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.

Large rooftop units are a fast-growing segment of the rooftop industry. A large VAV (variable air volume) rooftop unit with VAV terminals can be used in the place of multiple smaller constant volume units as a way of providing multiple zones of temperature control. With fewer rooftop units, duct systems, power supplies, and roof penetrations, cost savings are realized. The VAV rooftop unit can be incorporated with a variety of VAV terminals to form a complete system. Large VAV rooftops units are also being used in some applications traditionally reserved for applied equipment, such as central station air handlers and chiller systems. The rooftop variable air volume system offers a competitive first cost, competitive operating cost, ease of service, good indoor air quality capabilities, and good part-load humidity control. The ability to deliver these benefits has led to increased use of variable air volume systems using large tonnage rooftop units.
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Introduction

Packaged rooftop units comprise the largest segment of the commercial HVAC marketplace in the United States. The focus of this TDP is large packaged rooftop units that are used in variable air volume applications. These units are typically available in capacities ranging from 20 to 100 tons or more. Each unit includes a compressor section, filter section, evaporator coil, air-cooled condenser coil, indoor fan section, and controls designed for VAV (variable air volume) duty, all in a packaged design for outdoor installation.

Large packaged VAV rooftop units, as shown in Figure 1, are designed to meet current industry trends. The procedure for selecting an appropriate unit and system for a commercial building has changed. Four major concerns now drive the HVAC unit and system choice in today’s marketplace:

- Full and part-load energy efficiency
- Part-load temperature and humidity control
- **Indoor air quality (IAQ)** within the building
- Acoustic considerations

A VAV rooftop unit can deliver high efficiencies at full and part load with good temperature and humidity control. Available features provide for desirable indoor air quality, and the unit design allows for flexibility in location to allow for better acoustical performance.

There are several building types that are good candidates for VAV rooftop units. There is also a variety of options and accessories available that will customize the VAV rooftop to the application. VAV terminals for zone control are also available in several configurations: series and parallel fan-powered terminals, single-duct terminals, and integral-diffuser units.

Overall, the resulting building indoor air quality benefits from the use of a VAV rooftop system. The ability to meet the four design requirements has led to increased use of variable air volume systems based on large tonnage rooftop units.
Common information applicable to this TDP is also contained in TDP-631, Rooftops Level 1: Constant Volume. This TDP will reference that publication as a source of further information.

As a final note, this TDP is meant to complement the Carrier System Design Guide on VAV Rooftop Systems. The Design Guide develops system-related topics like VAV rooftop layout, heating and cooling loads, duct design, operating cost analysis, and jobsite suggestions. These documents are shown in Figure 2.

**Market Overview**

The rooftop market has experienced a number of changing trends in design choices. One trend is toward fewer, larger tonnage units instead of large numbers of smaller sized units, as shown in Figure 3. One of the primary reasons is due to the cost of preventative maintenance. Other reasons are that the number of roof penetrations, electrical power supplies, and separate duct systems can be reduced with fewer, large-sized units.

For example, consider a structure with multiple small rooftop units. A simple task, such as changing filters, could take a technician a minimum of several hours. The air conditioning needs of the same building may be met with a single large rooftop unit distributing air to VAV terminals for zone control. The filter maintenance could now be accomplished in minutes. Scenarios like this are one reason for a general increase in the use of larger capacity rooftop units.
Large Rooftop Unit Types

Large rooftops are available in two configurations: packaged air-conditioner (PAC), or gas-fired heating and cooling year round air conditioner (YAC).

A packaged air-conditioner may provide cooling only or be equipped with gas-fired heaters, electric resistance heaters, hot water heat, or steam heating coils, depending on the size and manufacturer. When capable of heating, the unit may be used for “year round” heating and cooling duty. Traditionally, the YAC is given the year round designation by virtue of the fact it is factory-equipped with gas heat. Gas historically has been less expensive as a heating source than electric resistance heaters.

Variable Air Volume or Constant Volume

VAV units have the ability to vary the supply airflow. The most popular method utilizes a variable frequency drive (VFD) to control the rpm of the supply fan motor. See Figure 4. Varying the airflow as a function of space load requirements saves fan energy. The larger the rooftop unit motor is, the larger the potential for fan energy savings. Installing inlet guide vanes (IGV) on the supply fan can also provide fan modulation. Today, inlet guide vanes are used less frequently than in the past, primarily because they are less efficient and less reliable than VFDs. Also, the price of VFDs has decreased. For a complete discussion of fan modulation methods, see TDP-613, Fans in VAV Systems.

Variable air volume systems adjust the unit operation based on the volume and temperature of air required by the system. A VAV system can utilize an air handler, rooftop, or self-contained indoor unit to produce the required airflow.

VAV units typically use a multi-step discharge air controller to stage the compressors to maintain a constant air temperature off the cooling coil. VAV units may also incorporate a supply air temperature reset function. This feature automatically resets the supply air temperature upwards when the return air temperature (RAT) reaches the occupied space temperature set point. If the RAT equals the space temperature set point, all space demands should be satisfied. At that point, the controls can reset the supply temperature up a few degrees (usually from 55 to 60°F) to save compressor energy. Another reset function associated with VAV systems is zone demand reset. The cold air temperature can be reset based upon the requirement to satisfy the average occupied zone space temperature.

VAV Rooftop Unit Capacities

At one time, 100 tons of capacity was seen as the practical maximum for a rooftop unit. Today, 130 tons is common, with a few manufacturers offering units as big as 200 tons.
ROOFTOPS, LEVEL 2: VARIABLE AIR VOLUME UNITS

VAV units usually have more steps of cooling capacity than constant volume units, allowing them to maintain better control of the discharge air temperature. Some units that have a limited number of capacity steps may require hot gas bypass to protect the refrigeration system during low-load conditions. Hot gas bypass allows the compressor to operate even when the load requirements are less than the minimum step of compressor capacity reduction. Often hot gas bypass is not needed, as the VAV rooftop unit will control the discharge air set point and cycle last stage of compression to maintain set point even at low-load conditions.

Constant volume units base their operation on a thermostat in the occupied space (see Figure 5). Hence, constant volume units supply a fixed volume of air. Only the temperature of the air provided varies. They do not utilize a VFD or discharge air control.

**VAV versus VVT® Systems**

The percentage of large variable air volume rooftops sold versus the number of large constant volume sized rooftops continues to increase. The ratio is tonnage-dependent. For example, the larger the unit, the greater the percentage of variable air volume units sold. At least 50 percent of the 30 to 50-ton large rooftops are variable air volume. Above 50 tons, the ratio approaches 90 percent. This is because VAV systems are equipped to serve large cooling demands.

In the HVAC industry, VAV-equipped rooftop units are available starting about 20 tons in capacity. Below 20 tons, systems called variable volume and temperature (VVT) are often used. A VVT system is capable of supplying multiple zones of control from a constant volume rooftop. Instead of using a VFD to vary the airflow through the unit, unused supply airflow is bypassed from the main supply duct back to the unit return. See Figure 6.