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Energy Savings Found by Modifying Relative Humidity Setpoints

What kind of energy savings can you expect if humidity levels in your institution were allowed to drift slightly? Could active microclimate control help you save on your energy costs?

The attached study by Rob Bishop of Energy Solutions Limited was done to roughly determine some of the savings to be found by modifying humidity setpoints at the Te Papa Museum in New Zealand. According to this study, 50% of the humidification and dehumidification energy needed to maintain steady humidity could be saved just by changing the humidity set points from 55+/- 3% to 52 +/-7%.

This study was part of a larger project to reduce energy costs at the museum, which resulted in savings of over 50% per year. Conversations with the author indicate that this study has been written from a very conservative point of view, and that actual savings could be calculated at even higher percentages of total environmental control energy costs. The author is convinced that energy savings are probably underestimated, as the study is based on the assumption that the whole building is one zone. In reality, many zones would be doing different functions (heating, cooling, humidifying and dehumidifying) simultaneously. Please see the author’s notes at the end of this study.

Further, the climate in Wellington, New Zealand, where the Te Papa is located, is a mild maritime climate. This may indicate that substantially more energy costs could be saved when a similar approach is used in a museum where more intensive humidity control is needed.

As visitors and staff can adapt easily to small changes in the environment, the challenge is to provide adequate protection for the museum’s collections. The use of microclimate control applications allow wider setpoints in a museum by ensuring that sensitive artefacts in display and storage enclosures are maintained at constant relative humidity conditions. These conditions can be maintained regardless of external humidity and temperature variations. The addition of an active microclimate approach to these looser standards can be an effective green solution to steadily increasing energy costs. (see www. microclimate.ca)

Jerry Shiner

Energy Use Impacts of Te Papa Relative Humidity Setpoints

Slightly over half the costs of energy for humidification and dehumidification is saved by changing relative humidity setpoints at Te Papa from 55±3% to 52±7% according to calculations done by Energy Solutions Ltd. The absolute value of calculated savings was between 130,000 and 184,000 kWh per year, (worth between NZ$7,000 and $10,000 per year). This study explores the basis for this calculation.

The moisture released into and exhausted from the air within Te Papa was estimated, as explained below, and the amount of humidification and dehumidification needed to stay within the above humidity limits was calculated. The largest variable affecting the results was the amount of outside air added by the ventilation system. This was analysed at both 30 L per second per person and 10 L per second per person, as described below.

The total annual amounts of water needed to be added and removed for each of the four scenarios are listed in the table below, with the energy requirements for each and in total. The annual energy costs and savings are quite dependent on the time of day that the energy is used (or saved) and this was not calculated in detail.

	Humidification	Dehumidification	Energy to Humidify	Energy to Dehumidify	Total Energy
@ 30L/s/pers OA	[kg/yr]	[kg/yr]	[kWh/yr]	[kWh/yr]	[kWh/yr]
55% ± 3% RH	492,742	88,950	320,282	35,580	**355,862**
52% ± 7% RH	217,202	76,892	141,182	30,757	**171,938**
Savings	*275,540*	*12,058*	*179,101*	*4,823*	***183,924***
@ 10L/s/pers OA					
55% ± 3% RH	333,869	95,489	217,015	38,196	**255,211**
52% ± 7% RH	140,943	82,714	91,613	33,085	**124,698**
Savings	*192,926*	*12,775*	*125,402*	*5,110*	***130,512***

Moisture release was taken exclusively from people, at a rate of 150 gm/hr per person, with a constant occupancy of 675 people between 8 AM and 6 PM, 200 people between 6 PM and midnight, and 10 people between midnight and 8 AM, every day of the year.

Moisture exhaust was taken from calculating the air exchange rate between inside and outside, multiplied by the difference in absolute humidity (moisture content) of the air, again inside to outside.

The air exchange rate was estimated as a constant 10 m^3/sec of uncontrolled infiltration, and an allowance for outside air ventilation per person occupying the building. Two values were used for ventilation per person: either 30 L/s per person (based on historical data for Te Papa), or 10 L/s per person (the required value to meet the building code requirements for ventilation, and what would be expected after the energy efficiency project that changed the control of the Mixing Boxes in 2006 was completed).

The building temperature was taken as a constant 20.5℃ in winter (April through October) and a constant 21.5℃ in summer (November through March). Relative humidity setpoints were either 55±3% or 52±7%. These were converted to absolute humidity (moisture content) for the calculation of energy use. Outside air conditions (temperature and humidity) were taken from existing Wellington hourly weather data used for more detailed simulations.

For each hour of the year, the moisture released and exhausted was calculated, and then the resulting moisture content of the space calculated. If this were outside of the setpoints, then moisture was added or removed as necessary to just meet the setpoint. For some hours the moisture holding capacity of the building's air was enough to avoid any need for moisture to be added or removed to meet the setpoints.

During occupied hours, and especially in summer, moisture needed to be removed (the air dehumidified) most of the time. During unoccupied hours, and especially during winter, moisture needed to be added (humidified).

Te Papa was treated as a single air volume for the calculation. This assumption probably results in an underestimate of the energy use (and savings) for humidity control, as in reality there are over seventy individually controlled zones, some of which require humidification and some dehumidification at any time. Treating the space as a single volume of air allows the simultaneous humidification and dehumidification needs of different zones to cancel each other out in this calculation.

In terms of the energy requirements for humidification and dehumidification, humidification via gas-fired steam injection was taken at a cost of 0.65 kWh/kg of water. This correlates with the usage of the steam boiler, excluding blowdown effects. Dehumidification via refrigerative condensation was taken as 0.4 kWh/kg of water. This accounts for both the COP effect of the chillers (reducing the energy use) and the reheat requirements caused by overcooling.

The following two pages of graphs show the hourly moisture loads, and the required humidification and dehumidification to meet the chosen setpoints, for the two levels of outdoor airflow. The vertical axes have maxima of 500 kg/hr of water added or removed for all graphs.

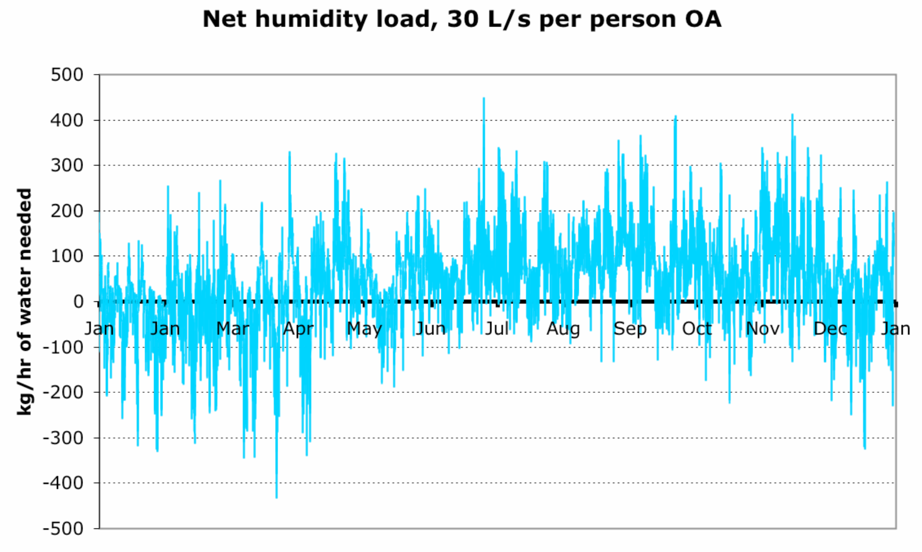
The first page of graphs shows results with 30 L/s per person of outside air ventilation. The first graph on this page shows the hourly amount of water added or removed from the building under the above conditions, through the year. The second graph shows the amount of humidification or dehumidification required to maintain the indoor relative humidity at 55% ± 3%, which is only slightly less than the values in the first graph. The third graph shows the requirements to maintain RH at 52% ±7%, which are significantly less than the other graphs.

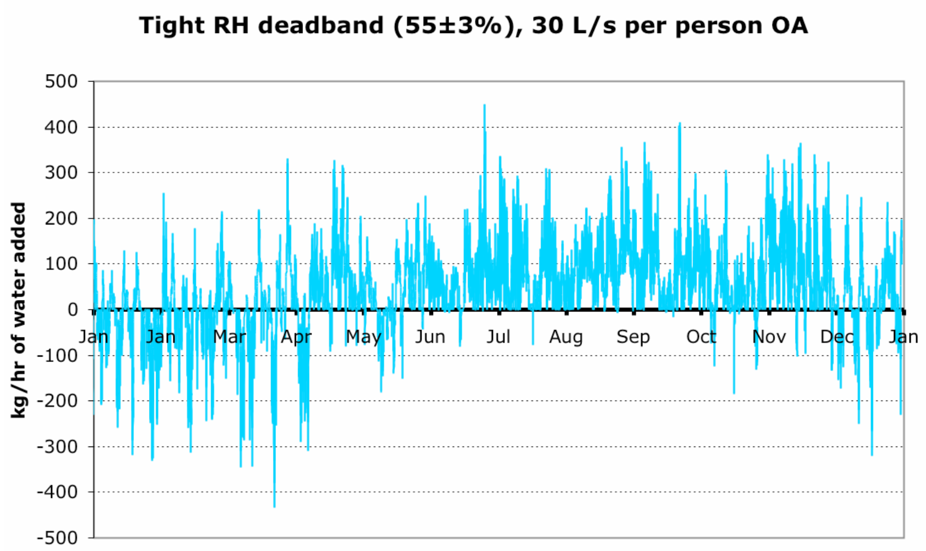
Most of the summer humidification load is removed, as is most of the winter dehumidification load. Most of the savings are in reduced humidification.

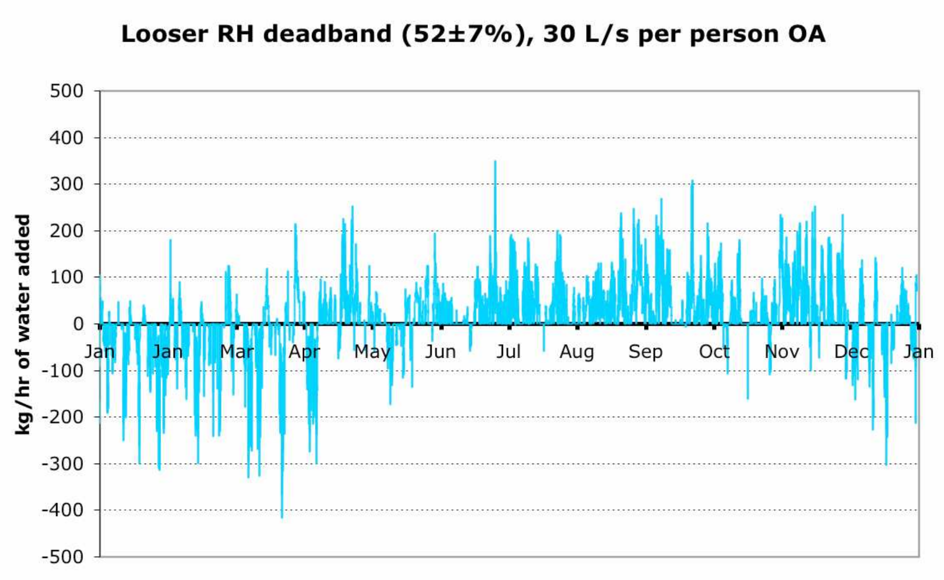
The second page of graphs shows the same results with 10 L/s per person of outside air ventilation. The same patterns hold, again with about 50% less humidification and dehumidification required with humidity setpoints at 52% ±7% instead of 55% ± 3%.

The original brief requested four weeks of analysis, using “typical weeks”, but it was easier and more relevant to do this using an entire year’s weather data.

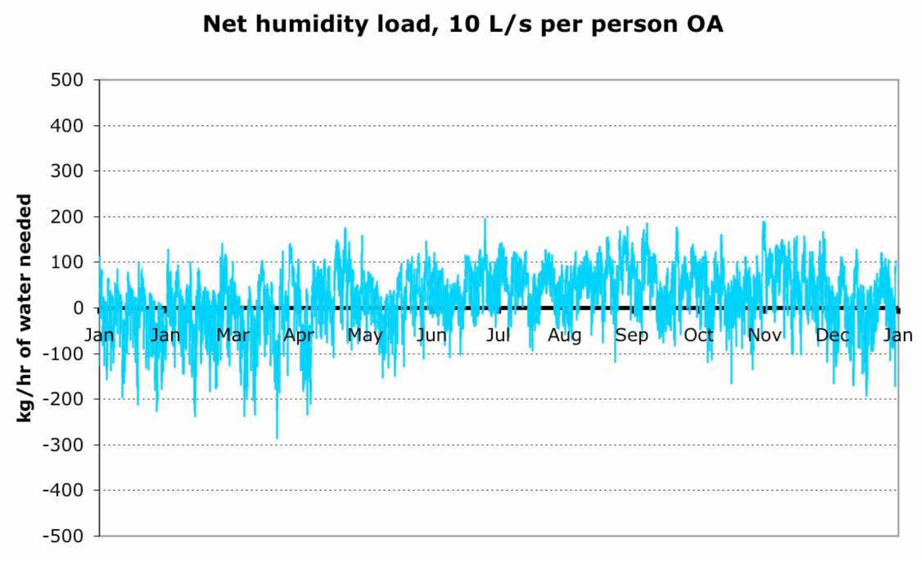
Hourly moisture requirements and amounts, with 30 L/s-person outside air

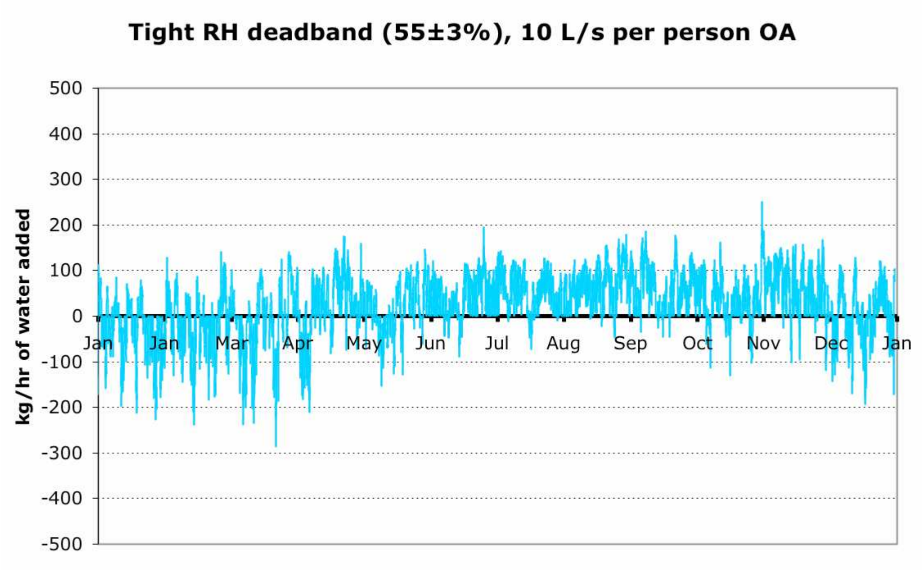


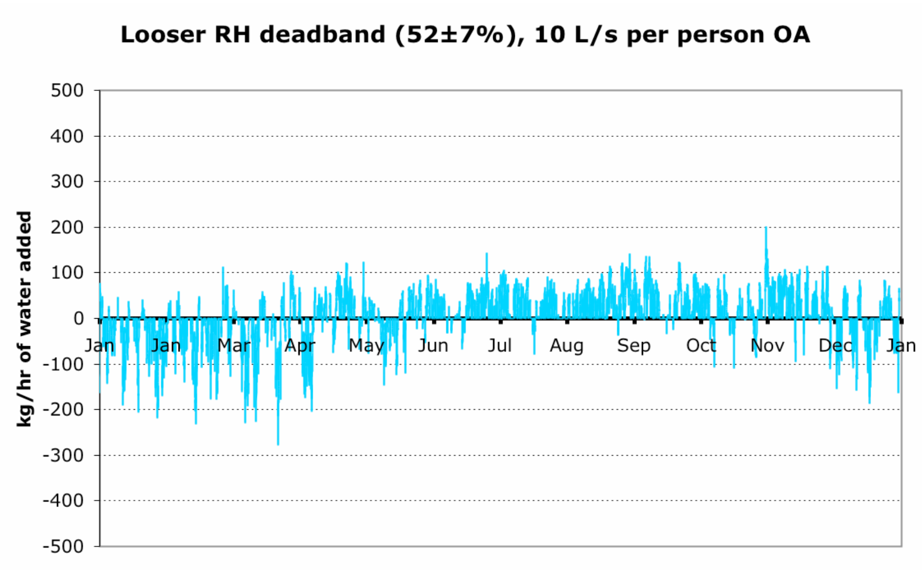




Hourly moisture requirements and amounts, with 10 L/s-person outside air




Tight RH deadband (55±3%), 10 L/s per person OA
kg/hr of water added
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan
Jan
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Looser RH deadband (52±7%), 10 L/s per person OA
kg/hr of water added
500
400
300
200
100
0
-100
-200
-300
-400
-500
Jan
Jan
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

Some notes from the author:

“This quick study I did for Tony Clarke at Te Papa was only a simulation, not based on real results. ‘All simulations are wrong, but some are useful.’

The important result was the 50% energy savings from reduced humidification and dehumidification by widening the humidity setpoints – the amount of energy savings could be off by as much as 100x (one hundred times, or 10,000%). This is because the simulation treated all of Te Papa as a single zone, behaving the same. In reality, Te Papa has about one hundred individually conditioned zones, and some zones are heating, some cooling, some humidifying and some dehumidifying at any time, so the actual amount of humidification and dehumidification was seriously underestimated in the simulation.

Again, the fraction of savings is what is important, not the absolute amount of kWh saved, which we know is far too low.

What we really achieved in our work at Te Papa was about 50% energy savings. Changing the humidity setpoints was only a small part of that effort – it was mostly developing data visualisation tools that enabled us to see what the control system was doing, then changing it so it worked better. And with this knowledge, we were able to reduce the outside air by about two-thirds.”