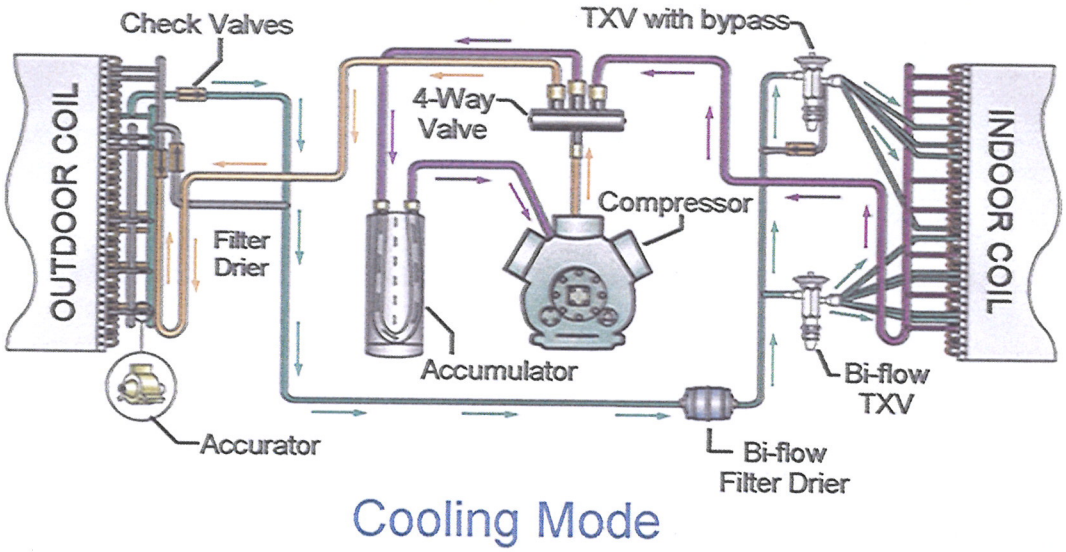


Figure 36

Heat Pump in Cooling Mode

Indoor Units

In most commercial applications, the indoor unit will be an air-handling unit (AHU), also known as an air handler. The AHU may be a simple packaged air handler. Packaged AHUs are typically available in capacities from 6 to 30-ton with the term "packaged" indicating that the product offering is available in a limited number of predefined sizes. The advantage of the packaged air handler is that the TXV(s) and nozzle(s) are factory installed. The other end of the spectrum for commercial AHUs is the applied air handler or central station air handler. The term "applied" is an appropriate description because air handlers of this type are designed and constructed in modules, based on the needs of the application. For example, the designer chooses the fan section, the coil, the filter section, etc.



Figure 37

Indoor Unit – Air Handler

Classification of Air Handlers:

Fan Coil – 1½ to 10-ton units with a fan, DX coil, filter, and optional heat. Fixed internal components and very limited options, fully factory-assembled.

Packaged Air Handler – 3 to 30-ton units, with a fan, DX coil, filer and optional heat. Fixed fan size with possible limited coil options.

Central Station Air Handler- 3 to 100-ton units, with a fan, DX coil and may include a number of other sections for heating, filtration, energy recovery, mixing box, etc., selected from a factory options list and configured for each job. Factory-assembled and shipped.

Custom Air Handler- 3 to over 120-ton units, with a fan, DX coil and may include a number of other sections for heating, filtration, energy recovery, mixing box, etc., selected for the project and factory-assembled in a casing and shipped assembled.

Field-Erected Air Handler – 3 to over 120-ton units, with a fan and a DX coil, and any other group of options. All components selected for the job and field-assembled.

IAQ Features

Indoor Air Quality (IAQ) features are an important consideration when selecting an AHU. The type of construction is a very basic choice. An AHU with double-wall construction sandwiches the insulation between the outer casing and an interior metal liner. This design prevents exposure of the insulation to the moving airstream, thereby eliminating any possibility that insulation particles may be carried into the space. Double-wall construction is common on built-up style AHUs, but typically is not available on packaged AHUs. Packaged air handlers typically use a dual-density, coated insulation, which is designed for exposure to the moving airstream, yet will not shed particles at velocities encountered inside the AHU. This type of insulation may also be treated with an anti-microbial coating to inhibit the growth of bio-aerosols inside the AHU. Foil-faced insulation is also common in packaged air handlers. The double-wall system or the insulations described, all offer an AHU interior that may be cleaned. Ultra-violet UV-c lights mounted inside the AHU may also be utilized to limit the growth of bio-aerosols on the coil or in the drain pan.

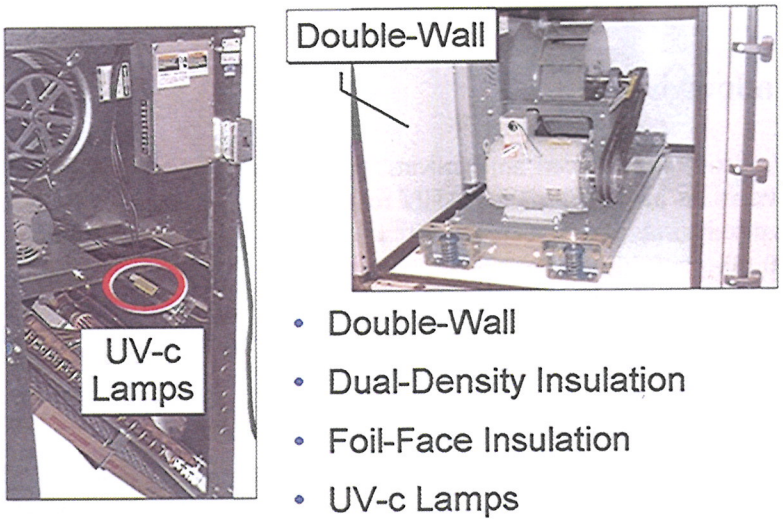


Figure 38

IAQ Features

Constant Volume AHU

Another facet in the choice of an indoor unit, specifically an air handler, is whether the system will be constant volume (CV) or variable air volume (VAV). In a CV system, the AHU fan operates at a constant speed and the external static in the system is constant. Therefore, the volume of air moving in the system is constant. Most units less than 30 tons use a variable pitch pulley on the air handler so the airflow can be adjusted during commissioning to meet the job requirements. After the unit is set up, the unit runs at a constant fan speed. A typical commercial condensing unit/packaged air handler combination, as supplied by the manufacturer, is designed for a CV application.

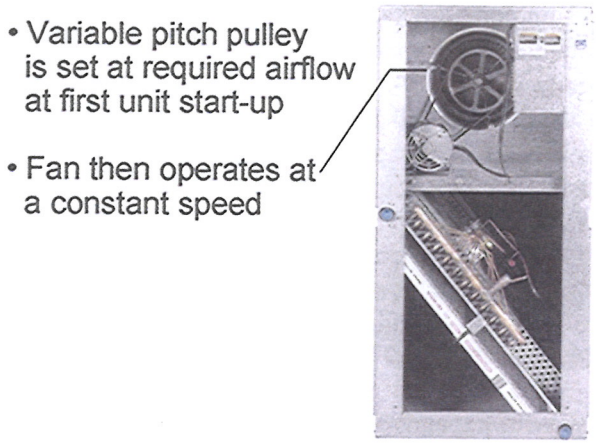


Figure 39

Constant Volume Unit

VAV Application

As the name implies, the volume of air moving through the VAV system is variable. The air handler fan must be capable of changing its airflow to respond to load changes in the space. This may be accomplished in a number of ways. The speed of the fan in the AHU may be variable, perhaps controlled by a variable frequency drive (VFD). The fan may be equipped with inlet guide vanes that mechanically change the inlet flow conditions to the fan, thereby varying the airflow. The air volume may also be controlled at the end of the ductwork, at the terminal devices. VAV terminals effectively throttle the airflow into the space, thereby varying the airflow in the system.

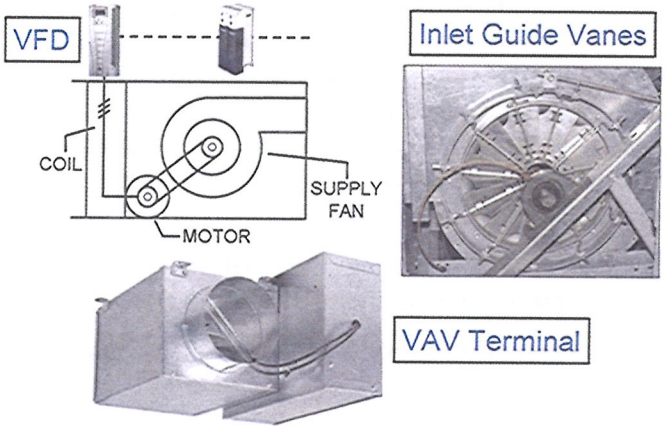


Figure 40

Variable Volume Units

VFDs

have become the first choice for fan volume control because of better part load efficiency versus inlet guide vanes.

Split System VAV Indoor Requirements

When selecting equipment for a VAV application, a number of issues must be addressed. It must be understood that as the air volume varies, so will the load on the system. Therefore, the indoor and outdoor units must equipped to vary the capacity of the system. In the case of the indoor unit, multiple coil sections or circuits typically accomplish this. At the very least, the indoor coil will require two circuits, preferably more. The system must be equipped with capacity control solenoid valves that may be used to stage the number of active coil circuits based on the load.

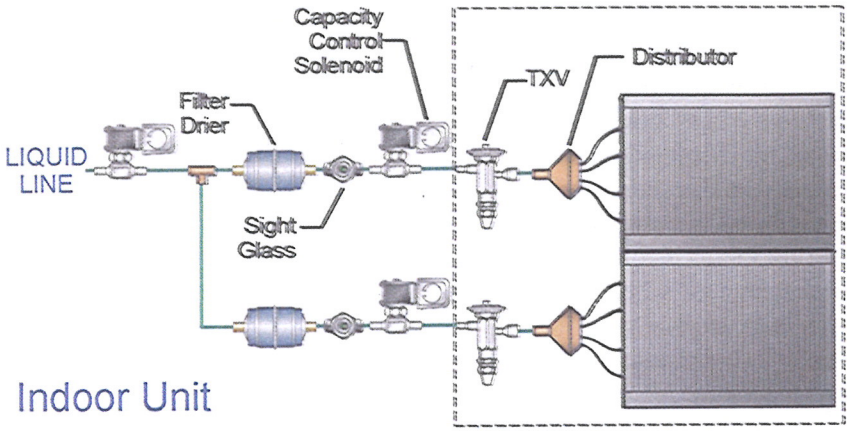


Figure 41

VAV System Requirements

VAV Outdoor Unit

Special consideration must also be given to the outdoor unit. Multiple stages of capacity are required, typically four or more. Commercial condensing units with four or more stages of capacity typically have capacities of 20 tons or more. Therefore, most VAV systems will be at least 20 tons in size. A condensing unit designed for VAV duty will differ from its CV counterpart in a number of ways:

- VAV condensing unit will have additional stages of capacity.
- Stages of capacity will be electrically controlled.
- Suction line accumulators will protect compressors.
- Condensing unit will interface with a VAV controller.

Split system VAV requirements:

- Fan volume control – VFD or inlet guide vanes on a packaged indoor AHU
- Multiple stages of capacity – multiple compressors or unloaders
- Multiple circuits on the indoor coil
- Accumulator
- Discharge airflow control and terminal interface

VAV Control

VAV split systems must be equipped with a control device or controller. This VAV controller must be capable of starting and stopping the compressors, staging the steps of capacity of both the indoor and outdoor unit, and controlling the fan. A typical VAV controller is a discharge air controller. The controller utilizes a sensor in the ductwork, downstream of the AHU. Based on the sensed supply air temperature and the offset from set point, the controller will vary the stages of capacity to maintain a reasonably constant discharge air temperature. The VAV controller may be as simple as a self-contained device or it may be part of building automation system.



Figure 42

VAV Controller

Indoor Coil Loading — Tons per Circuit

In a properly operating air conditioning system, the compressor oil is continuously circulating throughout the system. The oil is returning to the compressor at the same rate at which it leaves, thereby maintaining an adequate amount of oil in the compressor for lubrication. Compressor oil is fully miscible (mixes) with liquid refrigerant and readily moves with the liquid refrigerant. However, where the refrigerant is in a vapor state, for example in the evaporator, the refrigerant velocity must be high enough for the compressor oil droplets to be entrained with the refrigerant vapor. As long as the velocity of the refrigerant vapor remains high enough, the compressor oil droplets are carried by the refrigerant vapor and proper compressor oil management is achieved.

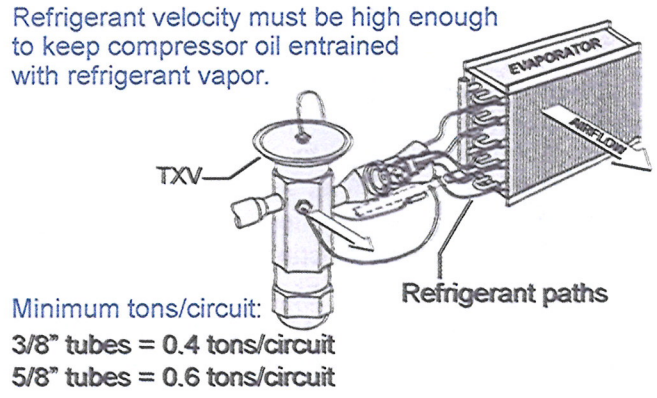


Figure 43

Tons per Circuit

The velocity of the refrigerant vapor in the evaporator is quantified by the term: tons per circuit, or stated another way, tons per refrigerant pathway. The circuits or pathways in an evaporator are the tubes that carry the refrigerant through the fins of the coil. The minimum tons per circuit (or path) for 3/8-in. tubing is 0.4 tons per circuit. In other words, if the capacity of the system using 3/8-in. tubes is equal to or greater than 0.4 tons per circuit (path), the velocity of the vapor will be high enough to insure that the compressor oil remains entrained with the refrigerant vapor. The minimum tons per circuit value for larger tubes is higher, for example, for 5/8-in.

tubes, the minimum tons per circuit is 0.6 tons per circuit. The refrigerant velocity will be lowest when the compressor is unloaded. Whenever you wish to add an unloader to a system, you must consider the refrigerant velocity at the minimum capacity step, when the compressor is fully unloaded.

Tons per Circuit Example

Let's consider a system using a 38ARS012 and a 40RM012. The 38ARS012 is equipped with a single pressure operated unloader as standard equipment. Therefore, the standard 38ARS012 when unloaded has a capacity of approximately 7 tons. The 40RM series uses 3/8-in. tubes and the size 012 has 18 refrigerant circuits (paths) in total, 9 circuits per split.

To determine the tons per circuit when the 38ARS012 is unloaded, simply divide the capacity of the *unloaded* condensing unit by the number of circuits. For the standard 38ARS012 with a 40RM012 system, the capacity of 7 tons is divided by 18 circuits and equals 0.4 tons per circuit.

40RM Model	# of coil splits	# of circuits/splits	# of circuits total
007	1	12	12
008	1	15	15
012	2	9	~~18~~
014	2	9	18
016	2	12	24
024	2	13	26
028	2	15	30
034	2	18	36

38ARS012 Standard – Unloaded capacity, 7 tons
ACCEPTABLE 7 tons/18 circuits = 0.4 tons/circuit

38ARS012 with additional unloader – Unloaded capacity, 3.3 tons
TOO LOW! 3.3 tons / 18 circuits = 0.2 tons/circuit

Add capacity control solenoid valve to 40RM012
ACCEPTABLE Now 3.3 tons / 9 circuits = 0.4 tons/circuit

Figure 44

Tons per Circuit Example

This meets the requirement for minimum tons per circuit. The 38ARS012 uses a six-cylinder reciprocating compressor so it is possible to add an additional unloader in the field. If an additional unloader is added to the 38ARS012, the condensing unit could then unload to approximately 3.3 tons. With a capacity of 3.3 tons divided by 18 circuits, the result equals 0.2 tons per circuit. That is much too low for adequate oil return. However, the 40RM012 coil uses a coil that is split into two sections. Therefore, the 40RM012 could be equipped with a capacity control solenoid valve to limit the flow of refrigerant to only one half of the coil when the condensing unit is unloaded to 3.3 tons. Then the equation becomes 3.3 tons divided by 9 circuits equals 0.4 tons per circuit. Therefore, if the application requires unloading to 33 percent with a 38ARS012 with 40RM012 combination, the 40RM must be equipped with a capacity control solenoid valve to effectively reduce the size of the coil when the compressor is unloaded to 33 percent.

In summary, when you are considering additional unloading for an application you must address two areas of concern:

- First, is it possible to add an additional unloader to the condensing unit, and
- Is the ton per circuit value high enough for adequate oil return when the compressor is fully unloaded?

It will only be possible to add additional unloading if you can satisfy both areas of concern.

Cased Evaporator Coils

Another type of indoor unit is the cased evaporator coil. These products are used where the air movement is accomplished by another component in the system, perhaps a furnace. Two types are shown here: an "A" coil design, which is used when two furnaces are twinned, and a simple cased evaporator coil that are installed in the ductwork. These coils are available in a variety of capacities; the most common are 7½ and 10 ton.

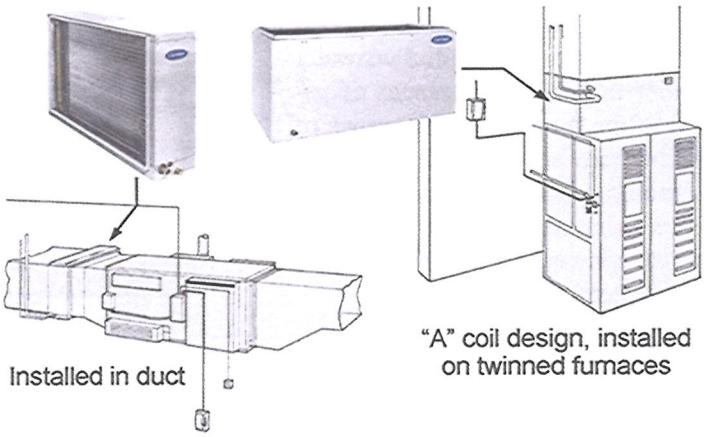


Figure 45

Cased Evaporator Coils

Residential Coils

Residential evaporator coils are similar to the cased evaporator coils described above, yet in smaller tonnage ranges. The coils are traditionally installed on the discharge side of a furnace. The coils are available in a number of configurations, "A," "N," slab, and in cased or uncased designs. The "A," "N," and slab refer to the shape the evaporator coil resembles.

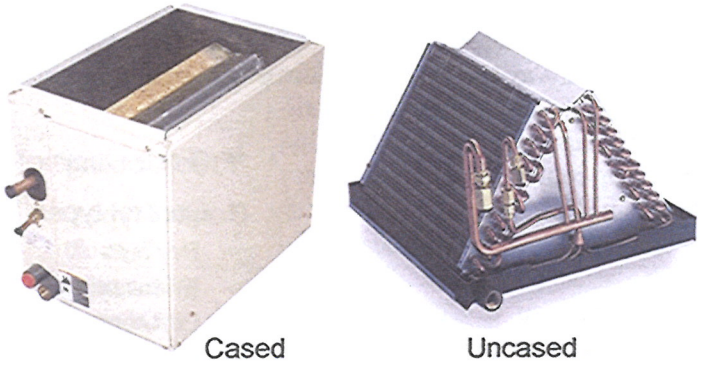


Figure 46

Residential Evaporator Coils

Remote Chiller Barrel

As mentioned previously, another type of indoor split system unit is a chiller (cooler) barrel or evaporator. This device is used in applications where an air-cooled system is desired yet it is necessary to locate the cooler barrel indoors. One reason for this choice is to provide freeze protection for the chilled water loop without the disadvantages of using glycol in the loop. Applications of this type require a condensing unit with multiple stages of capacity. A water temperature controller must control the compressor and stages of capacity electrically.

An alternative to this, once again, would be to use a factory-designed, air-cooled chiller and relocate the cooler barrel in the field if the manufacturer allows that configuration.

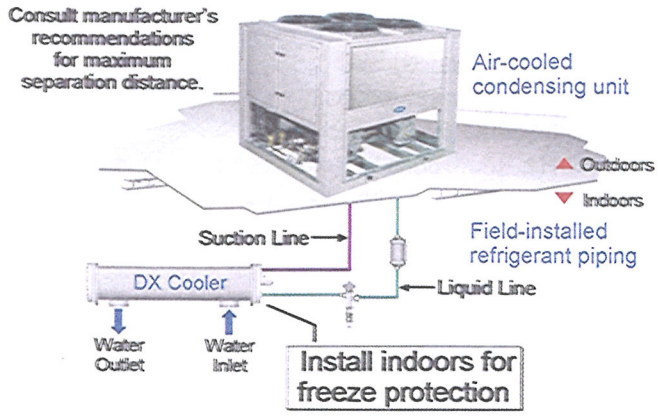


Figure 47

Remote Cooler Barrel

Accessories

Economizer

An important consideration in any split system is the introduction of outdoor air for ventilation purposes. One way to accomplish this is by using an economizer that also provides the benefit of "free cooling" when ambient conditions are appropriate. Historically, economizer control types included dry bulb control, enthalpy control, and differential enthalpy control. Today, CO_2 sensing is also a popular control method. The use of a CO_2 sensor-controlled economizer provides an effective method of demand controlled ventilation (DCV) for split systems.

As noted earlier, energy codes like ASHRAE 90.1 may require the use of an economizer and may dictate which type of control is to be used.

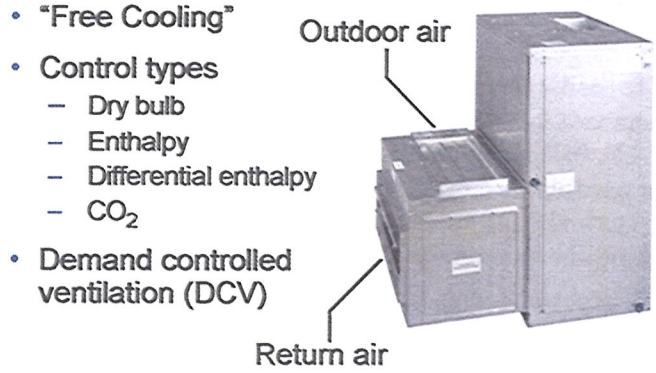


Figure 48

Economizer

Heating Accessories

The indoor units discussed previously focused on cooling only. Of course, many split systems also incorporate heating components. Heating may be accomplished in a variety of ways. Heating accessories for packaged air handlers include: electric, hot water, and steam heating options. These accessories are typically installed on the leaving airside of the packaged air handler. If the system is a heat pump, the coil in the indoor unit will provide heating when the system is operating in the heating mode. This type of heat may be referred to as "mechanical heating." Heat pump indoor units may also be equipped with accessory heating devices when the application requires more heat than the heat pump system can provide and to provide heating during defrost conditions.

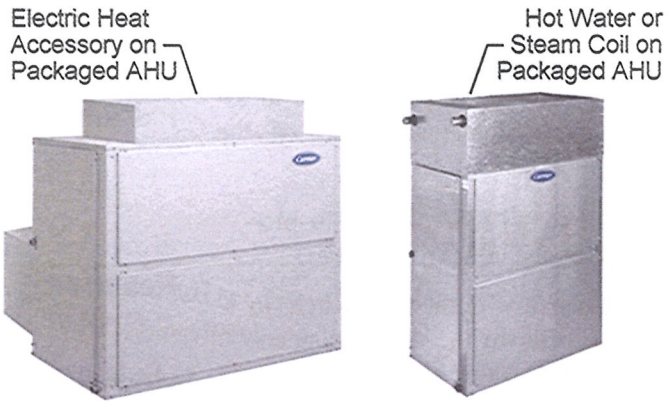


Figure 49

Heating Accessories

Furnaces

Heating may be supplied by a furnace. This furnace may be of the typical design with a cooling coil on the leaving side of the furnace. The furnace may also be a duct type furnace (not shown) placed downstream of the air handler. Furnaces can also be used in pre-selected pairs as shown, called twinned furnaces.

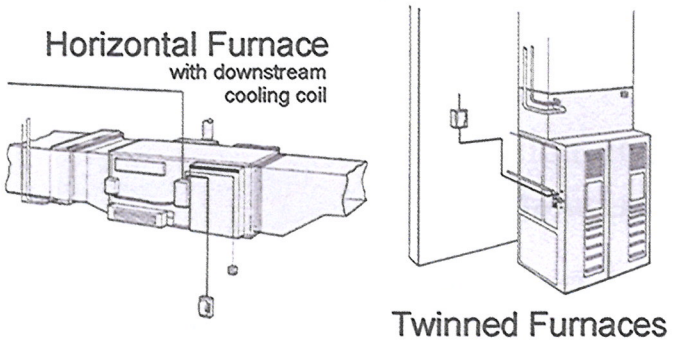


Figure 50

Furnace Applications

Other Accessories

A variety of other accessories may be available to complete the split system installation. These include:

- Plenum, used for free discharge applications.
- Return air grille, also used on free return to prevent larger debris from entering the unit.
- Subbase, used to hold the unit off the floor, typically to allow for installation of the condensate drain.
- Condensate drain kit, to provide the condensate trap.
- Overflow detection switch, to shut down the unit if condensate backs up.
- Suspension kit, provides the necessary brackets and in some cases isolation when the units are to be suspended from the structure above.

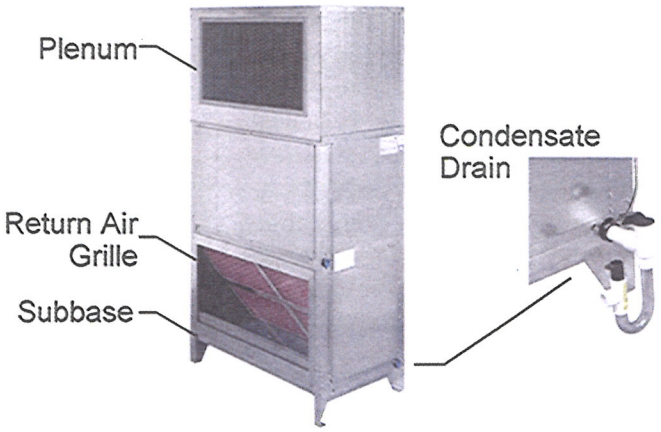


Figure 51

Accessories

Controls

Thermostat

From a control perspective, the typical split system is very simple. For this reason, the control is quite frequently a simple thermostat. The devices to be controlled include: indoor fan, outdoor fan, compressor, and liquid line solenoid (if equipped). On a very simple, small tonnage system, when the thermostat calls for cooling, the indoor fan is started, the liquid line solenoid opens, and the outdoor fan and compressor are started. When the thermostat is satisfied, the liquid line solenoid is closed, the compressor and condenser fan are cycled off, and the indoor fan stops. This type of control is known as solenoid drop control.

Simple control requirements:

- Indoor fan
- Outdoor fan(s)
- Compressor(s)
- Liquid line solenoid

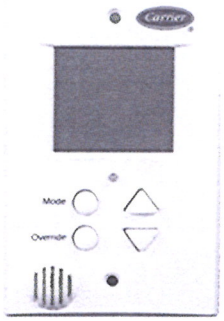


Figure 52

Control Thermostat

Two-Stage Thermostat

Dual circuit systems may be controlled similarly with a two-stage thermostat. In these applications, the first stage cooling (Y1) initiates the first circuit of the condensing unit. If the first circuit cannot satisfy the load demand on the space, the second stage cooling (Y2) function of the thermostat will initiate the second stage of the condensing unit.

- Y1 initiates 1st stage cooling
- Y2 initiates 2nd stage cooling

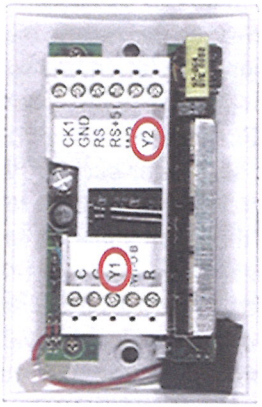


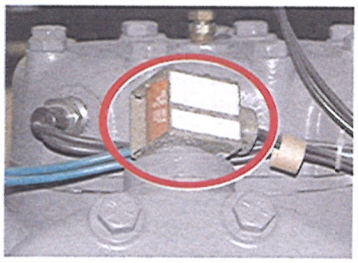
Figure 53

Two-Stage Thermostat

Electric Unloading

A two-stage thermostat may also be used to control a single reciprocating compressor equipped with an electric unloader. Y1 will start the cooling sequence as described previously and unload the compressor. In this way, the compressor will be operating at less than full capacity when the load is light. If the load cannot be satisfied with the compressor operating unloaded, Y2 will initiate and cause the compressor to load, thereby providing full coil capacity.

- Y1 initiates 1st stage cooling AND unloads the compressor
- Y2 loads the compressor



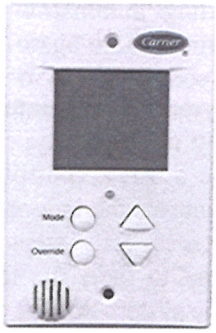


Figure 54

Electric Unloading

Capacity Control Valve

The two-stage thermostat may also be used to control a liquid line solenoid valve in conjunction with compressor unloading. First-stage cooling will start the cooling sequence, but only half of the indoor coil will be open to refrigerant flow. If the load cannot be satisfied with only half of the indoor coil active, Y2 will initiate and cause the second-stage liquid line solenoid valve to open, thereby providing full coil capacity.

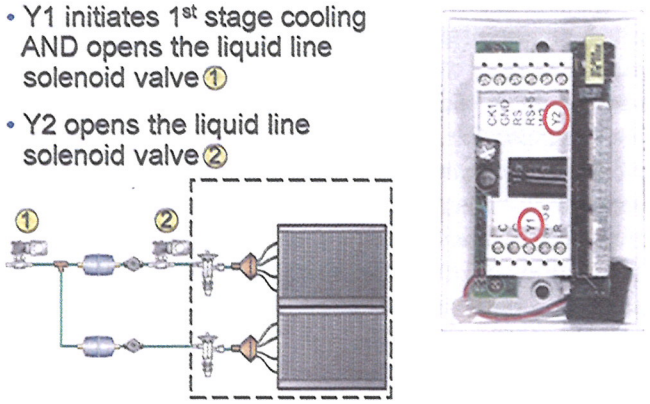


Figure 55

Capacity Control Solenoid Valve Control

DDC Control

Of course, digital controls or a building automation system may be required. Here again, the simplicity of the control needs of the typical split system allows interfacing with a variety of control types. An example may be a VAV controller, which not only controls the indoor unit, but also stages the capacity steps of the condensing unit to meet the load requirements of the system.



Figure 56

DDC Control System

Safety Controls

On a typical split system, the condensing unit is equipped with several safety controls. These may include:

- High-pressure switch, which protects the system from excessive discharge pressure.
- Low-pressure switch, to limit the minimum suction pressure and protect against loss of charge.
- Discharge gas thermostat, used on some units, which protects the compressor from overheating due to high condensing temperature or low return gas flow.

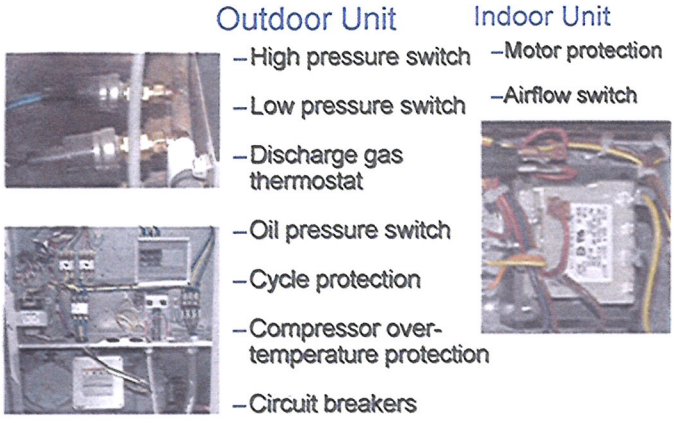


Figure 57

Safety Devices

- Oil pressure switch, on some units, that protects against a lack of lubrication.
- Compressor over-temperature switch, used on some units and internal to the compressor, to protect against compressor overheating.
- Circuit breakers, used on some units, others have internal protection, which protect against electrical motor overload.

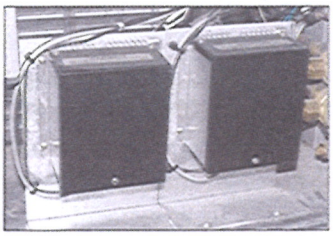
The indoor unit is typically equipped with indoor fan motor protection (internal protector or circuit breaker). Additionally, a common field-supplied safety is a proof-of-airflow switch. The proof-of-airflow switch is interlocked with the outdoor unit controls to prevent compressor operation if there is no airflow, in the event of indoor fan motor or belt failure. The primary control circuit is usually located in the condensing unit control box and the indoor and outdoor circuits need to be interlocked with field-installed control wiring.

Low Ambient Control

Another control issue that must be considered is the outdoor air temperature range at which the split system will be expected to operate. In order to ensure proper operation of the expansion device in the indoor unit, it is necessary to maintain a significant pressure differential across the expansion device. As the outdoor air temperature decreases, the saturated condensing temperature (SCT) of the system also decreases. The minimum outdoor air operating temperature is defined in the condensing unit application data. You will notice that the minimum outdoor temperature with standard outdoor fan (OFM) control is 35° F. If the system will be operated when the outdoor temperature is less than the standard value, it is necessary to apply a low-ambient control device to the condensing unit. The low-ambient control device is a speed control device that will vary the speed of the OFM motor(s) to maintain the SCT at a reasonable level, approximately 100° F. On split systems, DO NOT use a low-ambient control device that controls by cycling the fan motor off and on; it must be a variable speed motor control device. Notice in the table that these condensing units with low ambient control may be operated down to -20° F.

MINIMUM OUTDOOR-AIR OPERATING TEMPERATURE

UNIT 38AR	COND TEMP (F)	MINIMUM OUTDOOR TEMP (F)	
		Std.	With Motormaster® Control
Z007	80	35	-20
Z008	80	35	
Z012	80	35	
S012	80	35	
	80	35	
D012	80	35	



Motormaster® Control

- **Proper operation of expansion device at low outdoor temps**
- **Minimum outdoor air operating temperature**
- **Maintain minimum SCT**
- **Low ambient controller – OFM motor controller**

Figure 58

Low-Ambient Control

Fan-Cycling Pressure Switch

You may also encounter some condensing units that employ an intermediate season SCT control device, a fan-cycling pressure switch (FCPS). The FCPS is a pressure switch that senses pressure in the condenser coil. On condensing units that have multiple OFM motors, a FCPS may be used to cycle on or off one or more of the OFM motors. For example, on a condensing unit that has two OFM motors, a FCPS may control the #2 OFM motor. Once the FCPS has turned the #2 OFM motor off, if SCT temperature continues to fall, the low ambient control device must vary the speed of the #1 OFM motor to maintain a stable SCT. The important fact to remember is that the last operating OFM motor must be controlled by a variable speed device. Do not cycle the last operating motor.

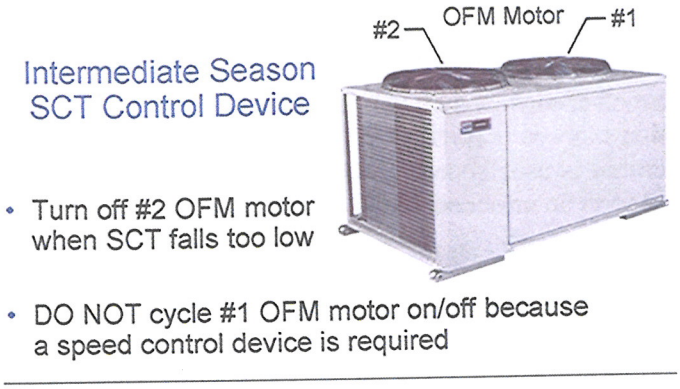


Figure 59

Fan-Cycling Pressure Switch

Wind Baffles

An additional element of the low ambient control system is the wind baffle. If the condenser coil is exposed to sustained winds, controlling the number of operating fans and/or, fan speed, may not maintain SCT at a reasonable level. The force of the wind alone may provide more air movement across the coil than is desired. In these applications, it is necessary to install wind baffles, at least on the windward side of the unit. Condensing units that employ horizontally-mounted coils do not require wind baffles.

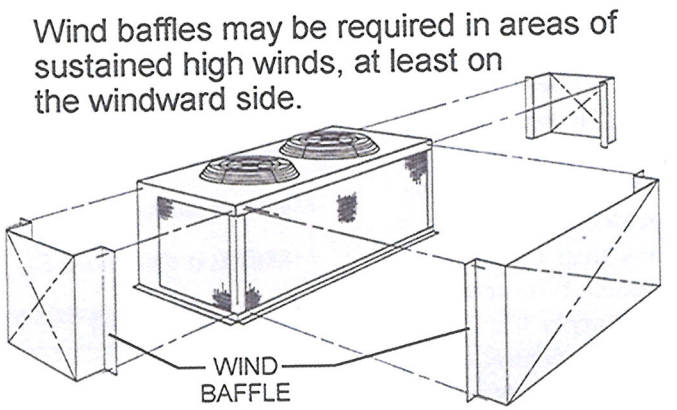


Figure 60

Wind Baffles

Installation

Designers should understand several issues related to installation in order to do a better job in system design. Understanding the requirements for electrical service, location, refrigerant piping, and control interfacing will result in more satisfactory split system designs.

Electrical

A split system has four electrical service requirements that need to be meet. First, the size of the wiring that needs to be run to the indoor and outdoor sections must be determined. Then the size of the fuse or circuit breaker that will protect each of the two sections from electrical overload needs to be determined. Third, the disconnect requirements for both the indoor and outdoor sections need to be specified. Finally, the requirements that interlock the two sections must be determined.

Power Supply

Another important part of the system designer's task is to define the power supply needed for the split system. Typically, this will involve at least two power circuits, one for the indoor unit, and one for the outdoor unit. If the indoor unit is equipped with electric heat and requires only one power supply, this is called a "single point" connection. If the electric heat is a duct heater or an add-on to the air handler, it may require separate power supplies for the air handler and the electric heater. The key terms to understand in defining the power supply requirements are Minimum Circuit Ampacity (MCA) and Maximum Over-current Protection (MOCP).

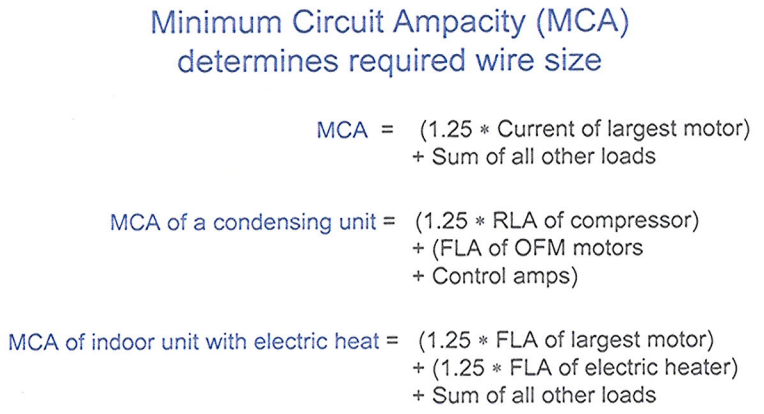


Figure 61

Power Supply MCA

MCA

The value of the MCA determines the wire size required for the circuit. MCA is calculated:

MCA = (1.25 * current of the largest motor) + sum of all other loads

The amperage drawn by a compressor depends on the operating point; the industry has agreed to determine this current draw at a selected set of operating conditions indicative of normal maximum current draw. This value is referred to as run load amps (RLA). Other motor amperage is listed based on the motor operating at fully-loaded conditions without going into the service factor, referred to as the full load amps (FLA).

Therefore, the MCA of a condensing unit would be:

MCA = (1.25 * RLA of the compressor) + (FLA of the OFM motors) + Control Amps

The MCA of an indoor unit is calculated similarly unless it is equipped with electric heat. If equipped with electric heat, the MCA is:

MCA = (1.25 * FLA of the largest motor) + (1.25* * FLA of the electric heater) + sum of all other loads

*1.00 if heater is 50 kW or larger

MOCP

The MOCP value defines the maximum overcurrent protective device. The key word is "maximum." If the MOCP for a condensing unit is 60 amps, this means the largest overprotection device (fuse or circuit breaker) allowed by UL or the NEC (National Electric Code) is 60 amps. If a 50-amp device is used, that is not a problem from the perspective of UL or NEC. The risk in using a smaller fuse or circuit breaker is that the unit could trip the protective device on start-up or in times of high current draw, for example, in high ambient conditions. The designer must consider the benefit of a smaller protective device (less cost) compared to the potential for nuisance tripping of the protective device. To calculate MOCP:

MOCP = (2.25 * current of the largest motor) + sum of all the other loads

If the value derived does not equal a standard current rating of an over current protection device, the MOCP is to be the next lower standard rating, but not lower than the MCA.

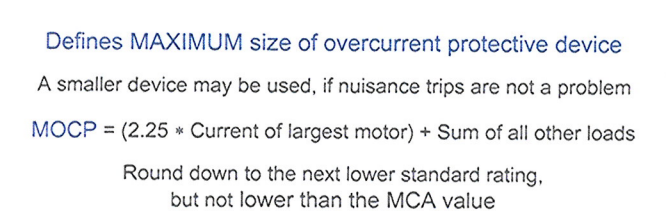


Figure 62

MOCP

ROCP

There is an alternate method of calculating overcurrent protection known as recommended overcurrent protection (ROCP). To calculate ROCP:

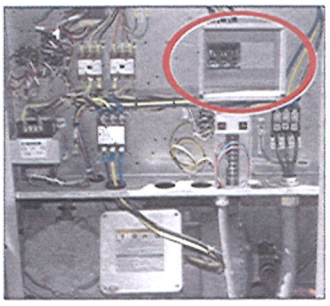
ROCP = (1.5 * current of the largest motor) + sum of all the other loads

UL1995 states that a value smaller than the MOCP, i.e., ROCP, may be published, if the unit is tested at the lower value and does not trip the over current protection device. The key point is that the unit must be tested at the lower value to confirm that it will function without nuisance trips of the overcurrent device.

Protective Device

The type of protective devices used in the HVAC industry may be fuses or circuit breakers, depending on the application and locale. If circuit breakers are used, they must be a type specifically designed for the HVAC industry, known as HACR breakers (heating and air conditioning rated). Generally speaking, HACR breakers will be used whenever acceptable by code and when available in the size required. Fuses will be used if required by code or if the MOCP value is greater than the largest HACR breaker available. Be sure to check the manufacturer's installation information since some units will be rated for use with fuses only.

- Fuse or Circuit Breaker
- HACR Breaker



Usage defined by code and availability

Figure 63

Protective Devices

Disconnects

For safety reasons, electrical codes such as the NEC require that a "disconnecting device" be located within line of sight of the unit. This disconnect may be installed in the field by an electrician or it may in some cases be provided as a factory-installed option. Disconnects may be fused or non-fused. If a non-fused disconnect is used to meet the "disconnecting device" requirement of the NEC, the circuit must still be protected by fuses or HACR breakers. These protective devices would then be located between the non-fused disconnect and the electrical power service to the building.

- Located within "line of sight"
- Field-installed or factory-supplied
- Fused or non-fused

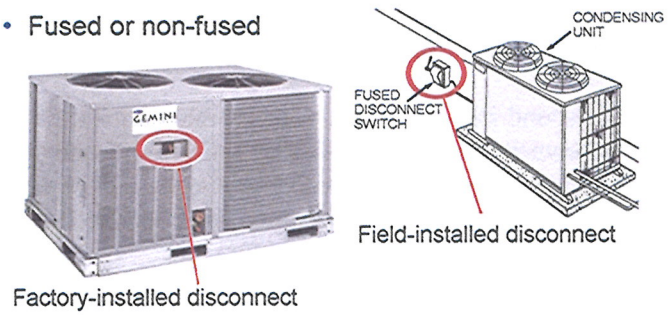


Figure 64

Disconnects

Installation Instructions

For specific information regarding installation, it is imperative to consult the manufacturer's installation instructions. Different units and different manufacturers for the same tonnage may have very different requirements for clearances, electrical service and refrigerant piping requirements. However, there are a number of general considerations that apply to most installations.

Installation cautions:

Check the manufacturer's installation instructions, different units and manufactures will have different requirements for refrigerant piping, location and electrical requirements.

Locate the indoor and outdoor units as close together as possible, Check for both refrigerant lift and run restrictions

Provide adequate service clearance and operational clearance.

The indoor and outdoor unit should be located as close to one another as is practical. This will keep the length of the refrigerant piping to a minimum. Long refrigerant lines increase the potential for performance problems and increase job installation cost. Be careful to check for the maximum separation between the indoor and outdoor sections, both for run (total line length) and lift (the height the liquid refrigerant must travel up to the evaporator). Different compressors can have very different requirements for run and lift. Use the manufacturer's piping recommendations to size refrigerant piping whenever they are provided. Piping recommendations are often the result of considerable testing for oil return and refrigerant charge limitations.

Unit location must also take into consideration condenser coil airflow (outdoor unit) and maintenance accessibility. Always refer to the manufacturer's recommended clearances when deciding where and how to locate the equipment. For the outdoor unit, be sure to consider the potential for vegetation growth blocking the coil in the future. Service pads are required for units mounted on the ground. It is sometimes desirable to hide the condensing unit for sound or aesthetic reasons. When this is done be sure that the barrier allows for adequate airflow and that it does not cause recirculation of hot condenser air.

Sound

The sound produced by air-conditioning equipment is becoming increasingly important as designers, owners, and occupants seek quieter and quieter environments. It must be recognized that split system components will produce sound, and steps must be taken to insure that the sound produced is not objectionable. The sound level produced by the equipment is typically identified in the unit product data. Manufacturers may also provide sound reduction accessories for the equipment to reduce the sound produced. It is equally important that designers consider the impact of sound when locating equipment. For example, it would not be wise to locate a large condensing unit on the roof of an office building if the space directly below is the company president's office. It would not be wise to locate a packaged air handler in a closet with louvered return air doors at the back of a classroom. When in doubt regarding sound issues, utilize the services of a skilled acoustical consulting engineer.

SOUND LEVELS, dB

UNIT 38		SOUND RATING (60 Hz) dB (A)	OCTAVE BANDS							
			63	125	250	500	1000	2000	4000	8000
ARZ	007	80.0	71.5	76.8	75.3	74.0	73.9	74.1	73.5	64.0
	008	84.0	84.1	84.5	80.4	78.6	77.2	76.9	78.8	72.5
	012	85.0	88.7	85.4	81.7	80.9	82.1	76.2	73.6	67.1
ARS	012	83.0	78.0	82.6	84.9	78.6	79.5	72.1	69.9	65.8
AKS	014	86.2	—	93.0	86.0	83.0	80.0	78.0	73.0	71.0
	016	86.2	—	93.0	86.0	83.0	80.0	78.0	73.0	71.0
	024	90.0	83.5	81.5	88.5	86.5	85.5	82.5	76.5	61.5
ARD	012	85.0	87.3	84.1	85.9	79.2	77.6	75.3	75.0	68.2
	014	86.9	—	90.9	86.1	83.1	84.0	73.5	71.7	66.7
	016	87.5	—	90.9	86.1	83.4	84.5	76.6	73.2	63.5
	024	88.0	—	90.9	86.1	83.8	84.5	79.2	74.3	65.5

- Understand sound power (both indoor and outdoor)
- Utilize sound reduction accessories when available
- Consider the effect of sound when recommending unit location
- Isolate and support refrigerant tubing

Figure 65

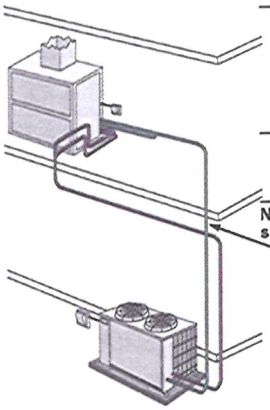
Typical manufacturer's sound ratings.

Some units have options available that can be used to assist in controlling the sound levels. These should be used whenever the job is acoustically sensitive.

One often-overlooked sound issue with split systems is the refrigerant piping. It is good design practice to allow for some movement in the piping, and use piping supports to isolate the units and prevent the piping from transmitting vibration and noise.

Elevation

The indoor and outdoor sections may be located at the same elevation or they may be located on different elevations. If the indoor unit is located above the outdoor unit, the outdoor unit must "lift" the liquid refrigerant up to the indoor unit. In this case, the designer must confirm that the vertical distance between the indoor and outdoor unit does not exceed the liquid lift capability of a condensing unit. If the separation is too great, one or both of the components must be relocated. The lift impacts the pressure drop in the liquid line. Excess pressure drop can result in the liquid flashing to vapor in the line and result in hunting problems with the TXV.



LIQUID LINE – 38AKS012-024 UNITS

UNIT 38AKS	MAX ALLOW. LIFT (ft)	LIQUID LINE	
		Max Allow. Pressure Drop (psi)	Max Allow. Temp Loss (°F)
014 016 024	67 82 87	7	2

NOTE: Data above is for units at 45° F saturated suction and 95° F entering air.

Figure 66

Elevation

Suction Riser

If the outdoor unit is located above the indoor unit, consideration must be given to the vertical section of the suction piping known as the suction riser. In order to ensure proper compressor oil management, the velocity of the refrigerant must be high enough to entrain compressor oil with suction vapor in the suction line. The manufacturer's data may also define limitations on the maximum length of suction risers where applicable. In some cases, it may be necessary to use two refrigerant lines in the suction line to assure adequate velocity for oil return. This arrangement is referred to as a double suction riser.

Double suction risers

Are avoided by using single suction risers that are sized for oil entrainment at minimum load. If the size of the single suction riser results in excessive pressure drop, then a double suction riser may be necessary.

Refrigerant Piping

Proper sizing and installation of refrigerant piping is imperative for proper operation and long component life in a split system. Information regarding refrigerant piping practices and methods may be found in TDP-501, Refrigerant Piping.

Caution: DO NOT bury refrigerant piping underground! Buried refrigerant lines can result in refrigerant condensing taking place in the lines and liquid refrigerant slugging back to the compressor.

Remember to select the proper size refrigerant lines (tubing) for split system applications. There are a number of sources of this information; always use the manufacturer's data when it is provided. If this data is not available from the manufacturer, then alternate sources such as the Carrier Refrigerant Piping Software and System Design Manual may be used. Refrigerant lines should always be sized for no more than a 2° F line loss.

UNIT 38AR	LINEAR LENGTH OF PIPING — FT							
	0-25		25-50		50-75		75-100	
	Line Size (in. OD)							
	L	S	L	S	L	S	L	S
Z007	3/8	1 1/8	3/8	1 1/8	3/8	1 1/8	3/8	1 1/8
Z008	3/8	1 1/8	1/2	1 1/8	1/2	1 1/8	1/2	1 1/8
Z012	1/2	1 3/8	1/2	1 3/8	1/2	1 3/8	1/2	1 3/8
S012	1/2	1 3/8	1/2	1 3/8	1/2	1 3/8	1/2	1 3/8
D012	(2) 3/8	(2) 1 1/8	(2) 3/8	(2) 1 1/8	(2) 3/8	(2) 1 1/8	(2) 3/8	(2) 1 1/8

LEGEND
L — Liquid Line S — Suction Line

NOTES:
1. Pipe sizes are based on a 2° F loss for liquid and suction lines.
2. Pipe sizes are based on the maximum linear length, shown for each column, plus a 50% allowance for fittings.
3. Charge units with R-22 in accordance with unit installation instructions.

Refer to manufacturer's recommendations

***DO NOT** bury refrigerant piping underground!*

Figure 67

Refrigerant Piping Sizes (6-10 Ton, R-22)

Maximum Length of Refrigerant Piping

A common question is: What is the maximum allowable length of the refrigerant piping system? Unfortunately, the best answer is, "It depends." For example, the maximum allowable linear length of piping for a commercial heat pump application is 100 ft. Lift and suction riser limitations determine what portion of the 100 ft can be vertical. The maximum allowable length will vary based on the manufacturer and the size of the unit. Typically, larger condensing units will allow larger maximum line lengths. Refer to the manufacturer's guidelines when a long line application is being considered.

Note:

Always consult manufacturer's recommendation for the length of refrigerant lines. As a general recommendation line lengths over 75 ft or so, are considered long line. Lift over 25 ft should be checked for capability with the system being used. Heat pumps are limited to 100 ft of line length.

Long Line Applications

A long line application is defined as one that has a total linear length of 75 ft or greater. Long line applications require special considerations to reduce the risk of equipment failures. For example, all long line applications must have a liquid line solenoid valve(s) and a suction line accumulator(s) to provide an additional degree of protection for the compressor.

On long line applications:

- *Use an accumulator*
- *Use a liquid line solenoid*
- *Slope the lines to avoid logging refrigerant in the line*
- *Compressor MUST have a crankcase heater*

System Selection

Selection of split system units can be more complicated than the selection of packaged rooftop equipment for two reasons. First, it is possible to match a condensing unit to several different combinations of evaporators, and second, a considerable distance may separate the evaporator and condensing unit. Both of these can influence the selection.

- System Balance Point:
  - Coil performance plotted
  - Condensing unit performance plotted
  - Suction line losses:
    Suction Line: 2.0° F loss
    Accumulator: 0.5° F loss
- Balanced SST = 45.6
- Balanced SCT = 126.6
- Balanced Total Capacity:

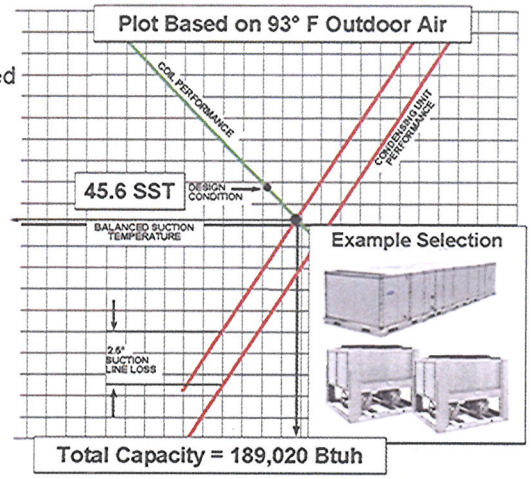


Figure 68

Balance Diagram

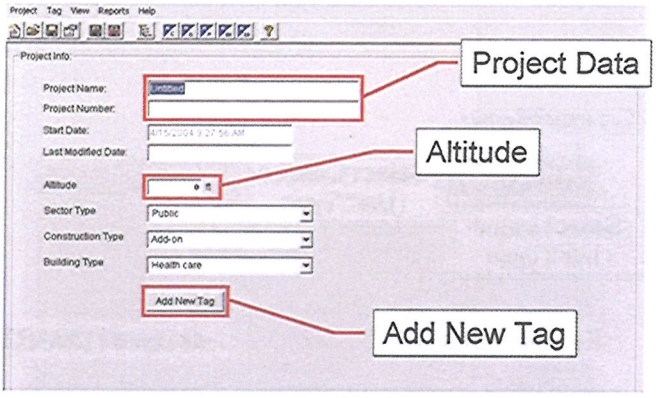


Figure 69

Sample Input of Carrier's E20 Input Screen

In the past, it was necessary to make a selection by graphically plotting the performance of a condensing unit against the performance of an evaporator using a balance diagram. Since electronic selection programs have become available, computers can easily perform the balance.

Manufacturers now provide split system selection software tools that evaluate both the indoor and outdoor unit as a system. As an example, the Carrier selection program is used in the next few sections to explain the procedure and the required inputs. The programs result in outputs that provide the designer with all the information normally required to complete the schedule for the design drawings.

The first data input screen is primarily for project management, with the exception of the altitude input. Inputting an altitude above sea level, will automatically be compensated for air density at the altitude specified. A "Tag" is just a name for the unit, for example "SSU-1 Office area."

Input

Next, select the type of equipment, DX Cooling, DX Heat Pump, or Chilled Water. If one of the DX choices is selected, the program will select a system using an indoor and outdoor unit. If "Chilled Water" is selected, the program will select a chilled water indoor unit only. Electrical service is the next important consideration. Select the electric service for the indoor and outdoor units. The values do not have to be the same. The only other data that is required to make a selection is indoor unit airflow.

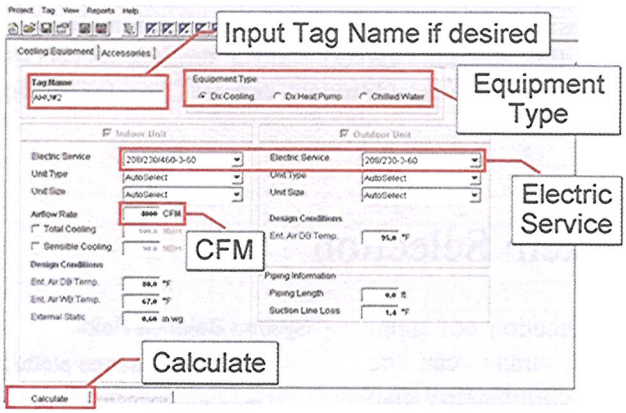


Figure 70

Input Screen

If you input 4000 cfm and press the "Calculate" button, the software will return a list of all of the available combinations that will safely operate at 4000 cfm at the default ARI rating conditions

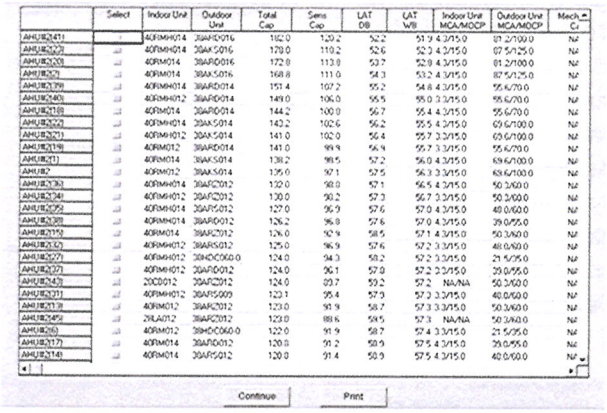


Figure 71

E-Cat Initial Results

Notice that the list is rather lengthy. Therefore, you would typically make additional selections in each of the drop down boxes to narrow the number of choices. For example, you may know that the indoor "Unit Type" desired is a packaged AHU. You may desire a single circuit, scroll compressor, condensing unit. Input the design conditions for your application. Press the calculate button now and see all of the combinations that meet your criteria and the performance of each, or take one more step to further reduce the choices.

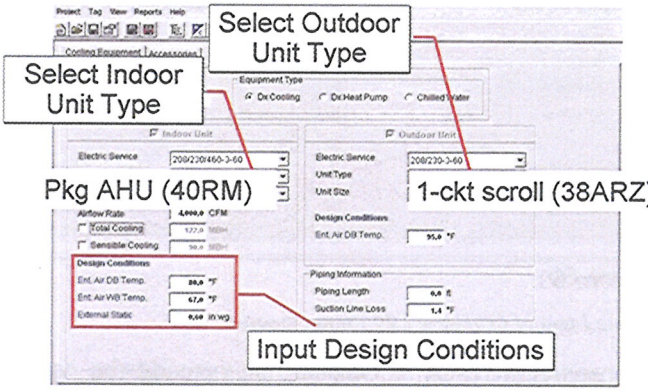


Figure 72

Narrow the Choices

Specify Total or Sensible Cooling

Input the amount of Total Cooling or Sensible Cooling required, and then press the calculate button. The system will now return only those combinations that fit the physical criteria and meet your performance requirements. Note the fields for Piping. Some programs will calculate the impacts of pipe size and lengths on the performance.

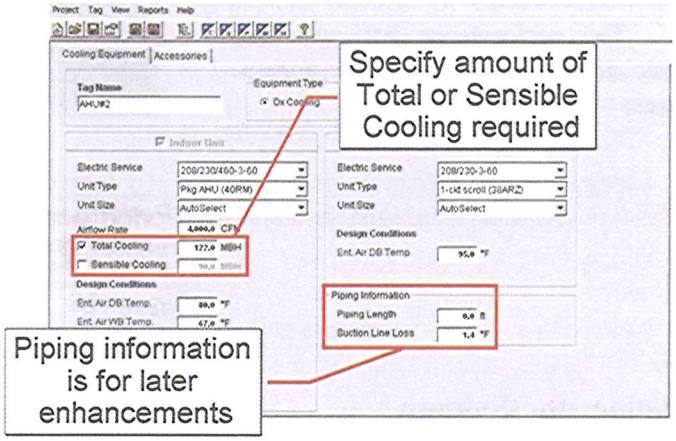


Figure 73

Specify Cooling Needs

Input Accessories

If the indoor unit will be equipped with accessories that will affect the unit's performance, you should click on the accessory tab. Select the appropriate accessories and then recalculate.

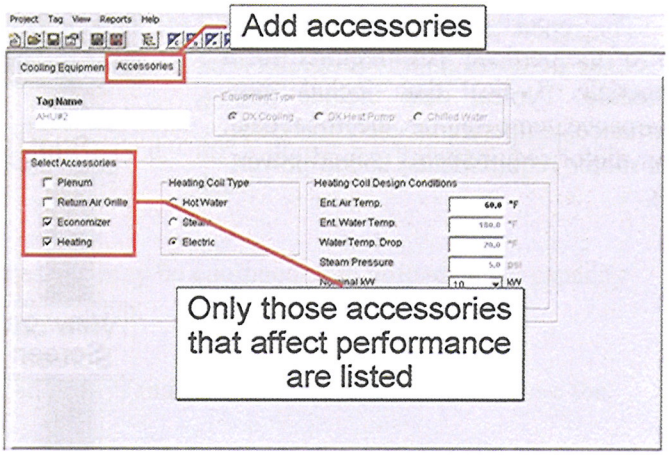


Figure 74

Add Accessories

Performance with Accessories

The performance will now take into account the effect of the accessories.

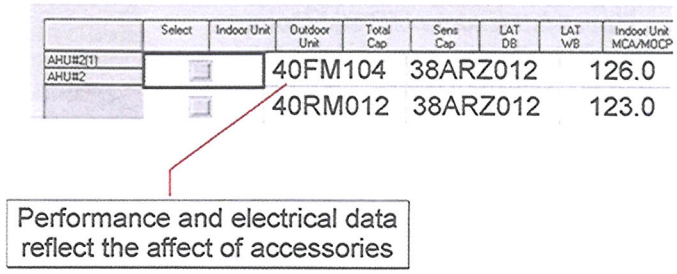


Figure 75

Performance with Accessories

Select the System

To see the complete data on the system, select the system desired, and then click "Print" at the bottom of the screen. The result will be a screen print of the Performance Data Report.

Performance Data Report

The report generated will provide all of the pertinent data required for a schedule. Typical data include performance, temperatures, electrical data, fan motor requirements, sound power, etc.

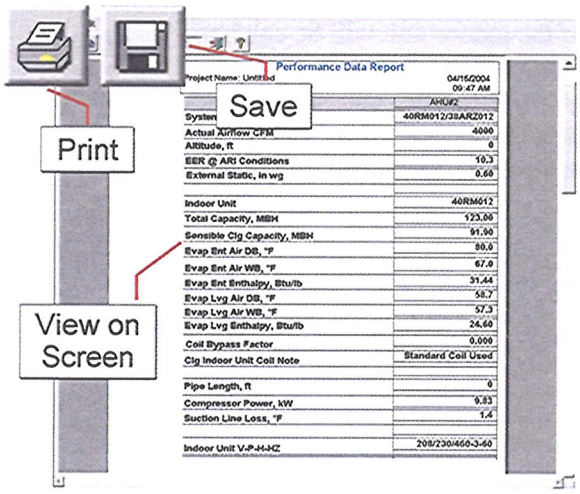


Figure 76

Performance Report

Summary

The objective of this module has been to familiarize the participants with split system equipment, the nature of the business, and the technical aspects of selection and application of split systems. Specific attention has been given to the flexibility of the system, issues which are specific to split systems and the tools available to the designer.

Split systems

provide the designer increased flexibility with the benefits of packaged equipment.

Work Session 1

Multiple-choice questions may have more than one correct answer; identify all correct selections.

1. A typical commercial split system includes _____.

   a) an indoor unit only
   b) a compressor, an indoor fan, an evaporator and condenser as one or more sections
   c) an indoor and an outdoor unit
   d) a compressor, an indoor fan, an evaporator and condenser as a package

2. True or False? All commercial split systems are at least dual circuit. _____

3. True or False? Net capacity will always be greater than gross capacity. _____

4. SEER applies to _____

   a. units which are cooling and heat
   b. all units under 65,000 Btuh
   c. single phase units under 65,000 Btuh
   d. all units under 135,000 Btuh

5. The standard ARI rating condition used to calculate EER for commercial splits is _____

   a. 80° F db/57° F wb indoor , 82° F outdoor
   b. 70° F db/57° F wb indoor, 47° F outdoor
   c. 80° F db/67° F wb indoor, 95° F outdoor
   d. 80° F db/67° F wb indoor, 82° F outdoor

6. True or False? Semi-hermetic compressors may be equipped with unloaders for capacity control. _____

7. True or False? Heat pump systems can always match an indoor unit one size above the nominal capacity of the outdoor unit. _____

8. The condensing unit used in a VAV application will differ from a condensing unit used in a CV application in which of the following ways? _____

   a. They are the same only the indoor section is different.
   b. VAV units have a suction line accumulator.
   c. VAV units have additional steps of capacity.
   d. VAV units have a VFD on the compressor.

9. Calculate the MOCP and MCA for a condensing unit that has one compressor rated at 75 amps, one indoor fan rated 21 amps, and two outdoor fans rated at 6 amps each.

_____

10. Find the system EER for a unit with a gross capacity of 137,000 Btuh, two OFM motors at 1500 Watts, and a 5 hp indoor fan motor operating at 4.1 bhp. The compressor draws 6 kW.

_____
_____
_____
_____

11. Refrigerant lines with a length greater than 75 feet require _____.

a. a compressor which unloads to 33 percent capacity
b. a suction line accumulator
c. a receiver
d. a double suction riser and a solenoid valve

12. A condensing unit can be unloaded from 10 tons to 4 tons, the indoor coil has 20 circuits of 3/8 in. tube. Is this an acceptable combination? Why? _____

_____
_____
_____

13. Split systems are a good selection for applications_____.

a. requiring high latent capacity.
b. requiring high sensible capacity.
c. that are not concerned about building aesthetics.
d. such as a shop in a downtown district located on the first floor of a 5-story building

14. The following are appropriate accessories for a condensing unit. _____

a. Hot water coil mounted on the discharge
b. Enthalpy-controlled economizer
c. Condensate trap
d. Unit mounted disconnect switch

15. Residential systems differ from commercial systems in the following ways. _____

a. Because they do not have any options
b. They have fixed metering devices on all models
c. They are units of 5 tons or less
d. They can only be used on residential homes

Notes

Notes

Appendix

Work Session Answers

1. c. split systems are two or more sections
2. False – units may be single or dual circuit
3. False – gross capacity is larger on cooling equipment
4. a. SEER applies to both
   c.
5. c.
6. True, this is the way it is done
7. False – heat pumps are only nominal capacity and tested combinations
8. c.
   d.
9. MOCP = 1.25 Largest Motor + Sum of other motors
   MOCP = 1.25 * 75 + 6 * 2 = 105.75 amps
   MCA = 2.25 * largest motor + sum of other motors
   MCA = 2.25 * 75 + 6 * 2 = 180.75
   Closest size is a 175-amp fuse
10. First determine the net capacity
    Net capacity = Gross capacity – fan heat
    IFM Watts = (BHP*746)/motor efficiency = (4.1*746)/0.83 = 3685 Watts
    IFM Heat = Watts * 3.414 Watts/Btu = 3685 * 3.414 = 12,580 Btuh
    Net Capacity = 137,000 – 12,580 = 124,420 Btuh
    Now determine system power
    Total Power = IFM + OFM + Compressor
    Total Power = 3685 + 2* 1500 + 6000 = 12685 Watts
    Then system EER is EER = Net capacity/Watts = 124,420 Btuh/12685 Watts = 9.8 EER
11. b.
12. Minimum tons /circuit for 3/8-in. tube is 0.4 tons per circuit.
    Tons/circuit for this example = 4 tons/20 circuits = 0.2 tons per circuit; TOO LOW!
13. a.
    b.
    d.
14. d.
15. c.

Notes

Prerequisites:

This module assumes the participant has an understanding of industry terminology, basic concepts of the air conditioning, and the mechanical refrigeration process. The following TDPs are good reference for this material:

Form No.	Color Book	Instructor Presentation	Title
TDP-102	796-026	797-026	ABCs of Comfort
TDP-103	796-027	797-027	Concepts of Air Conditioning
TDP-105	796-029	797-029	Comfort Design Steps
TDP-401	796-037	797-037	Principles of Mechanical Refrigeration
TDP-404	796-040	797-040	Compressor Types

Learning Objectives:

At the conclusion of this module, participants will be able to:

- Identify applications that utilize the strengths of split systems.
- Demonstrate an understanding of the various components of split systems.
- Explain how codes and rating requirements affect selection of a split system.
- Describe the common types of outdoor units and the differences in each.
- Describe the common types of indoor units and the differences in each.
- Describe the options and application limits when applying CV or VAV type systems.
- Calculate the minimum circuiting requirements.
- Select the appropriate control system for a split system application.
- Identify the key installation issues when applying a split system.
- Describe how to size refrigerant piping for split systems.
- Describe how to select a split system unit and what precautions are needed.

Supplemental Material:

Additional information on subject covered in this module may be found in:

Form No.	Color Book	Instructor Presentation	Title
TDP-501	796-042	797-042	Refrigerant Piping
TDP-403	796-039	797-039	Expansion Devices and Refrigeration Specialties
TDP-701	796-066	797-066	System Features and Selection Criteria
TDP-702	796-067	797-067	Comfort Control Principles

Instructor Information

Each TDP topic is supported with a number of different items to meet the specific needs of the user. Instructor materials consist of a CD-ROM disk that includes a PowerPoint™ presentation with convenient links to all required support materials required for the topic. This always includes: slides, presenter notes, text file including work sessions and work session solutions, quiz and quiz answers. Depending upon the topic, the instructor CD may also include sound, video, spreadsheets, forms, or other material required to present a complete class. Self-study or student material consists of a text including work sessions and work session answers, and may also include forms, worksheets, calculators, etc.



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