

Alternate Air Delivery Systems for Hot and Humid Climates

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ABSTRACT

Carter & Burgess first began using triple deck multi-zone units, in place of traditional VAV systems, on the Texas State Capitol restoration. Since the completion of that project design in early 1991, our firm has now used triple deck multi-zone units in the Harris County Criminal Courts Building in Houston, one of the most hot and humid climates in the United States, as well as in several other facilities. This paper will discuss the adoption of ASHRAE 62, its effects on VAV systems, and how triple deck multi-zone units offer an alternative system to cooling in hot and humid climates. We recommend all design firms add triple deck multi-zone units to their repertoire of design solutions.

CATALYST FOR CHANGE

The adoption of ASHRAE 62 by the building code authorities has made a major impact on air-conditioning design. The impact has been greatest in hot and humid climates where the outside air load is a large percentage of the total building load.

Although it varies slightly with occupancy, the new requirements change the outside air requirement from 5 to 7.5 CFM per person to 20 CFM per person. This adds more than 1300 Btuh per person in a hot and humid climate. The change in required outside air CFM translates to the addition of more than a ton of load for every 10 people.

The impact is even larger on a DX system that normally operates at an 80% sensible ratio. In a hot and humid climate, the outside air load has a 60% sensible ratio. A standard DX system cannot remove the higher ratio of latent heat from the air. Many code officials are applying the outside requirements to the people counts generated by the maximum life safety occupant calculations. This number may exceed the number of occupants expected by the owner. In other words, the number of people used to calculate the outside air must often match the posted maximum occupancy of the building.

For the purpose of illustration, let us use an example of a 20,000-square foot area. This area would traditionally use approximately 60 tons of air conditioning. If 100 square feet per person was allowed, for example, 200 people would require 4000 CFM of outside air. This is a 20-ton air conditioning load. With the additional outside air requirement, the rise in the load for the 20,000-square foot area is 15 tons with 35% of the total load coming from outside air.

Many problems are caused by having a high percentage of the air conditioning load come from outside air. In the above example, 35% of the load varies with outside conditions. It is very difficult for the control valve and coil to control the discharge air temperature over a load with this much variation. This same coil and valve combination must also react to the changes due to interior load variation, skin, and solar loads. In a typical VAV system, a single coil and valve combination are controlled from discharge temperature. When the water flow is reduced by more than 20%, the ability to control the latent load is greatly diminished. When the outside air load is controlling more than 30% of the total load, the latent load is not controlled and the system does not respond to variations in internal load.

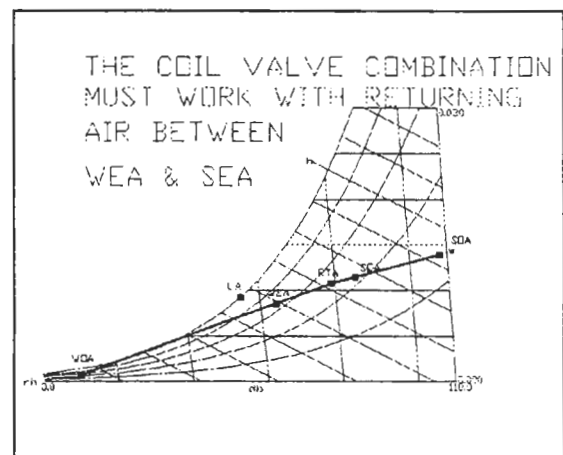


Figure 1: A typical VAV system with no pre-treat. A single coil and valve combination must work over a large range in this example.

PRETREATING THE OUTSIDE AIR

The heavy outside air load is best handled with the addition of a separate outside air unit. The outside air unit can be sized to handle the entire outside air load. If the entire load is too large, the unit may be sized to reduce the sensible load and handle only a portion of the latent load. The air coming off this pre-treat coil will be near the saturation curve. That means if the leaving air temperature is 70°F, it will be at 90% relative humidity. For good humidity control, the pretreat air temperature should be driven below 65°F.

In our example, pretreating the outside air to 62°F takes out 22.5 of the 30 tons added by ASHRAE 62. This returns us to about the same conditions we had before adding the extra outside load. Therefore, the traditional main system sizing solution can be used.

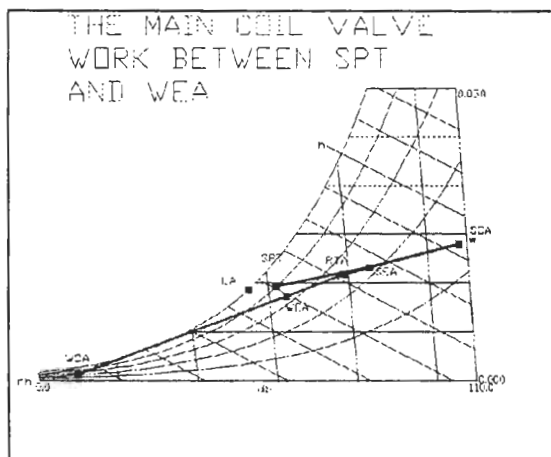


Figure 2: Using the same state points, the pre-treat unit now handles one-third of the load. The rest of the loads can be better controlled by the main coil and valve combination.

The fan in this unit becomes an outside air control fan, which assures compliance with ASHRAE 62. The total amount of outside air supplied to the building can be set by simply setting fan capacity. The outside air control fan can have an occupied/unoccupied mode or can use a more complicated variable speed operation which tracks occupancy. In either case, it is good practice to positively pressurize the building to supply the required amount of outside air.

VAV SYSTEMS

The most commonly used airside system installed over the last several years has been the VAV supply system. This system has the advantages of multiple zones of control and a low energy use. This low energy use was especially true when boxes with 0 or 10% shut-off settings were used. Totally closing the air supply to a space in response to local thermostat control quickly fell out of favor due to complaints of stuffiness by occupants. The zero shut off boxes had a big energy advantage when matched with a variable speed inverter on the main supply fan. Obviously, the fan savings fell when the 10% shut-off became the norm. The boxes being 10% open caused some overcooling. When the VAV box was properly sized, the internal loads were large enough to compensate for the 10% of cold air being delivered to the space even when the thermostat was satisfied.

Much has been written on the subject of modifying the VAV systems to meet ASHRAE 62. The best way to meet ASHRAE 62 is to raise the minimum set on the VAV boxes. Today we are dealing with systems which are 20% to 35% outside air. Most energy codes do not allow reheat, or the heating of previously cooled air. This means that the boxes serving the exterior zones on cool days must be fully shut off before heating can begin.

ASHRAE 62 will permit this if the interior zones have a minimum shut off which will allow all of the outside air to be delivered to the space. Additionally, the exterior zone must use fan-powered boxes which draw outside mixed air from the plenum and supplies it to the space. This is often considered a poor solution which frequently results in occupant complaints. What is the minimum allowable setting for the interior boxes? In our 20,000-square foot example, the interior boxes would be 35% open at minimum set.

TRIPLE DECK MULTI-ZONE SYSTEMS

Have the advantages of the VAV system been reduced to the point that other systems should be considered before these extreme modifications are implemented? The desire for multiple zones of control is still present. Subsequent to the invention of VAV, this desire was met with multi-zone units. Just as the VAV systems have improved with better controls and damper designs, the multi-zone units have evolved. The most interesting multi-zone application is the triple deck multi-zone. This unit has the conventional cold and hot decks separated by

a neutral deck. The neutral deck supplies the air from the pre-treat unit directly to the space. This neutral air is mixed with the cold or hot deck air to satisfy the space condition. The key is that the cold deck supply air is never allowed to mix with the hot deck air. There is no reheat, making this unit very energy efficient.

The new digital control systems allow many sophisticated schemes to be applied to the multi-zone. Digital controls can track the exact position of each zone damper. With this information, the deck temperatures can be reset or fan speed can be changed. All of the multi-zone controls are located in the airhandling unit room. This system is easier to maintain than a VAV where many of the components are placed above the ceiling and maintenance is disruptive and difficult. The central unit location allows for inexpensive hot water heat without the piping cost and leak concern associated with hot water heat at the boxes. A negative factor is that space allowance must be made for the multiple ducts leaving the airhandling unit room.

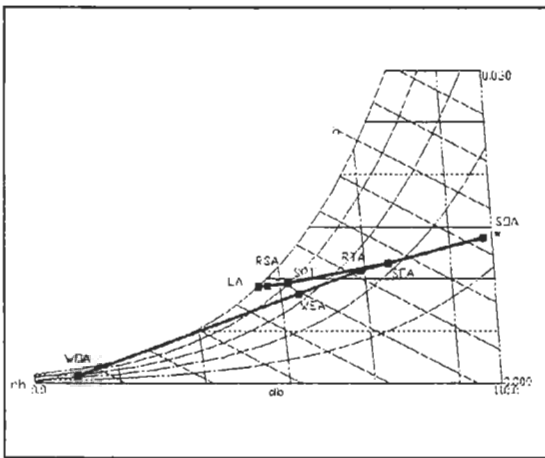


Figure 3: The triple deck multi-zone unit psychrometric chart is the same as the VAV unit in full cooling. The room supply air (RSA) moves up and down the mixed air line between SA and ENT depending on load.

The traditional worry of damper leakage has been resolved by new damper designs. These new designs make the damper stroke pass completely through the neutral deck before the hot or cold deck is reached. Leakage from the hot to cold deck would not occur if any of the damper edge seals remain intact. Since three dampers are now fastened to the

same shaft, the force required from the damper operator is higher and needs to be properly specified.

LIFE CYCLE COST

Engineers normally compare two systems by modeling them in terms of their life cycle costs. The comparison usually shows the VAV systems with a slightly lower life cycle cost until the minimum box settings are modeled. Even if a small box minimum set is used, the standard multi-zone units have a lower life cycle cost. Since the triple deck multi-zone units utilize a neutral deck for mixing with the hot or cold decks, and do not allow mixing of the hot and cold decks directly, they are obviously more energy efficient than a standard multi-zone unit. The triple deck multi-zone unit is difficult to model, but it is clearly more efficient than the standard multi-zone units.

STRATIFIED USES

Our firm first used triple deck multi-zone units on the Texas State Capitol Restoration. The goal of the project was to completely restore the 108-year-old building to its original splendor. This included raising the ceilings to their original height, which was set by the ornate cornice (at usually 22 feet). The design height above the ceiling was just 4 inches.

The Capitol, obviously, was built long before the advent of air-conditioning. The granite building was originally designed and built for gas lighting but was converted for electricity before it was occupied in 1888. There was no space, then, in the original design for ductwork or conduits to serve a modern office building.

The historical accuracy required by the State Preservation Board, which managed for the State the restoration effort of architects and engineers, was extreme. No access doors were allowed in any visible location. The combination of high ceilings and no access made the use of VAV boxes impossible. And there was a strict requirement of many zones of control. All of these factors lead us to look at multi-zone units.

The base design for the Capitol was complete in 1990 and included standard multi-zone units. During a review in 1991, however, we studied triple deck multi-zones and found them very energy efficient. We changed the design to incorporate triple deck units, which we located in the attic. The ductwork, which was trenched into the thick stone walls, served an area three floors down from the attic. The building structure would not allow more trenching, so alternate air conditioning systems were required for lower floors. The trenches were sealed, and blanket insulation was wrapped around the opening. The duct was then inserted, the insulation wrapped around the front of the duct, and the duct was plastered into the wall.

Air distribution is supplied from continuous slot diffusers that separate the plastered ceiling from the cornice and keep all non-historical air devices hidden from view. The control thermistors are located in the return portion of these slots, again keeping such items hidden from view. Rooms on the lower floors are served by custom air handlers built into the room furniture.

The unit controls for this project are fairly complicated. The building has four wings, each topped by an attic. There are four outside air pre-treat units, one for each attic. Outside air is supplied to each attic unit and to all of the individual units in the lower offices. The outside air duct to each unit has a control damper that shuts down when the unit is not in use. Units turn off on an occupancy schedule. Each office has a request switch that overrides the schedule if needed. The outside air unit has a variable speed fan which slows down as the control dampers close.

The triple deck multi-zone units also have a variable speed drive which slows down as the zone dampers move into the neutral deck. The water control valves maintain air discharge temperature on the hot and cold decks.

We have used triple deck multi-zone units on several projects since the completion of the Texas State Capitol Restoration. Two projects have been for the Federal Government and have successfully gone through their selection and justification procedure. These projects proved the life cycle cost effectiveness of the triple deck multi-zone units.

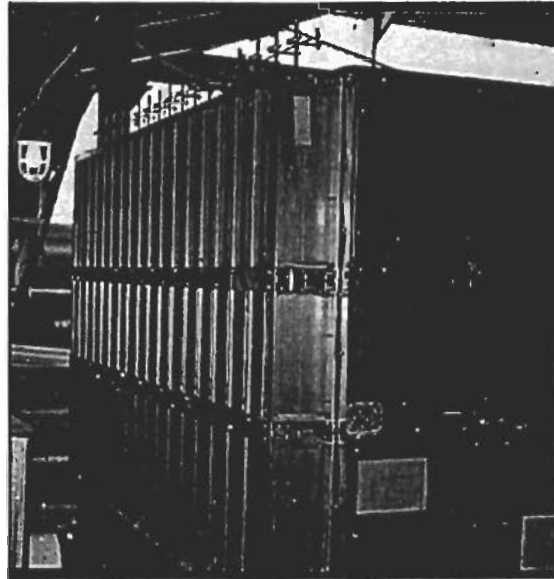


Figure 4: A triple deck multi-zone unit used in the Texas State Capitol Restoration project.

Our firm has recently completed the design of the Harris County Criminal Courts building in Houston, one of the most hot and humid climates in the United States. This large, multi-use building presented a particular challenge in cooling due to the varying occupancy of the facility. It combines jail, general office and courtroom spaces with a cafeteria and other public areas. The courtrooms themselves are large with a varying occupancy. A large amount of outside air is required by code for its occupancy. The air conditioning requirements were well suited for the use of triple deck multi-zones.

In all of the projects completed using triple deck multi-zone units, the owners have been well pleased with the environmental comfort. When the Texas State Capitol had its grand re-opening and rededication, the Governor and the legislators, along with their families, filled the House Chamber to capacity on a very warm spring day. The temperature throughout the room was measured using digital thermometers, moving throughout the space. The temperature was found to exactly follow the design conditions.

In summary, our firm has had only good experiences using these triple deck multi-zone units in hot and humid climates as replacements for traditional VAV systems. We recommend that all design firms consider such equipment during HVAC design specifications.