VAV System Design

An Online Continuing Education Course for Engineers

Course Number: HV-2024

Credit: 2 Hours / 2 PDH / 2 CPD

VAV System Design

Summary

This course provides recommendations to help engineers improve the efficiency of large HVAC systems. It focuses on built-up variable-air-volume (VAV) systems in multistory office buildings.

The recommended measures promote efficient, practical designs that advance standard practice, achieve cost-effective energy savings, and can be implemented using current technology. Here are some of the key recommendations:

- Reduce design system static pressure
- Employ demand-based static pressure reset
- Use low-pressure plenum returns/relief fans
- Employ demand-based, supply temperature reset to reduce reheat energy and extend economizer effectiveness
- Design fan systems to turn down and stage efficiently
- Size terminal units to balance energy impacts of pressure drop and minimum airflow control
- Set terminal unit minimums as low as required for ventilation and use intelligent VAV box control schemes to prevent stratification
- Employ demand-based ventilation controls for high-density occupancies
- Design conference rooms to provide ventilation without excessive fan energy or reheat

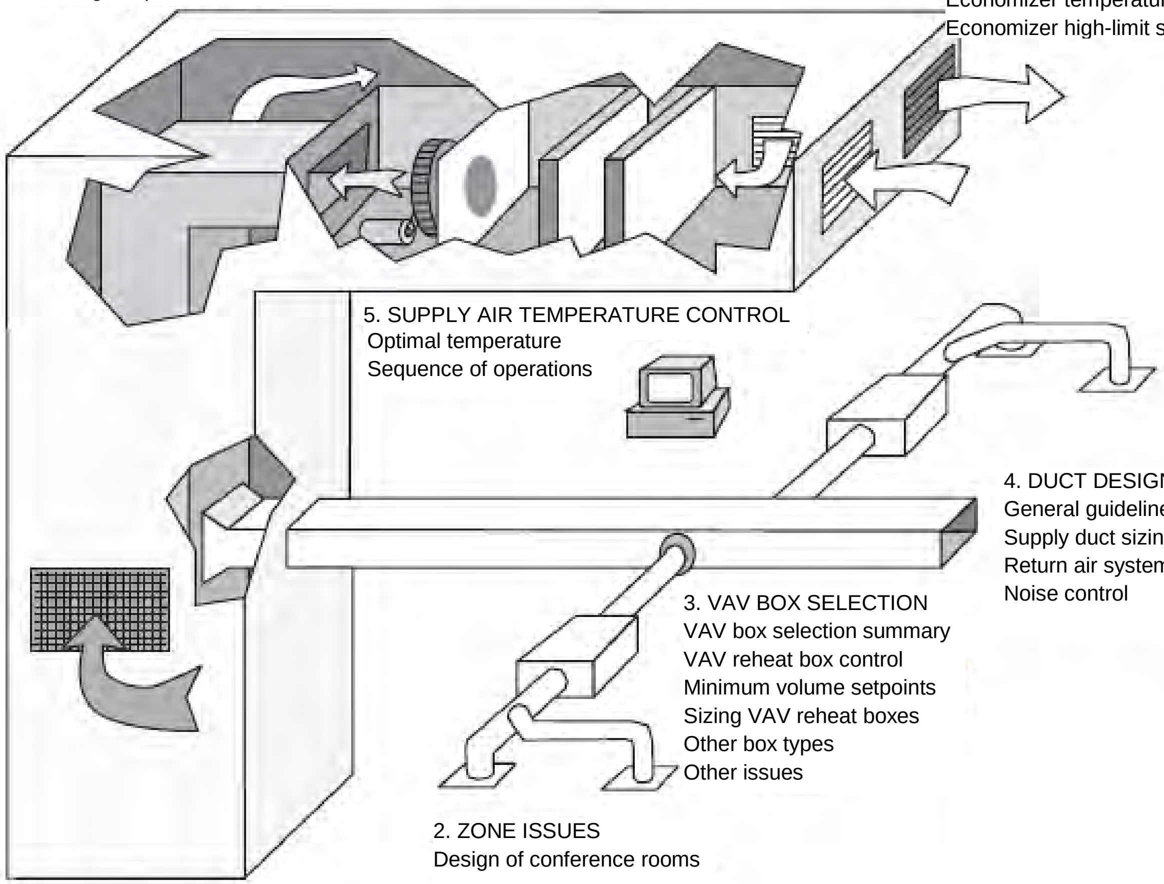
Of all the recommendations in this course, VAV box control and supply air pressure reset often have the largest impact on system efficiency. Design engineers are encouraged to pay particular attention to these two issues.

Many large HVAC systems use significantly more energy than necessary. Design engineers can improve the efficiency and cost effectiveness of built-up VAV systems by following recommendations that emphasize integrated design and designing for the full range of system operation.

Introduction

This course provides an authoritative new resource for heating, ventilation, and air-conditioning (HVAC) designers. It presents recommendations on variable-air-volume (VAV) airside system design, and provides information on fan selection and modeling.

This course is organized around key design considerations and components that affect the performance of VAV systems.



1. EARLY DESIGN ISSUES
Role of simulation in design
Location and size of airshafts
Return air system
Auxiliary loads
Design airside supply temperature
Determining internal loads
Integrated design

2. ZONE ISSUES
Design of conference rooms

3. VAV BOX SELECTION
VAV box selection summary
VAV reheat box control
Minimum volume setpoints
Sizing VAV reheat boxes
Other box types
Other issues

4. DUCT DESIGN
General guidelines
Supply duct sizing
Return air system sizing
Noise control

5. SUPPLY AIR TEMPERATURE CONTROL
Optimal temperature
Sequence of operations

6. FAN SELECTION
Fan selection criteria
Visualizing fan performance

7. SUPPLY AIR PRESSURE RESET
Static pressure sensor location
Demand-based SP setpoint reset Fan operation and isolation

8.COILS & FILTERS
Construction filters
Pre-filters
Final filter selection
Filter area
Extended surface area filters
Coil selection
Coil bypass

9. OUTSIDE, RETURN & EXHAUST AIR CONTROL
Control of minimum OSA for VAV
Design of airside economizer systems
Economizer temperature control
Economizer high-limit switches

Figure 1: Overview of Course Contents

TYPICAL VS. BEST PRACTICE PERFORMANCE

Significant fan and reheat energy savings are possible through the design strategies promoted in this course. The potential savings are illustrated in the graphs below, which present results of simulations conducted as part of the Advanced VAV System Design study mentioned above. In this example, the “Standard” case is a reasonably efficient code-complying system, while the “Best” case includes a number of the improvements suggested in this course. The result of this simulation show that fan energy drops by 50 to 60 percent, and reheat energy is reduced by 30 to 50 percent.

Most of the savings are due to the efficient “turndown” capability of the best practices design and the fact that HVAC systems operate at partial load nearly all the time. The most important measures are careful sizing of VAV boxes, minimizing VAV box supply airflow setpoints, and controlling VAV boxes using a “dual maximum” logic that allows lower airflows in the deadband mode, all of which are discussed in section 3, and supply air pressure reset control, which is discussed in section 7. Together these provide substantial fan and reheat savings because typical systems operate many hours at minimum—yet higher than necessary—airflow.

While chilled water systems account for only about 4 percent of the HVAC systems in commercial buildings, they account for as much as 45 percent of the statewide cooling capacity. And chilled water systems with VAV reheat—the type of system addressed by this course—are estimated to account for slightly more than 20 percent of all cooling capacity. Clearly, the performance of these systems has a tremendous ability to affect statewide energy use.

These practices can lead to major improvements in system performance, energy efficiency and occupant comfort.

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Simulation results for a typical San Francisco office building, comparing standard VAV design practice to the best practices promoted in this course.

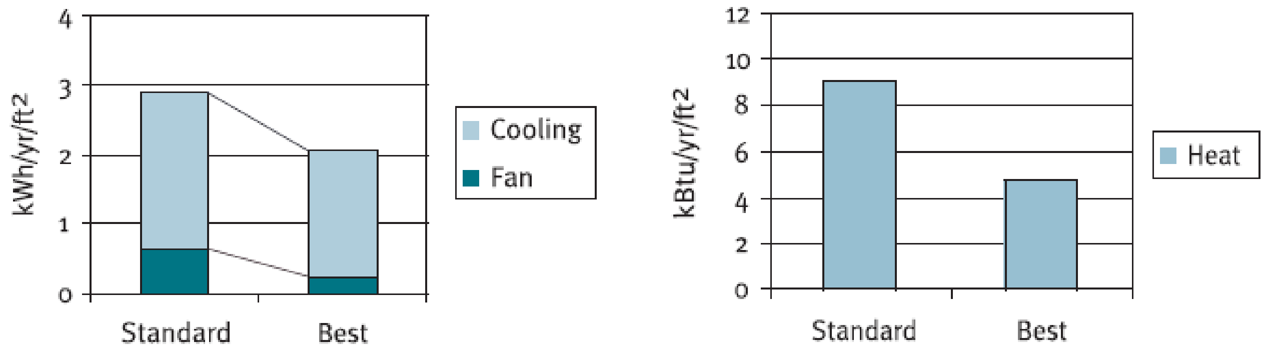

Figure 2: Fan and Reheat Energy Saving, San Francisco

Simulation results for a typical Sacramento office building, comparing standard VAV design practice to the best practices promoted in this course.

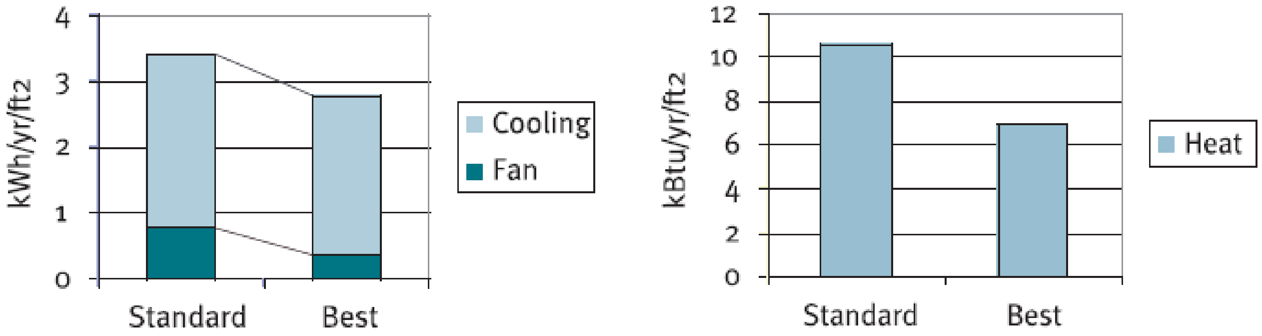

Figure 3: Fan and Reheat Energy Saving, Sacramento

Early Design Issues

The old adage, “An ounce of prevention is worth a pound of cure,” certainly holds true for the design of built-up VAV systems, which are complex custom assemblies. Extra time carefully spent in early design can save weeks of time later in the process. It can also help improve client relations and reduce construction and operating costs.

Below is a short list of early design issues that VAV system designers should pay particular attention to.

Key Recommendations: Early Design Issues

Use simulation tools to understand the part-load performance and operating costs of system alternatives. Because built-up VAV reheat systems are so complex, it is very important to use building energy simulation tools to assess design alternatives. Many of today’s powerful simulation tools are available for free or at a reasonable cost, and have simplified user interfaces that allow a complex model to be built in 15minutes or less. Building energy simulation should be an integral part of design at all phases, from schematic design through acceptance and post-occupancy.

INTEGRATED DESIGN

Achieving optimal airside efficiency requires more than just selecting efficient equipment and control schemes. It also requires careful attention to early architectural design decisions, and a collaborative approach to design among all disciplines.

Teamwork is critical to the design of high-performance buildings. Decisions that are not traditionally within the purview of the mechanical designer nonetheless have a great impact on the cost, efficiency, and success of their design. For example, the glazing selected by the architect affects thermal loads and comfort. Use of high-performance glazing or shading devices can drastically reduce the size of the mechanical equipment and improve comfort.

An integrated design process can improve the comfort and productivity of the building occupants while at the same time reducing building operating costs. A high-performance building can be designed at little or no cost premium with annual energy savings of 20 to 50 percent compared to an average building, but this level of savings will require a high level of cooperation among design team members.

Size and locate the air shafts to reduce system static pressure and fan energy use. The location and size of airshafts can have a tremendous impact on the cost and efficiency of the mechanical systems as well as on architectural space planning and structural systems. Good design practices include using multiple air shafts for large floor plates (over about 15,000 ft^2) and placing the air shafts close to, but not directly under, the air-handling equipment for built-up systems.

Use return air plenums when possible because they reduce energy costs and first costs. Establish the return air system design very early in the design process, because it has a significant impact on many issues, including the cost and complexity of the mechanical system. In general, plenum returns have a very low pressure drop, allowing the use of either barometric relief or low-pressure relief fans.

DESIGN FO
PART- LOAD OPE

Monitored loads of an off
Sacramento illustrate the
of designing for efficient p
operation. Figure 4, based
measured system airflow in
ft^2, 25- story office building,
the HVAC system may opera
one-half of the design airflo
bulk of the time.

This is quite typical for an off
building. The design airflow fo
typical floor of the monitored
is 0.83 CFM/ft^2. During cool w
the airflow doesn't exceed 0.4
and in warm weather airflow i
greater than 0.5 CFM/ft^2. Figur
shows similar results for coolin
delivered to that floor.

iently handle auxiliary
. Most buildings will
o serve loads that do not
m schedule. It is
nce of the HVAC
ds, which typically are
ing load.

at a fairly early stage
needs to be
calculate airflow
any office
f 52°F to 57°F
iencies of the
on system at peak
or 60°F or higher
pply air temperature
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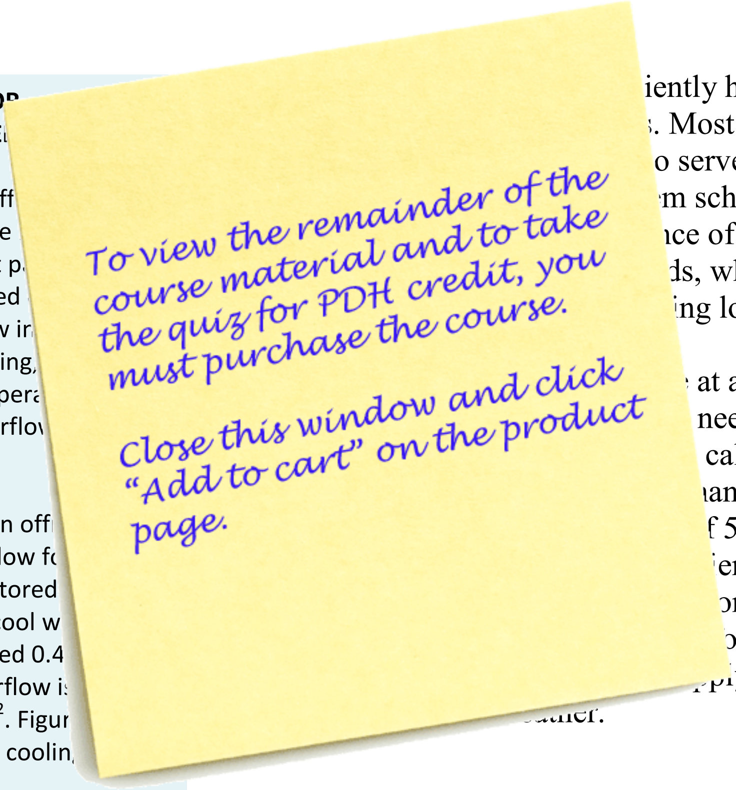
To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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Avoid overly conservative estimates of lighting and plug loads. Given the steady downward trend in lighting power, traditional lighting load assumptions may no longer be valid. Many office spaces are now designed with less than 0.8 W/ft of lighting. In addition, studies measuring plug loads show that actual loads are much lower than indicated by nameplate ratings and much lower than commonly used design values.