VAV Heating w/ a Ceiling Diffuser

This is in response to many inquiries as to why we have chosen not to have a VAV heating diffuser to compete with our competitors.

The primary reason is that the thermostat for heating would be located in the diffuser and the diffuser would, of course, be located in the ceiling. With the heating thermostat located on the ceiling, the temperature set point would be dependent on the stratification in the room. Stratification is dependent on skin loss, infiltration, ceiling height, the delta T between outdoor and room temperature, and whether the construction was slab on grade or over a conditioned space. To fully understand my decision not to introduce a VAV cooling/heating unit, an understanding of what makes a conventional ceiling diffuser work for heating would be in order.

Primary air discharging from the diffuser causes room air to be induced into the primary air stream. A four way ceiling diffuser would cause a negative pressure to develop under the center of the diffuser by the induction of secondary room air into the primary stream. This secondary induction of room air would cause a circular air pattern away from the diffuser at the ceiling then downward and finally circulating upward toward the center of the diffuser. It is this motion that breaks the natural stratification in a room. The volume and the velocity of the discharging primary air determine the magnitude of the secondary induction. For the stratification to be broken, the secondary induction must be strong enough to move and lift the heavier cold air at the floor.

Studies have been done to determine the skin loss and design temperatures that primary source heating from the ceiling is effective.

the secondary induction is not great enough to break or overcome the stratification.

In the case of a VAV diffuser with variable discharge area (Ak) the velocity would increase as the volume decreases causing a stabilizing effect on secondary induction. This would enhance the operation of VAV heating to a degree. Offsetting the energy of the discharging mass with increased velocity will only work to a limited degree before the magnitude of the secondary induction is not great enough to break the stratification. The stratification in a particular space will vary with the delta T between outdoor and room temperature. The second induction must be great enough to overcome the stratification in the worst extreme that is to be experienced.

It is not practical or effective to proportionately modulate the discharge air from the outlet and maintain an effective level of secondary induction. To maintain a constant temperature at desk level, the set point of the heating thermostat located on the ceiling would have to proportionately increase with the stratification.

I have built a prototype VAV heating unit and tested it in a test chamber with a cold wall. Supply air to the unit was maintained at constant temperature (115 degree F) and constant pressure (.15” WG at the inlet). This caused the unit to become the primary temperature control. In function, the diffuser performed as follows:

With a cold room the diffuser damper was full open. The warm air was discharging into the room at rated flow. Primary induction under the diffuser was strong

VAV Htg. w/ CD cont’d.

and little stratification (less than 2 degrees) was observed. As the room approached the set point, the damper started to close causing less primary air volume. The discharged velocity increased with the decreased volume due to the reduction in the frictional loss in the runout. This caused the pressure at the diffuser inlet to increase to system pressure. The damper continued to modulate closed.

The stratification remained constant until the threshold was reached where the increased velocity could not maintain the energy loss by the decreased volume. The stratification started to rapidly increase. The increase in temperature at the ceiling caused the thermostat to further close the damper. This cycle continued until the unit reached an equilibrium maintaining a constant temperature at the set point. Unfortunately, the constant temperature was only at the ceiling. The temperature remained constant at the set point and the desk temperature dropped proportionately with the cold wall temperature.

How does the competition do it?

Upon inspection, it was discovered that an 80-95 degree element is used for VAV heating control. This means that a constant stratification that can be varied is assumed for all operating conditions. I feel that this assumption is false. Again, as the stratification changes with the delta T between indoor and outdoor temperatures, the temperature in the occupied zone will proportionately change with it.

One of the purposes of VAV systems and VAV diffusers is to conserve energy by not over cooling or over heating the interior space. Introducing this VAV heating unit would be compromising our goal of

individual comfort and energy conservation. It has been proven that these goals cannot successfully be achieved by this method.

Energy is certainly not being conserved by overheating the ceiling, return plenum, and return duct.

What are the effects on the heating equipment when 80-95 degrees temperatures are maintained at the return of the equipment?

With heat pumps high return temperatures cause high head pressures, increased energy consumption, increased compressor component stress and wear, and high pressure limit cycling. In most cases, the effects are negative Basically it comes down to the fact that placing the heating thermostat on the ceiling without an effective means of breaking the stratification is a **poor** design.

Another test was conducted with the same VAV heating unit, but this time it was installed in an actual installation. The system consisted of roof top packaged heat pumps. The VAV cooling, VAV heating units were adjusted to maintain a comfortable temperature in the rooms. The operation was monitored for several days and recorded. What was observed was that the unit once set, never moved. This occurred because the system primary control cycled off the heat before the temperature set point was reached at the diffuser. The ceiling temperature never reached the temperature set point with the preprogrammed stratification. The net result is that the VAV heating/VAV cooling diffuser functioned as though it was a constant volume diffuser in the heating cycle. The competitors units function in the same manner.

If VAV heating can successfully be

accomplished from a ceiling diffuser as

promoted, then **why** are the operating temperatures of the elements (70-78 degrees F. for cooling and 80-95 degrees F. for heating) so different?

Operating installations can be monitored to verify my conclusions with these units. System parameters are usually such that these units end up functioning as expected or promoted. Constant volume heating has been successfully used for many years in a great number of installations. I rarely hear of complaints regarding heating but hear **many** in conjunction with cooling.

We have approached heating in a more conventional manner. Stratification will be minimized when discharge velocity and volume are maintained. This will allow heating from the ceiling in applications where the skin loss is less than 500 BTU per linear foot. The VFS 24 with the heating feature allows for constant volume adjustable heat.

This means that in the heating mode the diffuser can be set or balanced for a specific volume. When the unit changes from VAV cooling to heating, the pre-set heating flow will be maintained.

When the system changes over to cooling and the supply air temperature drops below 70 degrees F. the unit will automatically change over to VAV cooling.

In many applications, the heating unit is controlled by the return air temperature. In applications where constant volume heat is not acceptable, we offer an electric controlled unit. This model has a wall thermostat, built in changeover switch, and operates on 24 volts. A third alternative is available where electric or supplemental heat is required. This unit is thermally powered for VAV cooling but has a micro switch incorporated in the unit. The micro switch closes upon a two-degree temperature drop after the damper has fully closed. It can be inexpensively coupled to a radiant panel, electric baseboard, or hydronic zone valve to control heat.

By Robert Scacco-President