ASHRAE JOURNAL

Dehumidification and Cooling Loads From Ventilation Air

By Lewis G. Harriman III
Member ASHRAE
Dean Plager
and Douglas Kosar
Member ASHRAE

Ninety-five years since Willis Carrier began the modern era of air conditioning by dehumidifying a printing plant, our industry is becoming more concerned with the importance of controlling humidity in buildings. In part, this concern stems from indoor air quality problems associated with excess moisture in air-conditioning systems. But more universally, the need for ventilation air has forced HVAC equipment (originally optimized for high efficiency in removing sensible heat loads) to remove high moisture loads.[1]

To assist cooling equipment and meet the challenge of larger ventilation loads, several technologies have succeeded in commercial buildings. Newer technologies such as subcool/reheat and heat pipe reheat show promise. These increase latent capacity of cooling-based systems by reducing their sensible capacity. Also, desiccant wheels have traditionally provided deeper-drying capacity by using thermal energy in place of electrical power to remove the latent load.[2]

Regardless of what mix of technologies is best for a particular application, there is a need for a more effective way of thinking about the cooling loads created by ventilation air. It is clear from the literature that all-too-frequently, HVAC systems do not perform well unless the ventilation air loads have been effectively addressed at the original design stage.[3,4] This article proposes an engineering shorthand, an annual load index for ventilation air. This index will aid in the complex process of improving the ability of HVAC systems to deal efficiently

Fig. 1: Map of Ventilation Load Indexes (VLI) for selected locations.

with the amount of fresh air the industry has deemed useful for maintaining comfort in buildings.[5]

The proposed "ventilation load index" (VLI) is the total load generated by one cubic foot per minute of fresh air brought from the weather to space-neutral conditions over the course of one year. It consists of two numbers, separating the load into its dehumidification and cooling components: latent ton-hours per cfm per year and sensible ton-hours per cfm per year. For example, a ventilation air load index of 6.7 + 1.1 means that the total annual latent load is 6.7 ton-hours per cfm, and the annual sensible load is 1.1 ton-hours per cfm.

The "VLI" is proposed in the same spirit that led to the use of the "degree-day" as shorthand for expressing heating and cooling loads on the envelope of a building, or the SEER as a means of expressing the relative efficiency of cooling equipment over time. Those engineering shorthand values reduce great complexity to simple terms. Although they cannot replace detailed examination of the phenomena they represent, they allow rapid comparisons between similar items. In the same way, the ventilation load index allows for quick comparisons between loads in different geographic locations.

Latent vs. Sensible Ton-hours per SCFM per Year

To calculate the index for a given location, one must compare the temperature and humidity levels in the weather to the temperature and humidity in the conditioned space. Then a calculation is made for every hour of the year. One must also decide what values to use for "space-neutral" temperature and humidity set points to compare with the weather conditions.

In calculating the indexes contained in this article, "space-neutral" conditions are defined as 75°F (24°C), 50% rh (65 gr/lb [39 g/.45 kg]). One could equally choose different set points for specialty applications, but 75°F (24°C), 50% rh seems to represent values consistent with human comfort research findings. This set point is at the middle of the combined summer and winter comfort zones with respect to dry bulb temperature

About the Authors

Lewis G. Harriman III is director of research at Mason-Grant, Portsmouth, N.H. He is the Chair of the Handbook Subcommittee of ASHRAE Technical Committee 3.5 (Desiccant and Sorption Technologies) and is the author of *The Dehumidification Handbook*.

Dean Plager is senior analyst at Quantitative Decision Support, Portsmouth, N.H. He is also adjunct professor of quantitative analysis at the Whittemore School of Business Administration at the University of New Hampshire.

Douglas Kosar is principal product development manager at the Gas Research Institute, Chicago. His primary responsibility is development of gas-driven air treatment technologies for commercial buildings.

and towards the upper limit of 60% rh for moisture in the combined zones.[6]

The latent ton-hours per scfm in a given hour are calculated as follows:

Latent ton-hours per scfm =

$$\frac{(\text{Outside air humidity ratio} - 65\ \text{gr/lb}) \times 4.5 \times 1050}{7000 \times 12{,}000} \quad (1)$$

4.5 = lbs of air per hour per cfm

7000 = grains of water vapor per lb

1050 = heat of vaporization of water at standard temperature and pressure in Btu per lb

12000 = represents the Btu's per hour of one ton of air conditioning capacity

The values for each of the 8760 hours of the year are calculated and summed to form the latent (dehumidification) load portion of the index.

Similarly, the sensible ton-hours per cfm in a given hour are calculated as follows:

Sensible ton-hours per scfm =

$$\frac{(\text{Outside dry bulb} - 75°\text{F}) \times 4.5 \times 1.08}{12000} \quad (2)$$

Where the outside dry bulb is the average dry bulb temperature in degrees Fahrenheit, 1.08 is the specific heat of air at standard temperature and pressure in Btu per degree Fahrenheit per lb and 12000 represents the number of Btu's per hour of one ton of air-conditioning capacity. To arrive at the value for the annual sensible heat load, separate calculations are made for each of the 8760 hours of typical weather observations for a given location.

Note that the index does not consider hours when no load exists. If, for example, the outdoor dry bulb temperature is 75°F (24°C), then there is no sensible load added to the cumulative total from that hour's observation. Likewise, the index does not consider either "free cooling" or "free dehumidification." For example, if the humidity ratio in the weather air is below the indoor set point of 65 gr/lb (39 g/0.45 kg), then no "credit" is subtracted from the cumulative total annual latent load for that hour.

City	State	Ventilation Load Index (Ton-hrs/scfm/yr) Latent + Sensible	Total	Cumulative Load Ratio Latent:Sensible
Albuquerque	NM	0.2 + 1.0	1.2	0.2:1
Boston	MA	2.0 + 0.3	2.3	6.4:1
Detroit	MI	2.4 + 0.3	2.7	7.4:1
Minneapolis	MN	2.4 + 0.4	2.8	6.2:1
Pittsburgh	PA	2.5 + 0.4	2.9	5.8:1
New York	NY	2.6 + 0.5	3.1	5.1:1
Chicago	IL	2.6 + 0.5	3.1	5.0:1
Las Vegas	NV	0.2 + 3.7	3.9	0.04:1
Indianapolis	IN	4.0 + 0.6	4.6	6.6:1
Lexington	KY	4.1 + 0.6	4.7	7.4:1
Colorado Spr.	CO	0.6 + 4.2	4.8	0.1:1
Omaha	NE	4.0 + 0.8	4.8	5.3:1
Phoenix	AZ	1.3 + 5.0	6.2	0.3:1
St. Louis	MO	5.3 + 1.1	6.4	4.7:1
Oklahoma City	OK	5.0 + 1.6	6.6	3.2:1
Richmond	VA	5.9 + 0.8	6.7	7.2:1
Raleigh	NC	6.0 + 0.9	6.9	6.8:1
Atlanta	GA	6.2 + 0.9	6.9	6.7:1
Nashville	TN	6.2 + 1.4	7.6	4.6:1
Little Rock	AK	7.3 + 1.6	8.8	4.7:1
Charleston	SC	9.0 + 1.2	10.3	7.3:1
San Antonio	TX	10.4 + 2.4	12.8	4.4:1
New Orleans	LA	12.3 + 1.8	14.1	6.8:1
Miami	FL	17.8 + 2.7	20.5	6.7:1

Table 1: Ventilation Load Indexes calculated by the BIN program.

Advantages of the VLI

There are several useful advantages of this index. Perhaps most importantly, it represents the cumulative annual load, as opposed to the load at only a single point of operation. In addition, the index has other advantages:

• Small numbers in both I-P and S-I units

As can be seen from the values in *Table 1*, the index yields values which are small numbers, making variations between different locations apparent at a glance. Also, when the index is recalculated using S-I units (kWh/l/sec per year) the values are similarly small.

• Encourages examination of system behavior in different operating modes

In weather systems, temperature and moisture levels are related, but they vary independently. Therefore an air-conditioning system may cool without dehumidifying or dehumidify without cooling. By separating and quantifying the annual loads for the latent and sensible components of the total load, the index encourages the engineer to consider whether the ventilation system is in fact capable of controlling temperature and humidity independently, as suggested by weather variations.

Calculation Methodology

The TMY-2 data set of hourly weather observations and a newly-developed computer program which accesses those data sets in order to perform annual summaries were used to calculate the indexes displayed in *Table 1*.

Annual data set: TMY-2

The TMY-2 data set was selected for several reasons. First, it contains complete records for 239 locations within the United States, by far the largest number of credible and complete annual records available at the present time. Secondly, the data shows observed values, rather than averaged values, and the methodology for constructing a TMY-2 data set is well-documented and repeatable. Finally, the records were produced for the U.S. Department of Energy using public funds, and as such, are nonproprietary, in the public domain and readily available to the public.[7]

The acronym TMY stands for "Typical Meteorological Year." That methodology selects "typical" months of weather observations from a long-term record of hourly observations. A "typical" month is selected based on how closely it con-

See Harriman, Page 40