COMMERCIAL HVAC SYSTEMS

Variable Volume and Temperature

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.

VVT is an economical, all-air zoned system that is ideal for many commercial jobs, especially at a time when there is so much design emphasis being placed on high-quality air treatment, outdoor air ventilation, and room air circulation. VVT systems are a popular solution for heating and cooling multiple zone applications in small to medium size buildings. VVT controls typically are supplied pre-packaged from the HVAC equipment supplier and are ready to install by the mechanical contractor. Many manufacturers offer VVT-type systems. These systems are highly dependent on the control hardware and software used. This TDP uses the Carrier VVT system for all examples. The objective of this module is to define VVT, identify applications, compare it to alternative systems, and describe how it achieves zone temperature control.
Table of Contents

Introduction ................................................................................................................................. 1
The VVT System ............................................................................................................................ 4
  VVT is Variable Volume .............................................................................................................. 6
  VVT is Variable Temperature ...................................................................................................... 6
What is Zoning? ............................................................................................................................. 7
Types of VVT Jobs ....................................................................................................................... 8
  Jobs at 25 Tons or Less .............................................................................................................. 8
  Jobs Larger than 25 Tons ............................................................................................................ 9
Retrofitting Existing Systems with VVT ..................................................................................... 10
VVT versus Other Systems ........................................................................................................ 13
  VVT Advantages ...................................................................................................................... 14
  VAV System Comparisons ...................................................................................................... 16
  VVT versus Multiple Units ..................................................................................................... 18
Zoning the Building for VVT ..................................................................................................... 19
Basic Sequence of Operation .................................................................................................... 22
  Linkage .................................................................................................................................... 23
  Pressure Dependent (PD) versus Pressure Independent (PI) .................................................. 23
  Call for Heat/Cool and Equipment Mode ............................................................................... 24
  System Changeover .................................................................................................................. 25
  Selecting Zone Priority - Reference Zone .............................................................................. 26
  Fan Sequence of Operation ..................................................................................................... 26
VVT Air Distribution System Design ...................................................................................... 27
  Sealing VVT Ducts ................................................................................................................... 30
  Dampers .................................................................................................................................. 31
    Round Dampers ..................................................................................................................... 32
    Rectangular Dampers ............................................................................................................ 32
  Bypass System Layout ............................................................................................................ 32
    Bypass Components ............................................................................................................. 33
    Functionality .......................................................................................................................... 33
    Layout .................................................................................................................................. 34
  Damper Sizing .......................................................................................................................... 36
  Diffuser Layout ........................................................................................................................ 37
Control System Details ............................................................................................................. 40
  Linkage Coordinator versus Standard Zone Controllers ....................................................... 40
  Bypass Controller .................................................................................................................. 41
  The System Pilot .................................................................................................................... 41
  Space Sensor Locations and Options ..................................................................................... 42
  Combined Space Temperature and CO₂ Sensing ................................................................. 43
  Humidity Sensor ...................................................................................................................... 43
  Zone Sensor Averaging .......................................................................................................... 43
  Outside Air Temperature Sensor ............................................................................................ 43
  Zone Level Demand Controlled Ventilation (DCV). ............................................................... 44
    Zoning Systems with DCV .................................................................................................. 44
    Wiring and Power Requirements ......................................................................................... 45
  System Options ....................................................................................................................... 45
Supplemental and Perimeter Heat ............................................................................................ 46
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary</td>
<td>49</td>
</tr>
<tr>
<td>Work Session</td>
<td>50</td>
</tr>
<tr>
<td>Designer Checklist</td>
<td>52</td>
</tr>
<tr>
<td>Engineering Design Steps</td>
<td>52</td>
</tr>
<tr>
<td>Installation Notes for Contractors</td>
<td>54</td>
</tr>
<tr>
<td>VVT Installation Start-up Request Checklist</td>
<td>56</td>
</tr>
<tr>
<td>Work Session Answers</td>
<td>58</td>
</tr>
</tbody>
</table>
Introduction

VVT (variable volume and temperature) is an economical, all-air zoned system that is ideal for many commercial jobs, especially at a time when there is so much design emphasis being placed on high quality air treatment, outdoor air ventilation, and room air circulation. When a single heating/cooling unit is used, VVT works well for systems up to about 25 tons of total cooling capacity. Multiple systems make its application practical for much larger jobs.

This module defines VVT and describes how it achieves zone temperature control. Applications for the system will be identified and VVT will be compared with alternative systems. Since the operation of the VVT system is under the direction of a complete, factory-packaged DDC (direct digital control) control system, various pre-programmed, operational sequences will be described so that the way it works will be clear. Guidelines for VVT system design are given so that the designer may focus on some of the unique aspects of the system.

Air conditioning design is all about solving building comfort needs to satisfy the occupants of that building. One of the buildings we will use to illustrate zoning and the use of VVT is this manufacturing office, which is a 60’ x 100’ single-story commercial construction attached to a small, air-conditioned electronics manufacturing and assembly factory. This is an owner-occupied office with relatively permanent partition arrangement and an expectation for a reasonably good level of comfort. Occupants will be exposed to the indoor environment for long periods of time, so their comfort expectation will tend to be high. In addition, they are sedentary, for the most part, which increases their sensitivity to variations in temperature, air distribution and air stratification.

Figure 1
Manufacturing Office Example Building
Figure 2

60’ x 100’ Manufacturing Office VVT System Layout
The task of the air-conditioning system is to maintain comfort in the building by simultaneously controlling space temperature, humidity, air motion, air purity, air quality, and mean radiant temperature. In our case, the system will be a VVT system. The layout shown in Figure 2 includes many details for a real design. In a sense, this is your “map” for the information that is coming. It will help you to focus on the area of the system being addressed in virtually every portion of this module.

Take a few minutes to look the layout over, reading the designer’s system comments, which describe the VVT system designed for this job.

For this VVT system, a single heating/cooling, constant volume packaged rooftop unit provides central heating or cooling capacity to the VVT boxes. Each box modulates its volume control damper in response to the zone thermostat or sensor. Air not used by the zones is bypassed into the return air ceiling plenum. Thus, the zone airflow is variable but the rooftop airflow is relatively constant. This permits the use of standard constant volume equipment. Each box has a user-defined minimum cfm setting to ensure adequate room air circulation and outdoor air ventilation in the zone regardless of zone load reduction. Typical minimum airflow settings vary from about 10 to 30 percent of design flow and are subject to local codes.

The VVT system is designed to provide all cooling capacity centrally and as much central heating as possible. When all zones require some degree of cooling, the unit remains in the cooling mode. When all zones require some degree of heating, the unit remains in the heating mode. However, when both heating and cooling loads occur at the same time, it becomes a time-share system. That is, its electronic controls determine the greatest need (heating or cooling) and they first satisfy that mode centrally. Then, once satisfied, it switches over to the opposite mode. The system can continue switching over from central cooling to central heating, back and forth, to satisfy all zones; thus, the concept of capacity time sharing.

Because zone 7 (interior zone) requires year-round cooling whenever occupied and lighted, the unit will need to remain in the cooling mode during most of its occupied cycle. Therefore, all perimeter zone damper units are equipped with a hot water supplementary heater. Electric heaters may be used instead. The supplementary heaters will pick up any zone heating load during the occupied cycle of operation if the central unit is in the cooling mode. The supplementary heaters will be off if the central unit is in the heating mode. The supplementary heaters are deactivated during the unoccupied cycle in both the heating and cooling modes. If a separate system is installed in the zone with an unusual load pattern (zone 7), the energy efficiency of the system will be enhanced at the expense of a more costly installation.

Linear slot diffusers are used to keep cold primary air up on the ceiling at the reduced airflow occurring at partial cooling load. Conventional concentric, perforated, or curved-blade diffusers will create dumping of cold supply air on the occupants, causing poor room air mixing and temperature sensing, with the associated customer complaints. Director linear diffusers are used around the perimeter to enhance overhead heating. They contain a heat-sensitive element to change the direction of air diffusion to one-way when warm air is being delivered. That way, warm supply air washes the outside wall, as it should. Conventional, low-velocity, low-pressure sheet metal ductwork is used. It has a 1-in. duct wrap. Pre-insulated flex duct is used for limited lengths to make diffuser connections. All diffuser runouts include a round butterfly balancing damper. Observe local code limitations on flex duct use. The VVT boxes are sized to match the ductwork for ease of installation and fewest fittings.
The building occupants have comfort needs that the system is designed to solve. The system components provide heat transfer, filtration, ventilation, and air circulation capacity necessary to control the comfort conditions, like air temperature, humidity, cleanliness and distribution in the building spaces. In this module, we will refer to the central equipment as the packaged air handler; air source; HVAC equipment; packaged unit, or rooftop unit.

Even though VVT systems typically use packaged rooftop units for their central air source and heating/cooling capacity, VVT can also be applied to a split system with a packaged air handler. The VPAC (vertical packaged air conditioner) is another good air source for VVT, since it tends to be applied floor-by-floor for renovating existing buildings, where some zoning would be welcome. In essence, the VPAC is the indoor version of the rooftop unit, since it is a self-contained packaged air handler with all refrigeration cycle components included in one factory-assembled package. The only thing needed for the VPAC is a cooling tower to reject heat from the water leaving the water-cooled condenser at each unit. Air-cooled versions are also available, which reject condenser heat locally, through a wall, window, or by using a remote air-cooled condenser.

The VVT System

VVT stands for variable volume and temperature. VVT is provided with a complete factory-packaged control system designed to provide multiple zones of temperature control using a low cost, single zone, constant volume heating and cooling packaged rooftop unit, VPAC, or split system. Packaged rooftop units (RTUs) are most often used.

In the past, some manufacturers marketed a dump-box zone terminal that sent supply air that was not needed at the zone to the ceiling plenum return space. Systems using this kind of terminal were called VAV bypass systems. Carrier developed VVT, which uses a bypass concept, but does it at the air handler rather than at the space. It incorporates a complete, factory-designed DDC control system for the entire system instead of merely using dump-box terminals. Today VVT can be applied to air systems using either a ceiling return air plenum or a ducted return.