THE BENEFITS OF SYSTEM-BASED DESIGN

By: **James Pegues**
Senior HVAC Systems Engineer, Carrier Software Systems
Carrier Corporation
Syracuse, New York

April, 2002

(Intentionally left blank for position only)

Introduction

In 1993 Carrier incorporated ***system-based design*** features in its Hourly Analysis Program (HAP) software. At the time, system-based design was a new concept that allowed the computer to do a more complete and accurate job of sizing equipment than the traditional load estimating approach. Ten years later, this approach still yields significant benefits to HVAC system designers because of the productivity advantage it offers. And even today it still serves to differentiate HAP from other load estimating and system design software on the market.

This paper explains system-based design and its benefits. First the paper discusses how traditional system design methods work and the shortcomings of the traditional approach. Next, the concept of system-based design is explained, and the benefits it offers are explored.

How Traditional System Design Methods Work

Many computer programs used for HVAC system design are based on a traditional approach that manual methods use. First, the engineer inputs weather data, information about the building construction, internal loads and layout, and HVAC sizing parameters. The latter includes such things as thermostat setpoints, the required supply temperature and the required outdoor air ventilation rate. Using this data the program then:

- Computes zone sensible cooling loads for all zones for a series of design cooling months.
- Identifies the maximum zone sensible load for each zone in order to calculate required zone airflow rates and the required supply fan airflow rate.
- Calculates central cooling coil loads for the months being considered in order to identify the maximum cooling coil load.
- If the system also provides heating, calculations are performed to determine the maximum heating coil load.

This procedure yields data useful for sizing terminal diffusers, the supply fan, the central cooling coil, and the central heating coil.

Shortcomings of the Traditional Approach

It is important to note the traditional approach does not explicitly consider the type of HVAC system being designed. This approach is acceptable when designing simple CAV or VAV systems. However, when an HVAC system with special features, components or aspects of operation is involved, the traditional approach has two important flaws.

First, it leaves a gap between what the engineer needs to design the system fully, and what the program provides as sizing data. Different types of HVAC systems contain different components which each need to be sized. Further, different types of HVAC systems require different sizing procedures. Therefore defining the system type is necessary to determine the components to be sized and the procedures to be used. The following examples illustrate this point:

- A single zone CAV system requires that the supply diffusers, supply fan and the central cooling and heating coils be sized. The supply fan airflow is equal to the required airflow for the single zone.
- A VAV Reheat system serving multiple zones requires that supply diffusers, the supply fan, the central cooling coil and the terminal reheat coils be sized. The supply fan is sized for the diversified peak airflow to zones, rather than the sum of zone airflows. The terminal reheat coils are sized using a procedure that is different from sizing a central heating coil.
- A VAV Fan Powered Mixing Box system serving multiple zones requires that supply diffusers, mixing box terminals, the supply fan and the central cooling coil be sized. Unlike other systems, the terminal equipment for this system includes both a fan and a reheat coil, both of which must be sized. Sizing procedures differ slightly depending on whether a series mixing box or parallel mixing box terminal is used.
- A 2-Fan Dual Duct VAV system serving multiple zones requires that supply diffusers, mixing box terminals, the cold deck supply fan, the hot deck supply fan, the cold deck cooling coil and the hot deck heating coil all be sized. This system contains a unique configuration of components not found in other systems. Procedures tailored to this

type of system must be used to properly size the equipment.

The second problem with the traditional approach involves accuracy. If the traditional approach is used to size a system such as series Fan-Powered Mixing Box or 2-Fan Dual Duct, additional hand calculations will be required to size components not addressed by the calculation. These additional hand calculations make the design more difficult, more time consuming and prone to error. In more complex situations, sizing is often approximated to save time. Thus, the traditional approach plus hand calculations is often less accurate than a computerized approach that considers system type and does a complete job.

System-Based Design and How It Works

The ***system-based design*** approach considers the unique features of the HVAC system being designed and then tailors the load estimating and sizing procedures to that system. It can therefore provide specific, accurate sizing information for each component of the system.

If a Series Fan Powered Mixing Box system is being designed, for example, the system-based approach will provide the information necessary to size the terminal mixing boxes, their fans and heating coils. It will also consider the special operating features of the system to determine accurate primary supply fan and primary cooling coil sizes. In this way sizing methods and output data are customized to each specific system type.

By providing system-specific sizing data, the system-based design approach can bridge the gap between what an engineer needs and what a computerized system design program provides.

How It Works. The information a designer must supply to initiate the design process is similar to the traditional approach. The engineer must:

- Input weather data.
- Input building construction, internal heat gain and layout information.
- Define the HVAC system. In addition to thermostat setpoints and sizing criteria, the engineer specifies exactly what type of HVAC system is involved and its attributes. For example, it could be VAV Reheat, VAV with baseboard heat, Series Fan Powered Mixing Box, Dual Duct VAV, etc...

Next, the system-based design computer program calculates loads and sizes system components:

1. **Zone Load Calculation.** The program first calculates hourly zone sensible cooling loads for all zones for the design cooling months being considered.

2. **Zone Airflow Sizing.** The program then identifies maximum zone sensible loads in order to determine required zone supply airflow rates and required central fan airflow rates. For some systems, such as fan powered mixing box systems, special aspects of system operation may influence the required airflow rates.

3. **System Simulation.** Once system airflows have been determined, the program simulates the hour-by-hour operation of the HVAC system and all its components to determine loads for all coils in the system. This mathematical simulation considers the interplay of component operation for the specific system being studied. Simulations are performed for the range of design cooling months specified by the designer and for the heating design condition.

4. **Coil Sizing.** Finally, the program searches results of system simulation to determine maximum required size for each component coil in the system.

Benefits of System-Based Design

The major benefit of the system-based design approach, of course, is that it gives the engineer exactly what is needed to design a system. Specific sizing data is provided instead of raw material for further hand calculations. The result is increased productivity for the designer because the computer is being put to work more effectively. The computer does a complete job of system sizing, not a partial job.

A related benefit is that the system-based approach does a more accurate and therefore reliable job of generating sizing data. This is because sizing calculations consider the specific operating nature of the system, not the features of a simple, generic system. Further, the

approach can evaluate more operating conditions than can be checked by hand, so that the approach is more thorough and comprehensive.

Finally, because detailed, dynamic system simulations are part of this approach, the method can potentially be used to investigate the effect on sizing of such devices and controls as:

- Outdoor air ventilation heat reclaim devices.
- Outdoor air economizers.
- Active dehumidification and humidification controls.
- Night-time free cooling controls.

Previously, such controls have only been evaluated in energy analysis simulations to determine effects on operating costs. But each can also have an effect on sizing which in turn can have a significant effect the first cost of the system.

CONCLUSION

Even though the concept is no longer brand new, system-based design still represents a promising advance in the field of HVAC system design. It offers improvements in productivity and accuracy, and opens new avenues of investigation to the designer in the pursuit of the optimal design. Look for it when choosing your HVAC design tools.

www.carrier.com