Dedicated Outdoor Air-Dual Wheel System Control Requirements

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ABSTRACT

The central thrust of this paper is to develop a clear understanding of the performance and control requirements for a dedicated outdoor air-dual wheel system. The dedicated outdoor air-dual wheel system discussed here is specifically intended to decouple all of the latent cooling from the sensible cooling done with a parallel system. The control requirements include identification of each local loop, instrumentation, control devices, sequence of operation, and a sample graphic programming language diagram. The dedicated outdoor air-dual wheel system consists of a preheat coil, an enthalpy wheel, a deep chilled water dehumidification cooling coil, and a sensible heat recovery exchanger. The imminent design paradigm shift over to the use of dedicated outdoor air systems is being restrained, in part, because of a general uncertainty about how best to control the equipment.

INTRODUCTION

Dedicated outdoor air-dual wheel systems offer the design engineer an outstanding tool for separating the ventilation requirements and latent load duty from the parallel space sensible loads duty (Figure 1a) at the lowest possible energy cost and indoor air quality (IAQ) litigation liability (Turpin 2000). The migratory path that has led to the recommended use of dedicated outdoor air systems is discussed in another paper (Mumma 2001). The current all-air VAV system is illustrated by contrast in Figure 1b. To realize the tremendous benefits of the dedicated outdoor air-dual wheel system approach, it is necessary to both completely understand how the systems are to operate thermodynamically and how to achieve that operation through proper control. Since this infor-

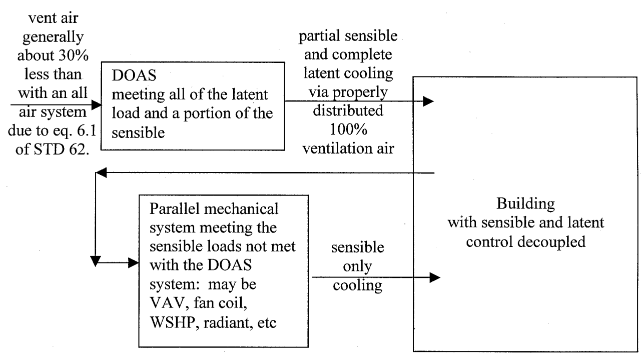

Figure 1a *DOAS/parallel arrangement with decoupled latent control—the new paradigm.*

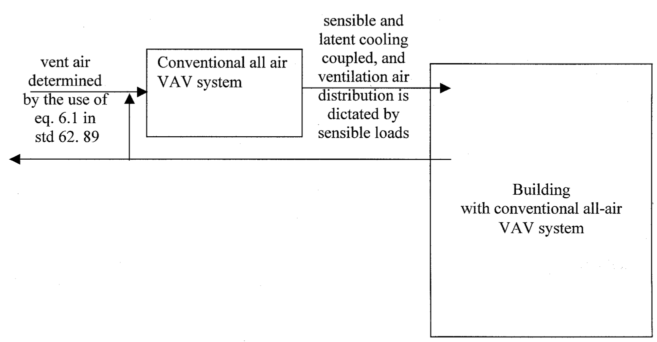

Figure 1b *Basic arrangement of an all-air VAV system—the current paradigm.*

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mation is scarce, and seemingly complex, many potential engineers have avoided using them. In spite of the need to rigorously understand how the system operates, once mastered, the controls are quite simple to understand and accomplish.

OVERVIEW OF SYSTEM OPERATION

A general overview of the dedicated outdoor air-dual wheel system, consisting of a preheat coil, an enthalpy wheel (ASHRAE 1996), a deep cooling coil, a sensible heat exchanger, and the prime movers, is illustrated in Figure 2 (from here on, this configuration of hardware will be referred to as a DOAS). A discussion of why this configuration was selected is discussed in another paper (Mumma and Shank 2001). In the configuration illustrated in Figure 2, the sensible heat exchanger is a sensible heat wheel. For the sake of the discussion here, a sensible heat wheel will be assumed, although equally good heat exchangers in the form of plate type or heat pipe are used in the industry (ASHRAE 1996).

As will be discussed later, the effectiveness (Kays and London 1984) of the sensible heat exchanger must be variable from zero to its maximum capacity. Heat exchanger effectiveness is defined as the ratio of the actual heat transfer to the heat transfer that would occur with an infinite area heat exchanger. Modulating the rotational speed can alter the effectiveness of a wheel. Heat pipe heat exchangers have some control of effectiveness by altering the unit tilt, but it is not possible to reduce it to zero in this manner. Plate type and heat pipe heat exchanger effectiveness must essentially be controlled by controlling the flow rate of one of the air circuits. Therefore, the latter two heat exchangers require face and bypass dampers to limit effectiveness, an alternative that will not be developed further in this paper. A discussion of the rationale for each of the components in the system and their performance characteristics will be presented next.

Enthalpy Wheel

The enthalpy wheel (also called a passive desiccant or total energy wheel) recovers both sensible (temperature) and latent (moisture) energy. The wheel's desiccant-loaded honeycomb rotor design (its appearance is like the edge of a cardboard box) provides for high heat transfer while simultaneously reducing pressure loss parameters. The enthalpy wheel performance on the psychrometric chart (Figure 3) is represented by a straight line connecting the thermodynamic state points of the two entering airstreams. The two entering airstreams, labeled in Figure 2, are thermodynamic state points 1 and 6 (from here on, the thermodynamic state points will be referred to only as state). If the two airstream flow rates are equal and the enthalpy wheel effectiveness is 85%, as noted in Figure 2, then the outdoor airstream is taken from state 1 to state 2, which is within 15% of state 6 (i.e., DBT, w, and h). The benefits of this level of total energy recovery are very strong in the summer in terms of cooling coil load and energy consumption reduction. It is

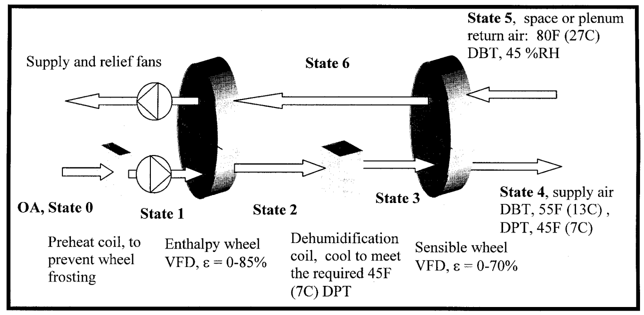

Figure 2 *General arrangement of the DOAS system.*

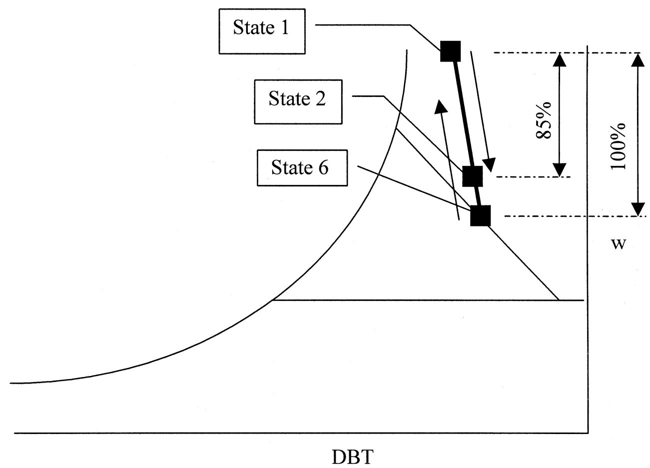

Figure 3 *Eighty-five percent effective enthalpy wheel process on the psychrometric chart.*

equally beneficial for minimizing heating and humidification energy use during the cold winter months.

A critical word of caution concerning the winter operating conditions. If the straight line joining states 1 and 6 crosses the saturation curve, condensation will occur in the wheel. If the temperature of state 1 is below freezing, then the condensate may freeze in the wheel. In order to avoid this unacceptable condition, preheat is required under certain conditions to prevent frosting of the enthalpy wheel. This situation will be illustrated later in the paper.

Preheat Coil

As noted above, a small preheat coil is required in many locations if the enthalpy wheel is to be used in the winter. With a proper preheat set-point reset control schedule, only minor preheat energy will be required to avoid freezing, and further heating of the outdoor air is virtually eliminated with the enthalpy wheel.

Deep Cooling Coil

For the applications addressed in this paper, relatively low DPT (42-48°F [6-9°C]) air is required in order to remove the entire latent load from the space with the ventilation air and still maintain a target space dew-point temperature in the neighborhood of 50-55°F (10-13°C). The required supply air conditions for the DOAS are discussed in another paper (Shank and Mumma 2001). During periods of outdoor air dew-point temperatures in excess of that required for supply, the cooling coil must be controlled to maintain the low DPT. However, when the outdoor air dew-point temperatures are below that required by the supply air, the control set point may be reset up to the desired supply air temperature. In this case, the cooling coil is no longer needed to perform dehumidification.

Sensible Wheel

If the space sensible loads were always sufficiently high to permit the cold air leaving the cooling coil to directly enter the space without local reheat, the sensible wheel would not be necessary or desirable. However, in many applications, the internal and envelope sensible cooling loads are not sufficiently high to prevent overcooling with the low-temperature ventilation air. Therefore, it is desirable to elevate the supply air temperature. For this paper, it is assumed that the supply air temperature is elevated to 55°F (13°C). This will be accomplished by the sensible wheel, although as mentioned earlier, other forms of sensible heat transfer equipment could be utilized.

When two equal flow rate airstreams exchange energy in the sensible wheel, virtually no moisture is exchanged. For the sensible wheel illustrated in Figure 2, the 45°F (7°C) air leaving the deep cooling coil is reheated sensibly to 55°F (13°C) with energy extracted from the return airstream. The return air is sensibly cooled by 10°F (6°C) in this process, thus lowering the energy content of the return airstream, reducing further the enthalpy of the outdoor air leaving the enthalpy wheel and entering the deep cooling coil.

Supply and Return Fans

The supply and return fans must be selected both to overcome the resistance to flow from the wheels, coils, and duct systems they serve and also to handle the excess air in the purge cycles (when utilized to flush the return air from the wheel before it enters the clean supply air) of the enthalpy wheel. These fans would be required at all times the building is occupied.

PSYCHROMETRICS OF THE DOAS SYSTEM

The operation of the DOAS (Figure 2) is best understood with the help of a psychrometric chart. The psychrometric chart illustrated in Figure 4 presents the four regions, A, B, C, and D, into which the OA may fall. It may be noted that there is a horizontal line representing 45°F (7°C) DPT, the assumed supply air DPT for this illustration. If the outside conditions fall above that line, the air must be cooled and dehumidified to 45°F (7°C) (or other DPTs as required to decouple the latent load from the sensible load that a parallel mechanical system is designed to serve) and then reheated to 55°F (13°C) with the sensible wheel, the desired supply air temperature for this illustration.

Also for this illustration, state 5 is given as 80°F (27°C) and 45% RH. The sensible cooling line from state 5 to state 6 is a result of energy extraction from the return air. An identical rate of heat is added to the supply air leaving the deep cooling coil at state 3, reheating it to state 4. A line of constant enthalpy passing through state 6 separates the area above the 45°F (7°C) DPT line into regions A and B. A discussion of how the system works in these two regions will be addressed later in the paper.

Another boundary is formed by the extension of a line through the return condition state 5 and the supply state 4. The line, which first appears at state 4 and proceeds to a humidity ratio of 0 gr/lbda (0 g/g), divides the area below the 45°F (7°C) DPT line into two regions, C and D.

The boundary between regions A and B (h_6) separates OA conditions, where dehumidification is required, into the two regions. In region A, full use of the enthalpy wheel dramatically reduces the cooling coil load. In region B, any use of the enthalpy wheel increases the cooling coil load; therefore, the enthalpy wheel must be off.

The boundary between regions C and D separates the OA conditions where humidification is required into two regions. In region C, sensible cooling is required. In region D, no sensible cooling is required. The operating status of the equipment in each of the four regions is presented in Table 1.

Since auxiliary reheat is never required in any of the four OA regions of the psychrometric chart (Figure 4) to produce the desired SAT (55°F [13°C] in the illustrations), it is not a control issue at the DOAS and will not be discussed in the next section. Much like a conventional VAV system with minimum box settings to ensure proper ventilation, terminal reheat may be required, at some limited times and in some spaces, to prevent overcooling. Control of terminal reheat is outside the scope of this paper, which is focused completely on the DOAS control.

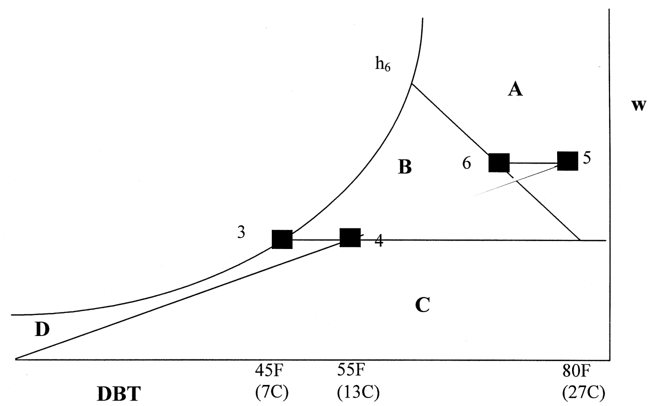

Figure 4 *Regions A, B, C, and D on the psychrometric chart.*

TABLE 1
Control Status of the Equipment

Region	Enthalpy wheel CTL	Cooling coil CTL	Sensible Wheel CTL
A	100% speed for max. effectiveness	Modulate to hold 45°F (7°C) LAT	Modulate to hold 55°F (13°C) SAT
B	Off! Must not modulate	Modulate to hold 45°F (7°C) LAT	Modulate to hold 55°F (13°C) SAT
C	Modulate to required DPT	Modulate to hold 55°F (13°C) LAT	Will modulate off
D	Modulate to required DPT	Will modulate off	Modulate to hold 55°F (13°C) SAT

CONTROL LOOPS

A first priority for the control of this system is knowledge about which region on the psychrometric chart (Figure 4) the outdoor air falls into. This is necessary since, as noted in Table 1 above, the equipment is to perform differently in the various regions. Specifically, by monitoring the outdoor air enthalpy and humidity ratio, signals can be generated that will guide the control loops of the various pieces of equipment.

Preheat Coil Control Loop

The preheat coil is only needed to keep the enthalpy wheel from frosting up when the outdoor air temperature drops below freezing. Hence, preheat is not needed anytime the outdoor air temperature is above 32°F (0°C). An easy way to control this local loop is to hold the preheat coil leaving air temperature at about 26°F (–4°C) (for most reasonable return air conditions, this temperature will prevent frosting) using a proportional-integral-derivative (PID) control loop. A setpoint reset schedule could also be used to greatly minimize the need for preheat. A proposed reset schedule, depicted in Figure 5, would operate as follows:

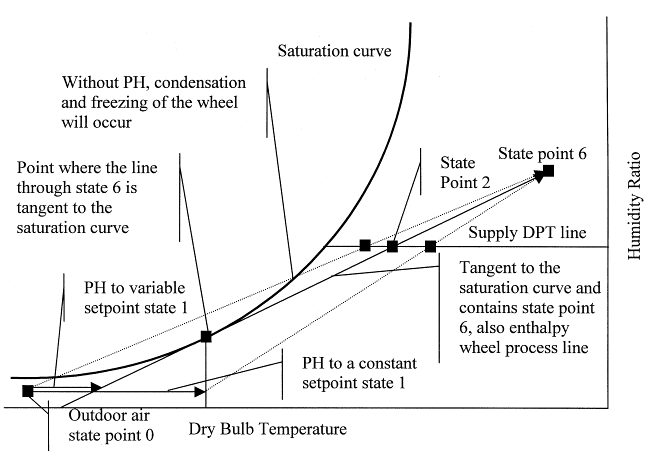

Figure 5 *Psychrometric example of two preheat controls.*

Step 1. Measure/compute the dry bulb and humidity ratio of the return air just prior to the enthalpy wheel, i.e, state 6 (see Figure 5 for location of this state on the psychrometric chart).

Step 2. Use state 6 and the equation for the saturation curve (subscript s),

$$w_s = 5.838 + 0.0656 \cdot \mathrm{DBT}_s + 0.0179 \cdot \mathrm{DBT}_s^2 \qquad \text{(I-P)}$$

$$[w_s = 3.75 \cdot 10^{-3} + 3.12 \cdot 10^{-4} \cdot \mathrm{DBT}_s + 8.29 \cdot 10^{-6} \cdot \mathrm{DBT}_s^2] \qquad \text{(SI), (1)}$$

on the psychrometric chart to compute the equation for the line tangent,

$$dw_s/d\,\mathrm{DBT}_s = 0.0656 + 2 \cdot 0.0179\,\mathrm{DBT}_s \qquad \text{(I-P)}$$

$$[dw_s/d\,\mathrm{DBT}_s = 3.12 \cdot 10^{-4} + 2 \cdot 8.29 \cdot 10^{-6}\,\mathrm{DBT}_s] \qquad \text{(SI), (2)}$$

to the saturation curve containing the return air state 6.

Step 3. Also compute the point where the tangent meets the saturation curve (i.e., DBT and humidity ratio at the tangent), a solution of the following quadratic equation for the DBT tangent to the saturation curve:

$$a \cdot \mathrm{DBT}_t^2 + b \cdot \mathrm{DBT}_t + c = 0, \qquad (3)$$

where

$$a = -0.0179 \qquad \text{(I-P)}$$

$$a = -\,8.29 \cdot 10^{-6} \qquad \text{(SI)}$$

$$b = 2 \cdot 0.0179 \cdot \mathrm{DBT}_r \qquad \text{(I-P)}$$

$$b = 2 \cdot 8.29 \cdot 10^{-6}\,\mathrm{DBT}_r \qquad \text{(SI)}$$

$$c = 5.834 - W_r + 0.0656 \cdot \mathrm{DBT}_r \qquad \text{(I-P)}$$

$$c = 3.75 \cdot 10^{-3} - W_r + 3.12 \cdot 10^{-4} \cdot \mathrm{DBT}_r \qquad \text{(SI)}$$

Variables with the subscript r represent the condition at state 6, and those with subscript t are at the point where the tangent meets the saturation curve. With DBT_t computed with Equation 3, solve for w_t using the saturation curve (Equation 1).

Step 4. For the outdoor air humidity ratio, compute the dry-bulb temperature that falls on that line (i.e., tangent to the saturation curve that contains state 6). The equation for this line can easily be determined with two points. The two points are (1) where the tangent touches the saturation curve and (2) state 6. For example, if the return state 6 is 80°F (27°C) DBT and 69 gr/lbda (0.01g/g), then the tangent through that point touches the saturation curve at a DBT_t = 23.75°F (4.6°C), and w_t = 17.5 gr/lbda (0.0025g/g). The resulting equation for the straight line through these two states is

$$w = -4.255 + 0.9157 \cdot \mathrm{DBT} \qquad \text{(I-P)}$$

$$[w = 3.58 \cdot 10^{-3} + 2.35 \cdot 10^{-4} \cdot \mathrm{DBT}]. \qquad \text{(SI), (4)}$$

If, for example, the outdoor air humidity ratio were 10 gr/lbda (0.0014g/g), using the linear Equation 4, the DBT on that line is 6.3°F (–14°C).

Step 5. If the outdoor air DBT is both below the DBT on the line for the corresponding OA humidity ratio and below the DBT_t where the tangent meets the saturation curve, then the outdoor air setpoint is the DBT on the line. If both of these conditions are not met, then the preheat setpoint is the outdoor air DBT and no preheat is required.

This process may seem a bit complicated, but its simplicity will be illustrated in the graphic programming section later in the paper. The main conclusion to draw from Figure 5 is the difference in the preheat needed from state 0 to state 1 with the reset schedule and the constant setpoint. At the given outdoor air state 0, the preheat for the reset schedule is always less than that of the constant setpoint schedule. For all outdoor air conditions that fall to the left of the constant setpoint temperature and to the right of the tangent, the reset schedule will need no preheat. On the other hand, with the constant setpoint schedule, preheat is required.

The energy use and equipment sizes for the two preheat control methods will now be compared. The comparison, shown in Table 2, is based upon typical meteorological year (TMY) weather data (GRI 1997) for Chicago (just as an example), a 10,000 scfm (4720 L/s) system operating all 8760 hours per year. With the reset schedule, only 16% as much energy is needed as with the simple 26°F (–4°C) setpoint discussed above. It also reduces the peak preheat load by 53%.

Enthalpy Wheel

The enthalpy wheel is controlled differently in the four regions of the psychrometric chart. When the outdoor air is in region A, the wheel is to operate at full effectiveness, as illustrated in Figure 6a. When the outdoor air is in region B, the enthalpy wheel must be off. When the outdoor air is in regions C or D, the enthalpy wheel speed must be modulated to passively humidify the outdoor air to the desired dew-point temperature, or humidity ratio, as depicted in Figure 6b.

Cooling Coil

The cooling coil is used to cool and dehumidify the outdoor air from state 2 down to 45°F (7°C) at state 3 whenever the outdoor air conditions fall into regions A or B (see Figure 6a). When the outdoor air falls in region C, dehumidification is not required, so the outdoor air at state 2 is sensibly cooled only to 55°F (13°C) at state 3 (see Figure 6b). The cooling coil is not required when the outdoor air falls in region D, but preheat may be needed.

Sensible Wheel

The sensible wheel is available for operation at all times and will modulate as necessary to meet the 55°F (13°C) supply air temperature at state 4 at all times. It will be needed when the outdoor air conditions fall into regions A and B. This is depicted in Figure 6a by the lines connecting states 5 and 6 and states 3 and 4. In region C, with the cooling coil setpoint

TABLE 2
Comparison of Two Preheat Control Methods Using Chicago Weather Data

Preheat control	Preheat hours	Peak preheat load, MBH (kW)	Annual energy use, 10^6 Btu/yr (kWh/yr)	Cost if by electric resistance at $23/$10^6$ Btu ($0.08/kWh)	Cost if by gas, 80% efficient at $5/106 Btu ($0.02/kWh)
Fixed setpoint at 26°F	660	360 (105)	96.5 (28,300)	$2,220	$460
Reset schedule	306	170 (50)	15.5 (4,550)	$360	$80

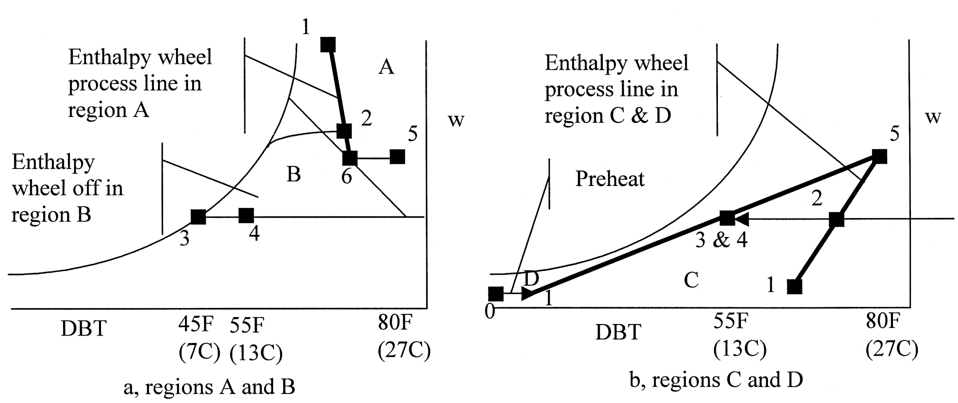

Figure 6 *Enthalpy wheel processes in (a) regions A and B and (b) regions C and D.*

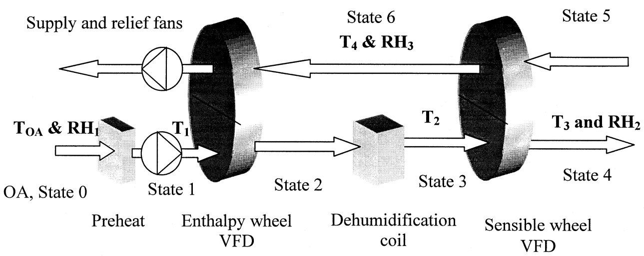

Figure 7 *Sensor type and location (bold print).*

elevated to 55°F (13°C), no reheat is required, so the modulating control will stop the wheel rotation. In region D, there will again be some need for reheat, and the modulating control will provide it.

Supply/Relief Fans and Outdoor/Relief Air Dampers

This equipment is to operate whenever the building is occupied.

SAMPLE SEQUENCE OF OPERATION

The following sequence of operation is based upon sensor placement as illustrated in Figure 7:

Unit is to operate from either a remote time-of-day and day-of-week signal or a local manual override. Upon notice to operate, the control system is to be energized, the dampers are to modulate to full open, and the fans to be energized.

Modes of operation are not determined by season but by outdoor air conditions.

The *sensible wheel* is to operate in all modes as follows: Based upon the SAT (T_3), the VFD speed control of the wheel is to respond to the output of a PI controller to maintain an adjustable setpoint (55°F [13°C] initial setting). On a rise in the SAT, the output of the controller is to decrease, thus decreasing the speed of the wheel.

The *preheat coil control valve* is to operate in all modes as follows: Based upon the leaving air temperature (T_1), the normally open control valve is to respond to the output of a PI controller to maintain setpoint. The setpoint is to be dynamically reset based upon the state 6 temperature (T_4) and humidity (RH_3) and the outdoor air state 0 temperature (TO_A) and humidity (RH_1). The reset schedule discussed in the preheat coil control loop section of this paper is to be used. On a rise in the leaving air temperature, the output of the controller is to increase, thus modulating the control valve toward closed.

Mode 1, OA DPT (computed from TO_A and RH_1) greater than 45°F (called the wet regions A and B, where dehumidification is required).

Cooling coil control valve: To be controlled with a signal from a PI controller to maintain an adjustable leaving air temperature (T_2) of (45°F initial setting). On a rise in the leaving air temperature, the controller output is to rise.

a. *Enthalpy Wheel*: To operate at full speed if the OA enthalpy is greater than h_6 (27.58 Btu/lbm in this example) or
b. *Enthalpy Wheel*: To shut down if the OA enthalpy is less than or equal to h_6 (27.58 Btu/lbm in this example).

Mode 2, OA DPT (computed from TO_A and RH_1) less than or equal to 45°F (called the dry regions C and D, where humidification is required).

Cooling coil control valve: To be controlled with a signal from a PI controller to maintain an adjustable leaving air temperature (T_2) of (55°F initial setting). On a rise in the leaving air temperature, the controller output is to rise.

Enthalpy Wheel: Based upon the supply air dew-point temperature (computed from T_3 and RH_2), the VFD speed control of the wheel is to respond to the output of a PI controller to maintain an adjustable setpoint (45°F [7°C] DPT, initial setting). On a rise in the SA DPT, the wheel speed is to be decreased.

GRAPHIC PROGRAMMING LANGUAGE DIAGRAM OF THE CONTROL FOR THE DEDICATED OA SYSTEM

A graphic programming software is used to generate the control logic (ALC 1999). This language makes creating the logic relatively easy and makes understanding the created logic very easy. It also offers both off-line as well as on-line simulation, a necessary check of the logic before actual operation of the software in the system. The author uses this programming language software in a building automation and control graduate course, where the clarity of logical thinking is rapidly exposed. The simulation feature allows the user to test and conquer the logic of sequences.

The control logic for this system is illustrated in Figures 8a and 8b, and is discussed below.

Mode 1 or 2 Determination

At the top of Figure 8a, the outdoor air T_{OA} and RH_1 are used as inputs to enthalpy and dew-point computation microblocks (control logic graphic icons). Implicit is the assumption that the outdoor air condition is in region A. The tests that follow may refute this assumption, but if not, then it is in region A. The OA enthalpy is tested to see if it is not in region A, and the DPT is tested to see if it is "dry" or in regions C or D (mode 2). This information is used at the bottom of Figure 8a.

Preheat Coil Control

A reverse acting PID control loop is used to control the normally open preheat coil, using the reset set-point scheme developed in this paper and the controlled variable value measured with T_1. The reset set-point scheme is the group of microblocks in Figure 8b. In the upper left-hand corner of Figure 8b, the state 0 and 6 temperature and relative humidity measurements enter. In the square block 1, the humidity ratio

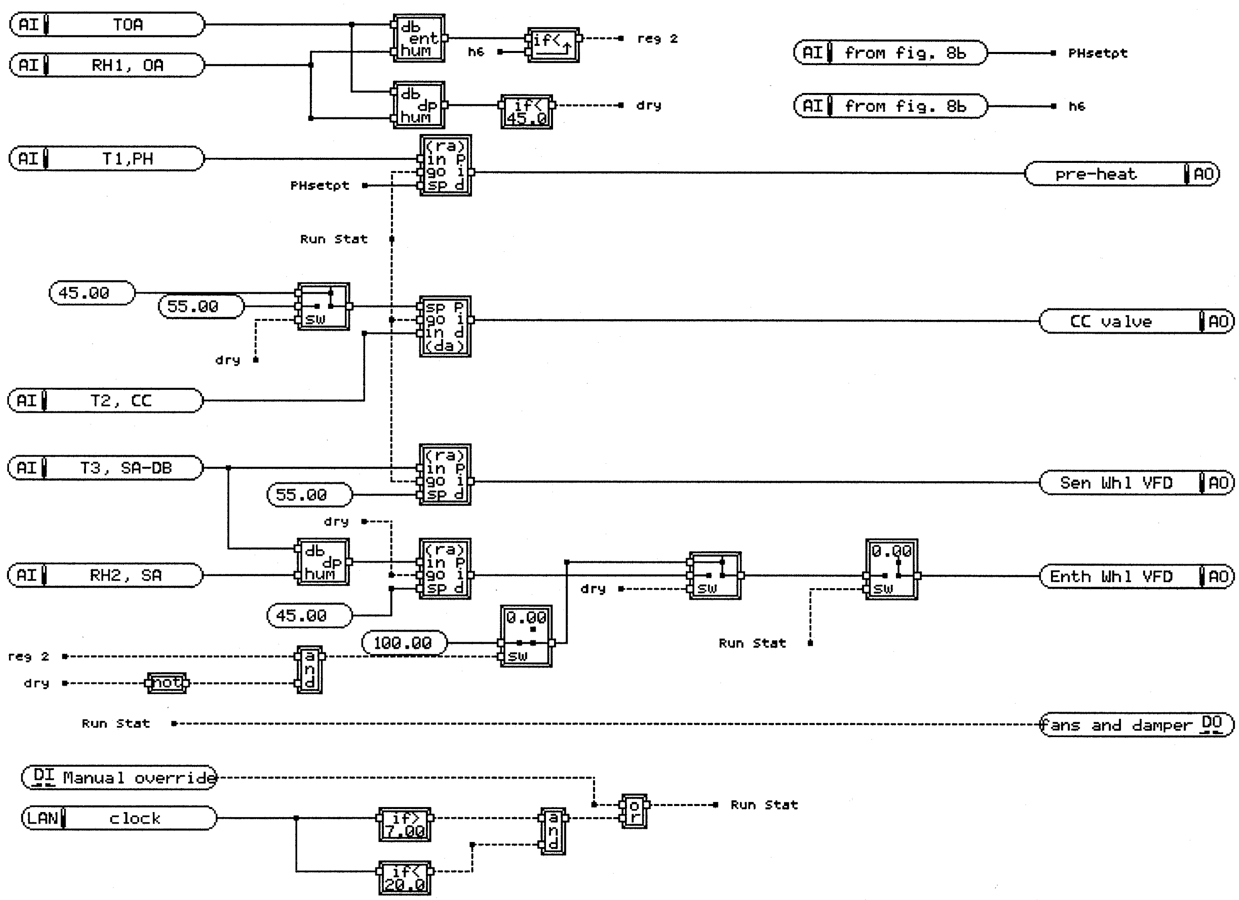

Figure 8a *GPL for the DOAS.*

of state 6 is computed using the enthalpy microblock. In this square block, as in blocks 4 and 8, the humidity ratio is computed via the linear relationship

$$w = 0.38 - 1.5 \cdot \text{DBT} + 6.36 \cdot h \qquad \text{(I-P)}$$

$$[w = 2.88 \cdot 10^{-4} - 4.5 \cdot 10^{-2} \cdot \text{DBT} + 4.12 \cdot 10^{-4} \cdot h]. \text{ (SI)}, (5)$$

The square block 2 is used to compute the constants in the quadratic Equation 3 discussed above. The square block 3 is used to solve Equation 3 for the DBT_t tangent to the saturation curve. The square block 4 is used to compute the humidity ratio (at saturation) at the DBT_t. Square block 5 is used to compute the slope of the tangent line passing through state 6. Square block 8 is used to compute the outdoor air humidity ratio. Square block 6 is used to compute the y-intercept of the tangent to the curve, and it also uses the slope equation to compute the DBT on the tangent curve at the OA humidity ratio. Square block 7 provides the logic concerning the preheat set point, as discussed above. If the OA DBT is less than both the DBT on the line corresponding to the OA humidity ratio and the DBT where the tangent curve touches the saturation curve, then the setpoint is the DBT on the tangent line. Otherwise, the preheat setpoint is just the OA DBT and no preheat is required.

Cooling Coil Control

A selector microblock, Figure 8a, is used to switch between two set points dependent upon the region in which the outdoor air falls. The normal position (not dry) for the toggle switch makes the setpoint 45°F (7°C). However, if the outdoor air falls into regions C or D (i.e., DPT below 45°F [7°C] or dry), there is no need for dehumidification and the set point is switched to 55°F (13°C). A direct acting PID microblock uses the measured controlled variable (T_2) to modulate the cooling coil control valve.

Sensible Wheel Speed Control

Air supplied to the space is maintained at a constant 55°F (13°C) at all times. If state 4 is below 55°F (13°C), the reverse acting PID microblock will increase the speed of the wheel in an effort to warm the air based upon the measured controlled variable T_3. If during the dry period the cooling coil is only producing 55°F (13°C) air, the PID microblock will slow the wheel to a stop since reheat is not necessary.

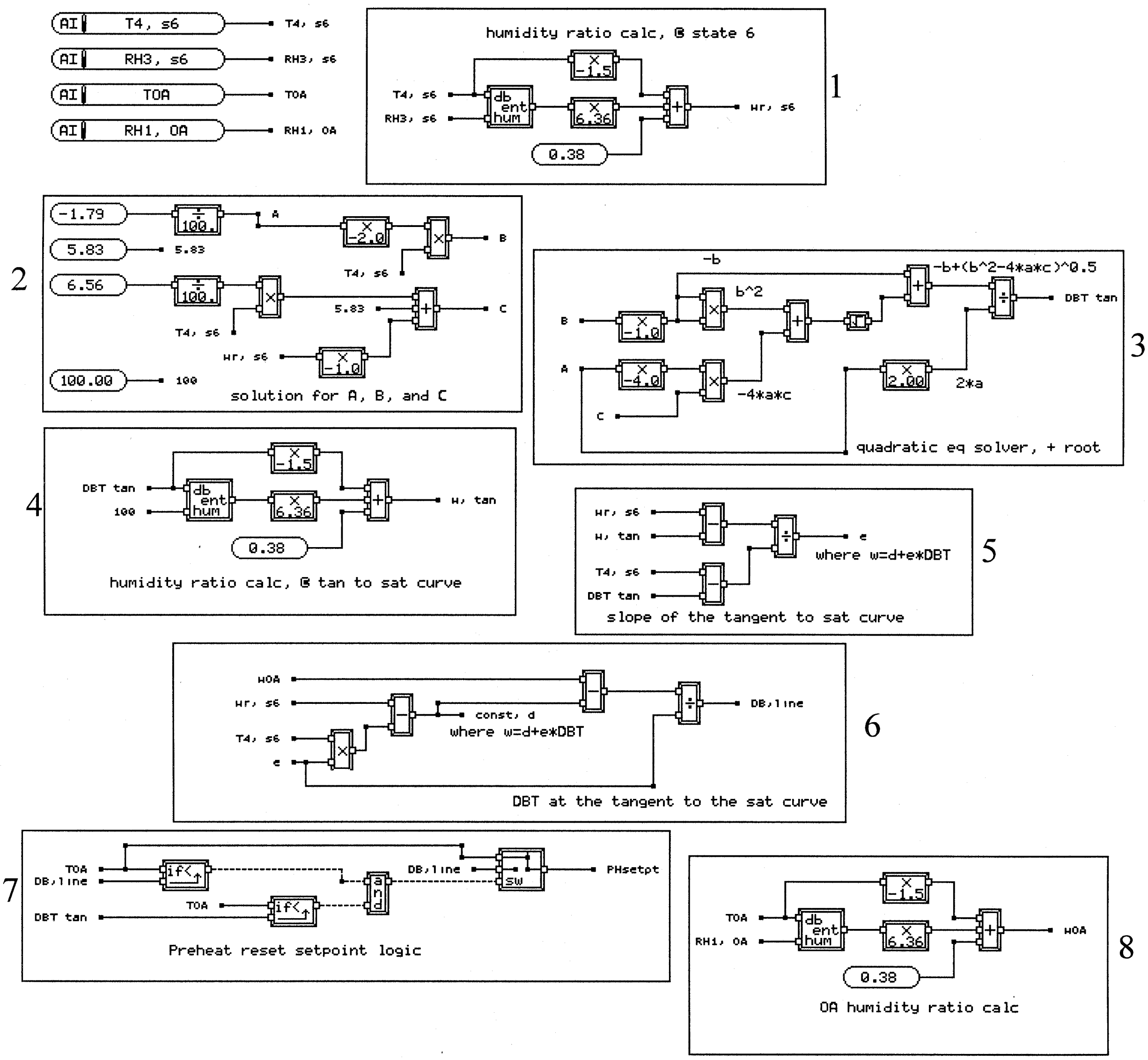

Figure 8b *GPL for DOAS, PH reset logic.*

Enthalpy Wheel Speed Control

When the outdoor air is in the dry region (C or D), then the control signal to the enthalpy wheel is from the reverse acting PID controller. The speed is modulated to meet the setpoint DPT based upon measurements of the supply air DPT (note, the cooling coil is sensible cooling only, if at all, so the DPT leaving the enthalpy wheel equals the supply air DPT). The DP temperature microblock computes the controlled variable value from inputs T_3 and RH_2. If the outdoor air is not in the dry regions, then it must fall into either region A or B. The selector switch microblock will switch the output between 0% and 100%. The logic imbedded here checks to determine if the outdoor air is not dry and is not in region A (all regions excluded except region B). If true, the selector switch microblock will switch to zero output and the enthalpy wheel will not run. If the outdoor air is not dry and not in region B (only choice is region A), then the selector switch microblock will switch to 100% and the enthalpy wheel will run at 100% speed.

Fans and Dampers

The fans and dampers are to operate whenever the building is occupied. For this example, it is assumed to be determined by a time clock. A manual override is also provided to send a run signal to the control loops and the fans/dampers. All of the PID microblocks take their "go" commands from this run signal, as well as the selector switch in the analogue wiring to the enthalpy wheel speed drive.

CONCLUSIONS

The control of a DOAS has been presented based upon its thermodynamic performance requirements. The control presented is quite different from that illustrated in manufacturers' cut sheets (Semco 1999; Des Champs 2000) and is expected to result in peak performance of such systems. The information presented in this paper fills an information void needed to facilitate timely migration from the old, integrated OA all-air VAV systems to the new decoupled latent cooling dedicated outdoor air paradigm.

NOMENCLATURE

AI	=	analog input
AO	=	analog output
Btu	=	British thermal unit
CTL	=	control
DBT	=	dry-bulb temperature
DI	=	digital in
DO	=	digital out
DOAS	=	dedicated outdoor air system
DP	=	dew point, assigned name of a microblock
DPT	=	dew-point temperature
gr	=	grains, or 1/7000 lb
GPL	=	graphic programming language
h	=	enthalpy
IAQ	=	indoor air quality
LAN	=	local area network
LAT	=	leaving air temperature
lbda	=	pound mass dry air
microblock	=	a control element icon
OA	=	outdoor air
PH	=	preheat
PI	=	proportional plus integral control
PID	=	proportional plus integral plus derivative control
Regions A, B, C, D	=	psychrometric chart regions into which the OA may fall; regions A and B need dehumidification, regions C and D need humidification.
%RH	=	percent relative humidity
RH_x	=	relative humidity sensor
SAT	=	supply air temperature
State #	=	thermodynamic state point as identified on Figures 2-7
T_x	=	dry-bulb temperature sensor
VAV	=	variable air volume
VFD	=	variable frequency drive
w	=	humidity ratio, grains/lb_{DA} (or dimensionless)

Subscripts

s	=	saturation
t	=	tangent
r	=	return condition state 6

REFERENCES

ALC. 1999. *Eikon Microblock Reference, 1-350*. Automated Logic Corporation.

ASHRAE. 1996. *1996 ASHRAE Handbook—HVAC Systems and Equipment*, Rotary air-to-air energy exchangers, p. 42.11. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Des Champs. 2000. Modular wringer plus catalog. MOACS Models, 69-71

GRI. 1997. *BinMaker hourly weather data for load calculations* CD. Gas Research Institute.

Kays, W.M., and A.L. London. 1984. *Compact heat exchangers*, 3d ed., p. 16. McGraw Hill.

Mumma, S.A. 2001. Overview of integrating dedicated outdoor air systems with parallel terminal systems. *ASHRAE Transactions* 107(1).

Mumma, S.A., and K. Shank. 2001. Achieving dry outside air in an energy efficient manner. *ASHRAE Transactions* 107(1).

Semco Incorporated. 1999. Packaged energy recovery systems, EP Series 42.

Shank, K., and S.A. Mumma. 2001. Selecting the supply air conditions for a dedicated outdoor air system working in parallel with distributed sensible cooling terminal equipment. *ASHRAE Transactions* 107(1).

Turpin, J. 2000. Dehumidification: The problem no one wants to talk about. *Engineered Systems*, April, pp. 46-52.