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Compliance to Standard 55

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I have been involved with ASHRAE's thermal comfort standard (Standard 55) since 1975. At that time, I was in dispute with the U.S. General Services Administration (GSA) over the minimum air speeds in office spaces. The GSA, in their "Peach Book" requirements for performance specifications, required a minimum of 20 fpm "at any measured point in the occupied zone." After a year of research, it was concluded that meeting such a requirement with accurate anemometers was not possible with any air-distribution system. This finding later led to a statement in the standard: "there is no minimum air speed for comfort." Air speed is one of the largest unknowns at the design stage for a conditioned space, but there are steps you can take to easily estimate it, understand its effect on vertical stratification, and use it to prove compliance.

Standard 55

Today, many building codes require compliance to Standard 55. For LEED certification, some designs have been awarded a point for compliance at the design stage, but the means by which compliance is proven, both for LEED and building codes, is more than a bit fuzzy. Fortunately, in Standard 55-2013, much of the text was moved into a series of informative appendices and left the mandatory (normative) portions in the body of the standard, making the path to compliance more clear.

As currently written, Standard 55 has multiple paths for compliance as a function of "air speed." Air speed can be the value at a point in space or an average of several points. Standard 55 refers to it as an average between head and foot at a point. Measurement of air speeds can be conducted using ASHRAE Standard 113, which was originally based on test procedures developed to prove compliance to the GSA "Peach Book" requirements. Using Standard 113, many detailed measurements of typical systems have been accumulated over the years.

Air Diffusion Performance Index

In fact, while I was developing criteria for a linear diffuser in the late 1970s, I conducted more than 1,000 tests using varying temperatures and airflow rates and calculated temperature/velocity profiles for each of them. The data obtained during these tests proved that even with the highest Air Diffusion Performance Index (ADPI), locations exist where the air speed exceeds 40 fpm (0.20 m/s). These findings were later presented in two ASHRAE technical papers.[1,2]

ADPI is one method of rating the uniformity of a given thermal environment (*ASHRAE Handbook—Fundamentals*). An ADPI greater than 80% is considered acceptable for a majority of occupants. It also indicates that the space is fairly "well mixed," which is the avowed goal of most overhead air-distribution systems. ADPI can be measured in accord with Standard 113, which is best accomplished in a laboratory, although it has been performed (with some difficulty) in actual office spaces. ADPI also can be predicted from a table in the *ASHRAE Handbook—Fundamentals,* which is based on diffuser spacing and diffuser isothermal throw data. Many manufacturers also provide computer programs that use this data to calculate ADPI for most ceiling air outlets. However, it applies only to cooling applications, as ADPI has not yet been correlated to heating performance.

When computing ADPI, "draft temperatures" are calculated from temperature and air speed measurements at many locations in the "occupied zone." While the "occupied zone" is defined slightly differently in several ASHRAE standards, it is typically the area from the floor to 6 ft (1.8 m) and no closer than 2 ft (610 mm) to a wall.

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The draft temperature at a point is sort of a "wind chill" number, which equals 0 when the air speed is 30 fpm (0.15 m/s), and the temperature is the same as the average at a given location in the occupied zone. Higher air speeds or colder temperatures will decrease the draft temperature, while lower air speeds or warmer temperatures will raise it. Acceptability is attained when the draft temperature is between –3 and +2. The percentage of points that meet this requirement (where the air speed is less than 70 fpm [0.35 m/s]) is the ADPI, or measure of air mixing in the space.

Once the ADPI is determined, making the direct correlation to Standard 55 can be challenging. However, if some basic assumptions are made about the comfort variables (that are not addressed by the ADPI methodology), such as occupant clothing and metabolic rate as well as humidity and radiant effects, a comparison can be made. Generally speaking, if ADPI is shown to be greater than 80%, it can be assumed that the vertical temperature stratification in the space is less than the maximum defined in Standard 55 (5.3°F). Moreover, by using the methodology outlined in the *ASHRAE Handbook—Fundamentals* (Air Distribution chapter), ADPI can easily be predicted at the design stage using the room load (in cooling applications only) as well as the diffuser's reported throw and spacing.

Having referred to ADPI or air mixing, we are, in effect, discussing thermal comfort, which over the years has been calculated using several different computational tools. In the early 1970s, Dr. Ole Fanger defined the calculation of predicted mean vote (PMV). This became the basis of both Standard 55 and the ISO 7730 Comfort Standard. Around that same time, Dr. A. Pharo Gagge at the John B. Pierce Laboratory at Yale University developed the "two node" method, which led to the development of the ET* value or Effective Temperature that represents the parallel between all the comfort variables and the temperature one would actually feel.

PMV Method

With these two competing methodologies in play, I was tasked in the 1980s (through ASHRAE TC 2.1) to find one that satisfied both. The result was the PMV-ET* method, which was presented in a technical paper and was included in the first ASHRAE Comfort Tool as the "Int-Hout Method." I confess though, I had little to do with this other than act as a mediator between the two actual experts. Last but not least, the Standard Effective Temperature (SET) method is required by the standard to determine the effect of air speeds greater than the 40 fpm (0.20 m/s) upper limit imposed by the PMV methodology.

Standard 55 requires that an operative temperature be used for PMV calculations. Operative temperature is defined as the average of the air temperature and mean radiant temperature. In a study reported in 1983,[3] which used globe and infrared measured surface temperatures, it was discovered that in all the evaluations that the mean radiant temperature was essentially the same as the dry-bulb temperature, regardless of having used overhead radiant panels, radiant panels under the windows, or all overhead air-distribution systems. This would suggest that operative temperatures are equal to air temperatures and that radiant temperatures could be ignored in comfort calculations.

Zone Air Speeds

Unfortunately, zone air speeds at a point cannot be predicted from ADPI. However, what can be concluded is that if the value is greater than 80%, it is unlikely air speeds exceed 70 fpm (0.35 m/s). In fact, it is very likely, based on the thousands of air velocity/temperature tests reported over the past 40 years, that air speeds in excess of 40 fpm (0.2 m/s) exist somewhere in any overhead air-distribution system. Per ASHRAE Standard 55, if air speeds exceed 40 fpm (or the met or clo rates are outside set parameters), one cannot use either the Graphical or PMV Method to show compliance. Instead, one must use the SET procedure. Fortunately, it is available within a comfort tool on the UC Berkeley site.

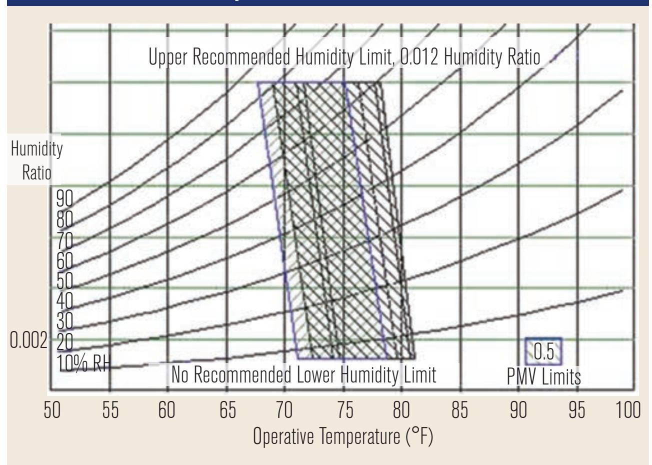
Naturally curious about the likeness of results, I decided to run a number of example scenarios through a couple of these comfort programs and came to an interesting conclusion. Using the SET program, I found that when calculating the comfort zones with an air speed of 70 fpm (0.35 m/s), the comfort envelope moves to the right less than the thickness of the line defining the comfort zone! Using the graphical comfort program developed in the late 1990s, I entered a range of clothing values from 0.8 to 1.2, metabolic rates from 0.8 to 1.2, and air speeds from 20 to 70 fpm (0.1 to 0.35 m/s), and plotted all the comfort zone results on a single chart (*Figure 1*).

Design Temperature

What becomes clear from these overlaid areas is that for an office environment, simply establishing a design temperature of 73°F (22.5°C) will meet the requirements of ASHRAE Standard 55 (for almost all occupants), regardless of the calculation method used, just as long as the vertical temperature stratification requirement is met. Moreover, it appears that when the ADPI is greater than 80%, the vertical stratification is within the 5.4°F (3°C) limits in Standard 55, for a standing person (seated persons are still under review).

What all this boils down to is that if you set the design temperature to 73°F (22.8°C), control relative humidity, and select an air-distribution system that avoids "dumping" (excessive drop at low airflow rates) or jet collisions at high air speeds, you should be able to effectively prove to any authority a design's compliance to ASHRAE Standard 55 for offices that are comprised of normally clothed occupants with typical metabolic rates.

FIGURE 1 PMV and SET analysis.



References

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2. Hart, G.H., D. Int-Hout. 1981. "The performance of a continuous linear diffuser in the interior zone of an open office environment." *ASHRAE Transactions* 87(2).
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