Application Note 15

Treatment of 100% Outdoor Air

INTRODUCTION

As ASHRAE 62 ventilation codes are implemented for existing or new buildings, many facility managers are encountering new indoor air problems in the form of high humidity, mold, and mildew. This application note reviews the unintended side effects of increasing outdoor air volumes, and describes a way to solve or prevent these new indoor air problems without the need to change air handlers.

ASHRAE 62 REQUIREMENTS

The updated ventilation code uses a two part formula to calculate the volume of outdoor air required to be introduced into a space. The first component is a rate per person. The second is a rate based on the surface area of the occupied space. When the default occupancy density is utilized, the combined ventilation rate is from 6 to 35 cfm per person. For an exact value, consult *ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality*. The most common approach to implementing ASHRAE 62 requirements in existing buildings is to simply modify the existing air handler so as to increase the outdoor air introduced. For new buildings, the first impulse may be to specify more air conditioning capacity to accommodate the added outside air during warm weather.

There is, however, an unintended consequence from these approaches. (Refer to Desert Aire *Technical Bulletin 14* for a detailed analysis.) For an existing air handler, the original sizing was likely aimed at handling the sensible (indoor) heat load plus only 5 CFM per person of outdoor load. The significant increase in outdoor air can result in greatly increased interior humidity during the warm, moist summer months.

For new buildings, even with added cooling capacity, the air handler can be inadequate for keeping up with incoming warm, moist air. Usually a certain leaving air dry bulb temperature is targeted, but then excessive moisture is left in the air. (In some cases a particular relative humidity is targeted, in which case the leaving air is far too cold for comfort.) Offices, public facilities, and schools are left with rising interior relative humidity because the air handler design simply cannot remove the additional latent heat load in the summertime.

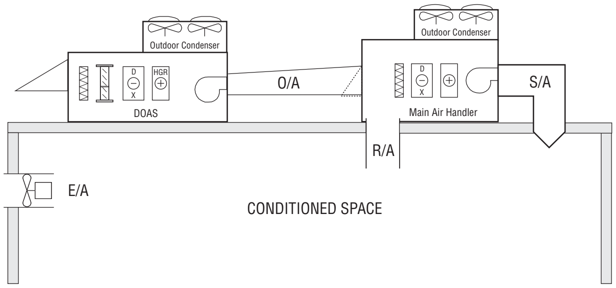

Figure 1 - Pretreatment of Outdoor Air Schematic

If humidity is left uncontrolled, new indoor air problems can occur. Occupants complain about working in a "cold swamp" and productivity falls. Viruses, bacteria, mold and mildew all grow in a humid environment. Increased mold and mildew on interior surfaces cause allergic reactions. Continued high humidity can damage wallboard, metal surfaces and ultimately the building's structural integrity. Increased outdoor air solves one indoor air problem only to cause others.

PRETREATMENT SOLUTION

Is there a way to successfully use existing air handlers, modified to draw additional outdoor air, to implement the ASHRAE 62 requirements? Can air handlers be applied in new buildings with ASHRAE 62 requirements in a way that prevents moisture problems? Yes! A pretreatment dehumidification system can be used to remove the peak moisture and heat prior to introducing the outdoor air to the existing air handler. (See Figure 1.)

Ideally, a pretreatment system should emulate the typical return air ("neutral") conditions of 72°F and 50% to 60% RH. Then the air handler would see only the level of latent and sensible heat load for which it was originally designed.

Caution must be applied in choosing the pretreatment system. A standard dehumidification system with full reheat can remove sufficient moisture, but will cause problems because its typical leaving air temperature can rise higher than 95°F. A standard air conditioner, meanwhile, cannot remove enough moisture to solve the problem. What is required is a dehumidifier with a partial reheat capability which can consistently ensure that the air leaving the dehumidifier is at 50% RH and neither excessively hot nor cold. In fact, the ideal dehumidifier would not only hit 50% RH, but would have a variable partial reheat capability so that the air passed along to the air handler is consistently at room air design conditions. This type of dehumidifier is more commonly called a dedicated outdoor air system or DOAS.(See Desert Aire *Technical Bulletin 16* for a discussion of options, and the energy consequences of various choices.)

DIRECT FEED TO SPACE

In some applications it is desirable to have the outdoor air fed directly into specific rooms, rather than using the indirect method of dumping the outdoor air into the air handler. Naturally, the issues just described apply in this situation as well. The solution is similar, except that the outdoor air, pretreated by the DOAS, now enters directly into the building rather than into the air handler.

When direct feed of outdoor air into the space is used, it is especially important to specify that the air temperature be controlled to a specific value in all modes of operation: full load, part load and winter. Without specific temperature control, room occupants are likely to be very uncomfortable as temperatures of the air being introduced vary widely. A variable partial reheat DOAS is especially useful in this instance in order to achieve temperature control.

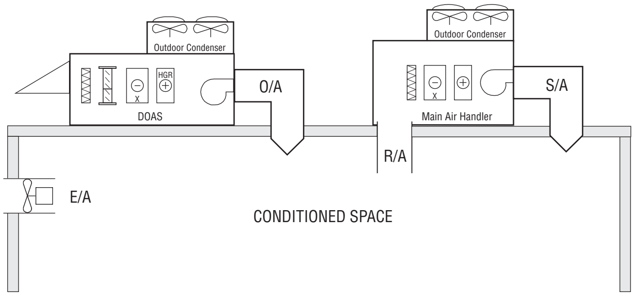

Figure 2 - Direct Feed of Pretreated Air to Interior Space

CALCULATING ENERGY REMOVAL REQUIREMENTS

The air entering the DOAS is 100% outdoor air. Proper system size is selected by calculating the amount of energy that must be removed from entering air at the maximum design condition to achieve a desired leaving air dewpoint (LAD). The most direct calculation method is known as the total enthalpy method. It is based on the enthalpy difference (BTU/lb) between the maximum design condition and the specified leaving air condition, multiplied by the airflow.

Rate of energy removal required (BTU/hr) =

Enthalpy difference H (BTU/lb) x airflow (cu ft/min) x 4.5 (min/hr x lb/cu ft)

The 4.5 is a conversion factor of 60 minutes/hour divided by 13.5 cu ft/lb (of air), and CFM is the specified outdoor air volume. Since the weight of air varies with temperature, further accuracy could be gained by using the precise weights for the two different temperatures involved, but this approximation is nearly always sufficient for sizing purposes.

The enthalpy difference is calculated by taking the enthalpy value (BTU/lb) at the entering wet bulb temperature and subtracting the enthalpy value at the design dewpoint. Table 1 provides typical design wet bulb values for major cities. (The data in Table 1 is taken from *ASHRAE Fundamentals 1%*.) Table 2 lists enthalpy values at various dewpoint temperatures.

As an example, suppose we are sizing a DOAS for a building in St. Louis, with required outdoor air introduction of 2,000 CFM. Table 1 gives a wet bulb temperature design value of 78°F, and Table 2 shows an associated enthalpy value of 41.5 BTU/lb (78°Fwb = 78°F dewpoint). If our air handler expects air at 72°F and 55% RH, or 55 dew point, we can look up a corresponding enthalpy from Table 2 of 23.2 BTU/lb. Our dehumidifier will need sufficient capacity to remove energy at the following rate:

Rate of energy removal required (BTU/hr) =

(41.5 - 23.2) x 2,000 x 4.5 = 164,700 BTU/hr

This energy removal rate is then compared to the capacities for various DOAS units to help determine the best system for the application.

Note that the total enthalpy method simplifies the sizing discussion by focusing on total energy removal (combined latent and sensible) rather than on a moisture load (often presented in lb/hr) to be handled by the dehumidifier. Instead of trying to develop a moisture load from dewpoint and wet bulb values, the values are used directly to arrive at the required DOAS capacity.

The ASHRAE guidelines in Table 1 state the design condition simply as a peak wet bulb temperature. Associated with that temperature is a wet bulb line on the psychrometric chart. Sizing for the enthalpy difference between the peak wet bulb and the leaving air dewpoint will ensure that the dehumidifier can handle the wide variety of dry bulb temperature / RH combinations that fall along or beneath the wet bulb line. (See Figure 3.)

OUTDOOR AIR MOISTURE CONTENT TO BE REMOVED											
State	**City**	**GR lbs**	**State**	**City**	**GR lbs**	**State**	**City**	**GR lbs**	**State**	**City**	**GR lbs**
AK	Anchorage	59	IL	Rockford	119	NY	Albany	109	TX	San Antonio	128
AK	Annette	65	IN	Fort Wayne	121	NY	Buffalo	108	UT	Salt Lake City	76
AK	Kodiak Island	60	IN	Indianapolis	130	NY	New York	121	VA	Norfolk	124
AK	Yakutat	65	KS	Wichita	120	NY	Rochester	116	VA	Richmond	130
AL	Birmingham	126	KY	Louisville	125	NY	Syracuse	110	VA	Roanoke	113
AL	Mobile	137	LA	Baton Rouge	136	OH	Cincinnati	120	VT	Burlington	105
AR	Little Rock	102	LA	New Orleans	143	OH	Cleveland	116	WA	Seattle	71
AZ	Phoenix	102	LA	Shreveport	134	OH	Columbus	119	WA	Spokane	61
CA	Long Beach	91	MA	Boston	112	OK	Oklahoma City	125	WA	Yakima	63
CA	Los Angeles	96	MD	Baltimore	120	OR	Eugene	73	WI	Green Bay	117
CA	Sacramento	72	ME	Portland	106	OR	Portland	72	WI	Madison	115
CA	San Diego	103	MI	Detroit	114	PA	Erie	114	WI	Milwaukee	115
CA	San Francisco	67	MI	Flint	117	PA	Philadelphia	124	WV	Charleston	120
CA	Santa Barbara	85	MI	Grand Rapids	116	PA	Pittsburgh	116	**CANADA**		
CO	Stockton	75	MN	St. Paul	114	PA	Scranton	114			
CO	Denver	78	MO	Kansas City	126	RI	Providence	114			
CT	Hartford	111	MO	St. Louis	132	SC	Charleston	136	AL	Calgary	69
DC	Washington	129	MS	Jackson	136	SC	Columbia	122	BC	Vancouver	76
DE	Wilmington	121	MT	Billings	70	SD	Sioux Falls	119	MN	Winnipeg	97
FL	Daytona Beach	137	NC	Cape Hatteras	142	TN	Bristol	118	NB	Saint John	87
FL	Jacksonville	134	NC	Charlotte	122	TN	Chattanooga	126	NF	St. John's	89
FL	Miami	137	NC	Raleigh	126	TN	Knoxville	124	NS	Halifax	100
FL	Tallahassee	136	ND	Fargo	109	TN	Memphis	132	ON	Ottawa	101
FL	Tampa	136	NE	Omaha	125	TN	Nashville	126	ON	Sudbury	93
GA	Atlanta	123	NH	Concord	109	TX	Brownsville	136	ON	Thunder Bay	91
GA	Augusta	128	NJ	Atlantic City	123	TX	Corpus Christi	141	ON	Toronto	108
HI	Honolulu	117	NJ	Newark	121	TX	Dallas / Ft. Worth	121	ON	Windsor	115
IA	Des Moines	122	NM	Albuquerque	80	TX	El Paso	99	QC	Montreal	106
ID	Boise	59	NV	Las Vegas	82	TX	Houston	135	QC	Quebec	100
IL	Chicago	118	NV	Reno	59	TX	Lubbock	111	SK	Regina	80

Table 1 - Geographic Outdoor Design Criteria (ASHRAE Fundamentals 1%)

ENTHALPY VALUES (BTU/lb)
AT VARIOUS DEWPOINT TEMPERATURES (°F)
RH = >99.90%

°F	BTU/lb	°F	BTU/lb	°F	BTU/lb
35	12.9	52	21.4	69	33.2
36	13.4	53	22	70	34
37	13.8	54	22.6	71	34.9
38	14.3	55	23.2	72	35.8
39	14.7	56	23.8	73	36.7
40	15.2	57	24.5	74	37.6
41	15.7	58	25.1	75	38.5
42	16.1	59	25.8	76	39.5
43	16.6	60	26.4	77	40.5
44	17.1	61	27.1	78	41.5
45	17.6	62	27.8	79	42.5
46	18.1	63	28.5	80	43.6
46	18.7	64	29.3	81	44.6
48	19.2	65	30	82	45.7
49	19.7	66	30.8	83	46.9
50	20.3	67	31.6	84	48.1
51	20.8	68	32.4	85	49.3

Table 2 - Enthalpy Values at Dewpoint

A DOAS sized to remove the necessary energy to meet a 78°F wet bulb requirement for St. Louis, for example, will also handle 85°F up to 70% RH or 90°F up to 60% RH. If the dehumidifier was tested at different points along the wet bulb line, the amounts of latent versus sensible heat removed would change significantly, but the total heat removed would not.

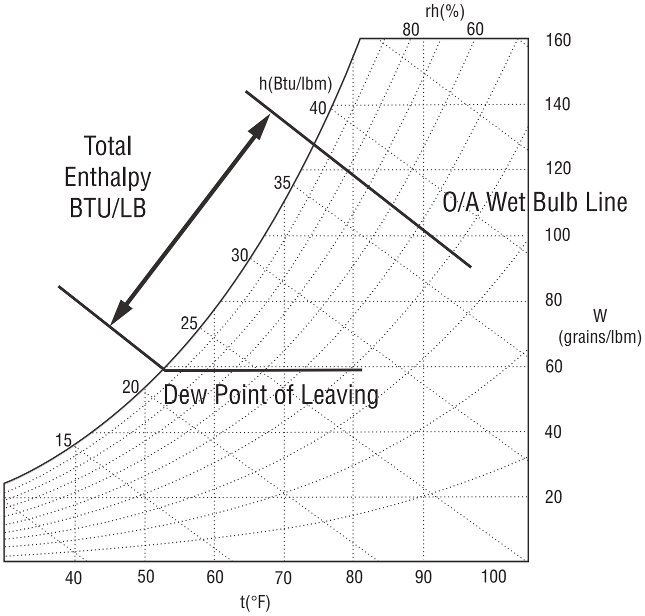

Figure 3 - Total Enthalpy Psychrometric Chart

DOAS SELECTION & PERFORMANCE

With a DOAS, it is important to understand how to select the correct system for the application as well as to understand how it will perform under the varying full and part load conditions it will encounter.

The correct DOAS is selected by specifying the following criteria:

- *Volume of air required*
- *Max. design condition (db/wb)*
- *Leaving air dewpoint required*
- *Desired leaving air temperature*

The DOAS will be sized to balance the air velocity across the coils, the capacity of the compressor and the condensing temperature of the condensers. A wide range of systems can be selected to meet the criteria above. Table 3 shows the various sizes and their corresponding leaving air dewpoints for various maximum design ambient wet bulb conditions. The selections are for 2,000 cfm at a 95° Fdb ambient.

Entering °Fwb	Unit Size (HP)	LA dP °F	Unit Size (HP)	LA dP °F
80	14	55	10	60
78	12	55	9	59
76	10	55	-	-
74	9	54	7-1/2	59
72	7-1/2	57	6	59
70	7-1/2	55	6	57
68	6	55	-	-
66	5	55	5	60

Table 3 - DOAS Sizing

The total energy removal required, and therefore the DOAS capacity needed, is directly proportional to airflow. Conversely, for the same airflow, a lower leaving air dewpoint can be achieved by moving to a DOAS with greater capacity.

For example, compare the performance of two DOAS units with entering air at 78°F wet bulb, a 2,000 CFM airflow requirement to meet ASHRAE 62, and a required leaving air dewpoint of 55°F or lower to match the original design conditions for an existing air handler. (See Table 3 for the capacities.) At an air flow of 2,000 CFM, the smaller unit can only produce a leaving air dewpoint of 60°F, which will not meet our 55°F requirement. The larger unit, at the 2,000 CFM airflow, can produce a leaving air dewpoint of 55°F, and would be acceptable for this application.

A convenient way to portray the performance of a DOAS over the wide range of ambient conditions is by plotting it on a graph with “entering air wet bulb temperatures” on the x axis and “leaving air dewpoint capabilities” on the y axis. The graph shows a family of curves corresponding to different airflow levels. (See Figure 4.) Given the entering wet bulb temperature and the airflow, the leaving air dewpoint can be read off the chart to show the resultant leaving air condition at part load conditions.

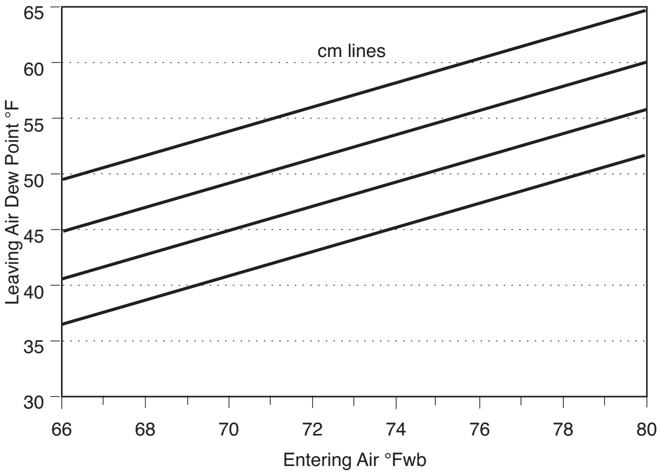

Figure 4 - Dehumidifier Performance

REHEAT

One of the greatest benefits of using a DX-DOAS for pretreatment is the availability of free reheat energy. A partial reheat DOAS will use energy recovered during moisture removal to produce, via hot gas reheat, leaving air temperatures in a range (typically 65°F to 80°F) that is likely to be acceptable to the air handler. A variable partial reheat adjusts the amount of hot gas reheat continuously to hit a particular leaving air temperature (e.g., 72°F) chosen by the design engineer.

Thus, the designer can specify the dry bulb temperature (or temperature range) and the RH of the pretreated outdoor air going into the air handler. Any energy required to warm the dehumidified air is recovered from the moisture removal process rather than being added using a heater. In contrast, when a standard air conditioner is used to remove large amounts of moisture from air, the leaving air is unacceptably cold unless a substantial amount of electric reheat is used. Using air conditioning for moisture removal significantly increases operating costs. (Refer to Desert Aire *Technical Bulletin 16* for a detailed analysis of reheat technologies and energy savings.)

CONCLUSION

To allow an existing air handler, modified to meet the ASHRAE 62 ventilation code, to function as it was originally designed, the added outdoor air must be pretreated to match typical return air conditions. Similarly, in new designs for ASHRAE 62, pretreatment of outdoor air before it is introduced to the air handler or the space is a necessary part of any practical solution, since simply adding air conditioning capacity is not a desirable method of removing moisture from that air. An effective solution in new and existing buildings is pretreatment by a DOAS with partial or variable partial reheat, to remove peak latent heat load and maintain reasonable entering air conditions for the air handler.

Proper DOAS sizing can be accomplished by calculating the amount of total (latent and sensible) heat to be removed per hour from the additional outdoor air, based on ASHRAE wet bulb temperature design values. As a convenience, some manufacturers provide graphs (for each size DOAS made) from which the leaving air dewpoint can be obtained for a given entering wet bulb temperature and airflow requirement.

Without pretreatment, increased outdoor air brought into an air handler solves one indoor air problem only to cause others. By pre-treating outdoor air with a partial or variable partial reheat DOAS, all the benefits of a healthy, productive environment for building occupants can be realized without introducing excessive moisture or improper temperatures.