Moving Air For Comfort

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Air movement can be an energy-efficient alternative to air cooling. However, in recent years it has been regarded more as a possible source of undesirable draft. Thermal comfort standards set room air speed limits low, even for temperatures as warm as 26°C (79°F). An exception was granted if the air speed source was under individual control, such as a window in a private office, or a desk fan, but only above 26°C (79°F).

Recent studies of occupied buildings provide consistent evidence that large percentages of occupants prefer more air movement than what they currently have, and small percentages prefer less. This is true in all conditions that occupants perceived as warm, thermally neutral, and even slightly cool. In terms of temperature, above 22.5°C (72.5°F) there is a small risk of draft and a strong preference for more air movement. This article describes these field study findings.

Responding to such findings, ANSI/ASHRAE Standard 55-2004, *Thermal Environmental Conditions for Human Occupancy*, is being updated with new provisions[1] that allow elevated air speed to broadly offset the need to cool the air in warm conditions,

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Thermal Sensation	Air Speed Range (m/s)	Percentage of Occupants Who Prefer			(N)	T_{op} (Standard Deviation) (°C)
		Less Air	No Change	More Air		
Cold (< −2.5)	0 to 0.2	33.33	46.85	19.82	111	22.66 (0.91)
	≥0.2	50.00	42.30	7.69	26	23.50 (1.45)
Cool (−2.5 to −1.5)	0 to 0.2	13.07	60.47	26.47	597	22.92 (1.08)
	≥0.2	11.55	72.51	15.94	251	24.28 (2.0)
Slightly Cool (−1.5 to −0.5)	0 to 0.2	10.75	53.08	36.17	1153	23.05 (1.23)
	≥0.2	11.35	62.23	26.42	458	24.59 (2.16)
Neutral (±0.5)	0 to 0.2	2.62	51.46	45.92	1407	23.30 (1.23)
	≥0.2	4.62	57.26	38.12	585	24.86 (2.03)
Slightly Warm (0.5 to 1.5)	0 to 0.2	2.31	27.73	69.95	822	23.65 (1.41)
	≥0.2	3.36	30.87	65.77	298	25.46 (1.85)
Warm (1.5 to 2.5)	0 to 0.2	4.24	18.37	77.39	283	23.75 (1.58)
	≥0.2	4.96	28.93	66.12	121	25.79 (2.08)
Hot (>2.5)	0 to 0.2	4.55	0	95.45	22	24.96 (1.28)
	≥0.2	7.14	14.29	78.57	14	26.23 (2.04)

Table 1: Air movement preferences by thermal sensation and for two ranges of air speed, n=6,148.

replacing provisions that originated primarily from climate chamber studies.

Building Occupants' Air Movement Preferences

Under ASHRAE sponsorship, field studies of occupant comfort in buildings worldwide have been assembled in a database.[2] Eleven studies in the database (comprising 53 buildings and 6,148 sets of data) included direct questions about the occupants' air movement preference. These studies (from Montreal and Honolulu, Sydney, Kalgoorlie, and Townsville in Australia) are used for the following analyses. The six Honolulu buildings are schools, and the others are office buildings. Except for two naturally ventilated schools and one mixed-mode office in Sydney, all the buildings are fully air conditioned.

Table 1 lists occupants' stated air movement preference by the thermal sensation they reported at the same time. They are also arranged into two speed ranges: V<0.2 m/s (39 fpm; 0.44 mph) representing conditions below the draft limit in Standard 55-2004, and V≥0.2 m/s (39 fpm), representing potentially drafty conditions (for the latter, the mean air speed was 0.32 m/s [63 fpm]). It is obvious that when people felt "neutral" or "warm" ("slightly warm," "warm," or "hot"), a small percentage of them (7% or less) wanted less air speed. This is true even for the higher speed range (V≥0.2 m/s [39 fpm]) in which at least 93% of people accepted the higher air speed, or wanted even more. For both speed ranges, it is only under "cold" sensation that more people "want less" air speed than "want more." Even under "cool" and "slightly cool" sensations, substantially more people preferred more air speed than less.

The associated operative temperatures are also shown.* Under the same thermal sensation category, the operative temperature for the higher air speed is between 1.5 K to 2 K (3°F to 4°F) higher than the temperature for lower speed. This difference illustrates the trade-off between air speed and temperature in producing equivalent levels of comfort.

Air Movement for People Feeling Neutral to Slightly Warm

The following figures summarize air movement preferences in the thermal sensation range of –0.7 to 1.5. A sensation of –0.7 is a little cooler than the usual definition of neutral, but it matches the cool end of the Category III range (for acceptable existing buildings) in the European standard CEN 15251.[3] The figures exclude sensations above 1.5 because, although *Table 1* shows that air movement is clearly welcome when sensation is above 1.5, this sensation is too warm for normal office environments and ideally would not occur often. The –0.7 to 1.5 range should give a conservative estimate of air movement preference for neutral and slightly warm people.

Figure 1 shows that under the sensation range (–0.7 to 1.5), far more people (52%) wanted more air movement than less air movement (3%). The percentage wanting more was greater than the percentage preferring "no change."

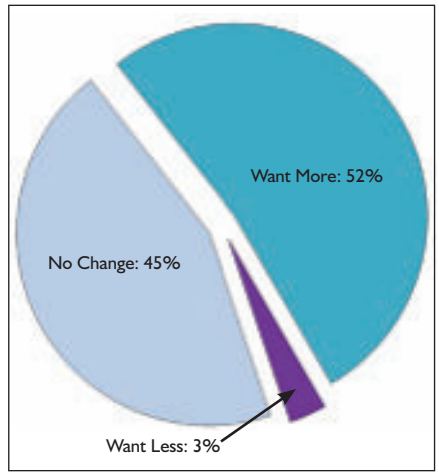
Figure 2 shows that when their air speed was at the higher range (≥0.2 m/s [39 fpm], *Figure 2*), a much higher percentage of people (47%) wanted more, or accepted the higher air speed (no change = 49%), than wanted less (4%).

Figure 3 shows that in the surveys, occupants also were asked whether the air movement was "acceptable." Twenty-nine percent of all occupants said it was not. Looking at these

* The operative temperature is a measure combining the air temperature (affecting the body by convection) and the surface temperatures of the surroundings (affecting the body by radiant exchange). It is defined as the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual nonuniform environment.

respondent's preference votes, one can see that the unacceptable air movement is due to too little air movement, not too much. 84% wanted more, 7% wanted less (*Figure 3*).

When people felt the air speed was not acceptable, *and* when they were experiencing the higher range (≥0.2 m/s [39 fpm]), did they feel the speed was too much and, therefore, not acceptable? *Figure 4* shows that for the higher speed range, when people said that they felt the speed was not acceptable, the unacceptability was still due to insufficient air movement. The percentage wanting more (73%) is still far more than the percentage wanting less (17%). The difference is now smaller, but it is still clear that the majority found the speed unacceptable because there wasn't enough, even with the speed in the higher range.



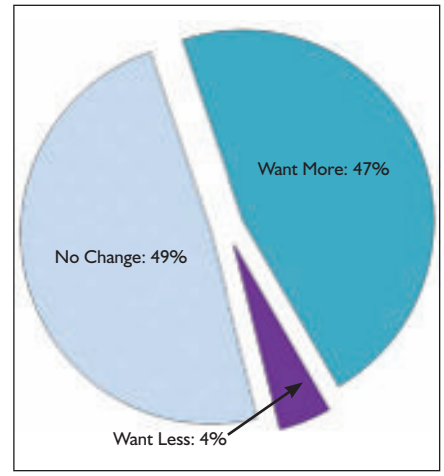


Figure 1 (left): Air movement preference (sensation –0.7 to 1.5), all air speeds (n = 3,230).
Figure 2 (right): Air movement preference (sensation –0.7 to 1.5), air speed ≥ 0.2 m/s (n = 924).

One may also calculate the draft risk percentage (DR) for all the database's occupants based on the equations provided in the previous ASHRAE standard, using air speed, temperature, and turbulence intensity as inputs. Looking at the air movement preference for those people when their DR exceeded 20% (thermal sensation again within –0.7 and 1.5, n=172), the percentage wanting less air speed was 8%; 59% wanted no change, and 33% wanted more. The result is that 92% of a population predicted to be at an unacceptable risk of draft accepted their air speed or actually wanted it higher.

Summarizing these ASHRAE field study results, it is clear that for sensations –0.7 to 1.5, air movement should be encouraged. The air movement should not be made so great that it leaves people feeling cold, but a certain amount of it does answer a basic need found in the surveys, and can offset an increase in temperature in the space. Similar results have been found for a building in which occupants have personal or group control over window ventilation.[4]

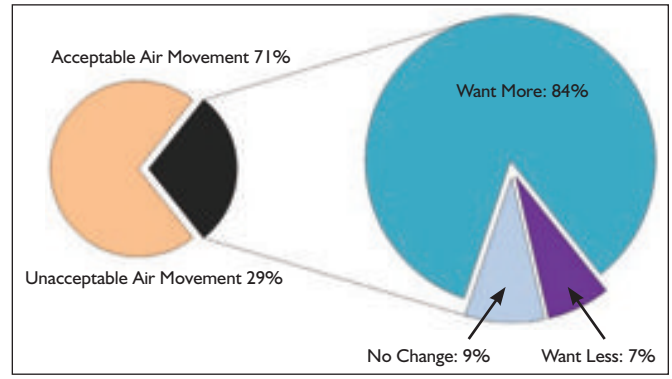


Figure 3: Air movement preference for people (sensation –0.7 to 1.5) who said the air speed was unacceptable. (n = 2,091).

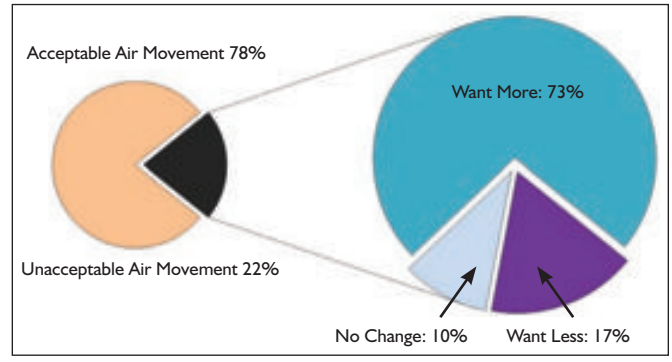


Figure 4: Air movement preference for people (sensation –0.7 to 1.5) who said the air speed was unacceptable, V ≥ 0.2 m/s (n = 324).

Provisions for Elevated Air Speed in Standard 55

Standard 55-2004 will soon provide a two-step procedure for setting a comfort zone for temperature, radiation, humidity, and air movement. Both steps of this process can be carried out using the ASHRAE Thermal Comfort Tool,[5] or can be interpolated from figures in the standard. The first step, unchanged from the previous standard, combines air temperature and radiant temperature in the index "operative temperature" as defined earlier, which is then combined with humidity to produce comfort zones for still-air conditions displayed on a psychrometric chart. This step uses the predicted mean vote (PMV) human heat balance model, combining these environmental variables with the occupant's clothing level (expressed in the insulation unit, clo) and activity level (expressed in the metabolic rate unit, met).[6,7]

The second step evaluates elevated air speeds. It uses a different model that better accounts for convective cooling of the body. The standard effective temperature (SET) thermo-physiological model is based on long-standing ASHRAE research and practice.[6,8] Equal heat balance and skin-wettedness for different air speeds can be plotted in

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