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January 2015 Volume 69 Number 1

IHEEM
Institute of Healthcare Engineering and Estate Management

Health Estate

JOURNAL OF THE INSTITUTE OF HEALTHCARE ENGINEERING AND ESTATE MANAGEMENT

Controlling humidity for healthier hospitals

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Controlling humidity for healthier hospitals

Eaton-Williams examines the importance of getting humidification levels right in hospitals and other healthcare facilities, to maximise comfort, safety and help minimise the risk of infection transmission and spread. Experience shows that the importance of installing new humidification equipment is often overlooked, existing equipment is switched off where it needs to operate, or simply not replaced when it breaks down.

As seen from the psychrometric chart (Fig. 1), cool outdoor air introduced into buildings in the UK during winter months has its temperature raised to comfort levels, usually around 20˚C. However, as the temperature is raised, the relative humidity (RH) falls dramatically. For example, outdoor air at –5˚C and 100% RH has a moisture content of 0.0025 kg moisture per kg of dry air. When raised to 21˚C dry bulb, with no humidification control, the resultant RH is 18%, which is very dry.

In summer months, meanwhile, comfort air-conditioning will remove moisture from the air, which can again lead to a dry air condition. Medical research has shown that a number of health issues, experienced particularly during winter months, can be directly linked to this low relative humidity condition.

Viruses and relative humidity

A virus is a small infectious agent that can replicate only inside the living cells of an organism, whereas bacteria are present in most habitats on earth, such as soil and water, for example. We will mainly consider viruses (such as influenza), but will briefly address certain bacteria.

Human exposure to viruses occurs via one of three ways – touching contaminated surfaces, direct exposure to large droplets, or inhalation of smaller droplets.[1] Speaking, coughing, or sneezing, expel a large number of 'aerosols', which are suspensions in air of solid or liquid particles. A significant proportion of the particles expelled are between 5-10 microns in diameter. These particles then, in dry air, almost instantaneously evaporate, rapidly shrinking in size, and thereby increasing the number of particles behaving as aerosols.

The fall rate of these droplets (see Table 1) depends on particle size, the crucial point being that the much smaller particles do not settle, so can therefore travel further, and remain airborne for longer – hence a virus can become 'airborne'.

A key variable in aerosol transmission

These virus particles are also hygroscopic, and when exposed to humid air they will group back together,[1] so humidity is an important variable in aerosol transmission because it induces droplet size transformation.[2] Humidification enables particles to collect back together, and, in forming larger droplets, fall to a surface (as Table 1), where they can be more easily be managed.

Medical research has also shown the following impacts of relative humidity on the (aerosolised) influenza virus:

Table 1: Settling rates of different-sized aerosol particles in air, for a 3-metre fall.[1]

Spherical unit size	Time
100 μm	10 seconds
20 μm	4 minutes
10 μm	17 minutes
5 μm	62 minutes
3 μm	Don't settle

- **Transmission**: A dry air condition favours transmission. Low relative humidities produced by indoor heating and cold winter temperatures are features that favour influenza virus spread.[3] Higher levels of vapour pressure can significantly reduce the transmission of viruses associated with influenza.[4,5]
- **Survival**: Tests on aerosol transmission of influenza A show that the virus lives longer in dry atmospheres – influenza showed the best viable survival at low relative humidities,[6] as shown in Figure 2).

  Viruses such as influenza survive longer at lower (20% to 30%) RHs. There is a mid-range of relative humidity between 40% and 70% that minimises the survival of organisms.[7,8] This suggests that infection control measures may warrant humidification control, especially in high risk applications such as nursing homes and emergency rooms.[4]
- **Infectivity**: A test of influenza on white mice showed 100% mortality rates of animals at very low and very high relative humidities, while a 22% mortality resulted at 50% RH,9 (i.e. the mid-range of relative humidity conditions minimises the infectivity of organisms.[7,8])

Persistent low RH (below 40%) also has a direct impact on the human body. Breathing dry air causes moist tissue in the nose, throat, and lungs to dry out, leading to damage which would render the body susceptible to infections.[3,5,10]

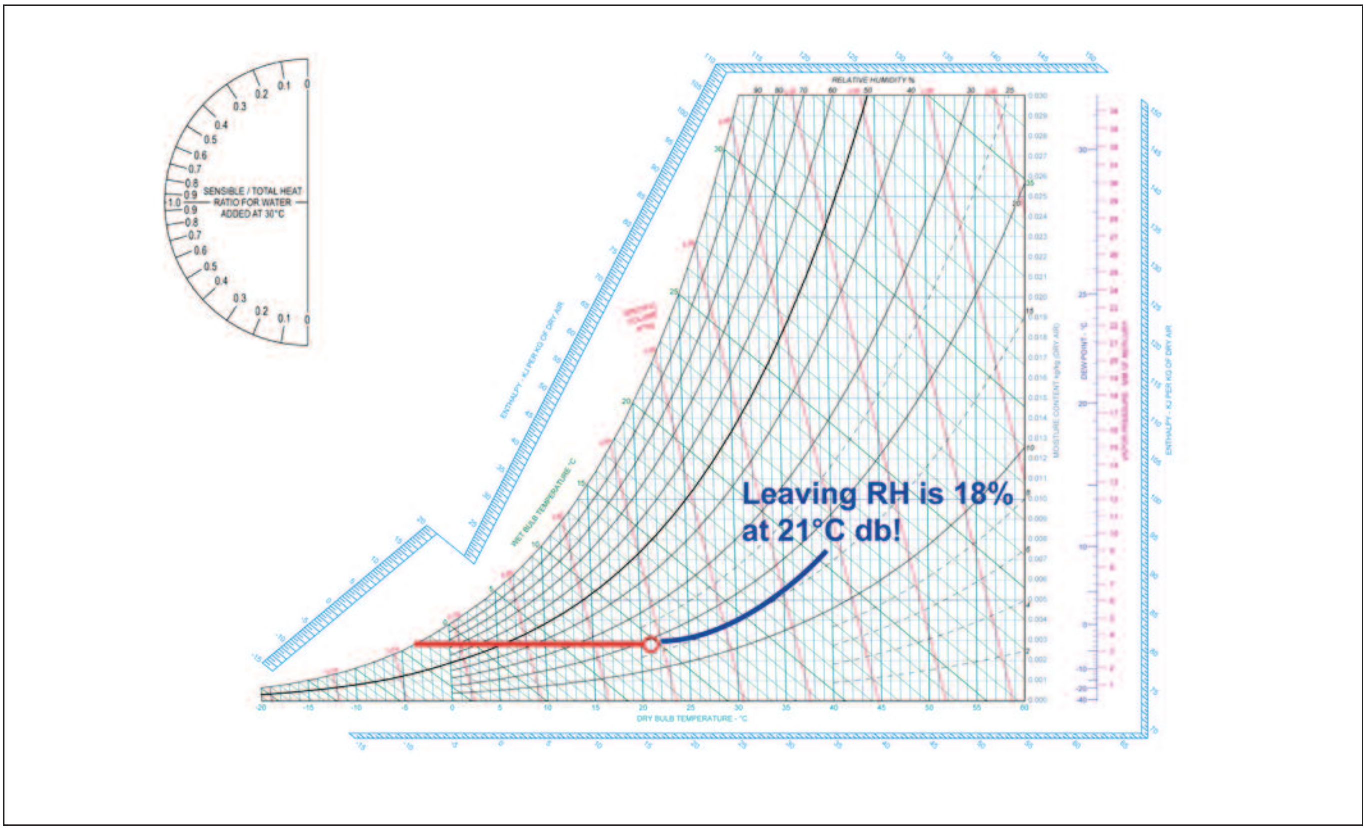

Figure 1: A psychrometric chart of a simple process – heating air, and the impact on RH.

> It is generally accepted that good design practice for comfort and well-being in general building environments is between 19˚C-23˚C dry bulb temperature and 45%-55% relative humidity

Raising the relative humidity to a mid-range not only has a desirable effect on viruses, as we see above, but also has a positive effect on the human body.

Bacteria and relative humidity

Relative humidity can be seen to have a similar impact on bacteria as it does on viruses, in that intermediate RH conditions have a considerable influence on bacteria survival, both airborne and on surfaces. A high death rate of airborne pneumococci, streptococci, and staphylococci, is seen at intermediate RH levels.11,12 Furthermore, increased decay of a hospital strain of *Staphylococcus* is seen at higher humidity levels.13 Let us consider other bacteria that have had high public visibility in recent years:

- MRSA (Methicillin resistant *Staphylococcus aureus*) – It was found that survival of MRSA was significantly reduced when contaminated surfaces were stored in 45% to 55% RH than at 16% RH; as RH increases, bacterial surface contamination decreases.[14] Also, an RH of 35% allowed organisms to remain viable for longer.[14] Another study noted that low relative humidities are more favourable than higher ones for the viability of *Staphylococcus aureus*.
- *Legionella* – is often quoted as a concern in relation to the application of humidification equipment. However, there are very few recorded instances of *Legionella* attributable to humidifiers.[5] Most epidemics have been traced to contaminated air-conditioning equipment and cooling towers.[8] In fact, isothermal (i.e. steam) humidification systems operate at temperatures at which *Legionella* is not deemed to be a risk.[5] As regards the impact of relative humidity on this bacterium, we find, as with viruses above, that *Legionella* is least 'stable' at 55% to 60% RH.[7]

Before leaving this subject, norovirus has also had increasing public visibility. As we might expect, research has shown that increases in norovirus are associated with dry air conditions.[15]

Avoiding high RH conditions

Obviously, high relative humidity conditions are to be avoided; excessively high humidity (above 70%) is associated with mould growth, and the multiplication of house dust mites, and these can have adverse implications for asthma and allergy sufferers. Mould, once established, will continue to grow even at lower humidities, and so continue to release musty odours.[5]

Figure 3 puts into context what we have discussed so far.

Mitigating adverse health effects

We can see that the majority of adverse health effects could be mitigated by maintaining indoor humidity levels at between 40% and 60%. This would require humidification during winters in areas with cold winter climates.[8]

Surface-borne infection – some other considerations

We have previously examined the impact of humidity on airborne agents. Surface-borne infections are also worth examining. Static electricity is an issue when relative humidity is very low. Raising the humidity level above 35% allows all surfaces to become covered in a thin film of moisture that dissipates the static charge harmlessly to earth. That thin film of moisture that dissipates the static also aids more effective surface cleaning. We know that survival of the influenza virus on surfaces is modulated by moisture levels.[16]

It is also known that, below 40% humidity, some bacteriological microorganisms spore, making them more difficult to kill by means of surface disinfectants. One study noted that some Bacillus spores were not completely killed after a 30-minute exposure to chlorine

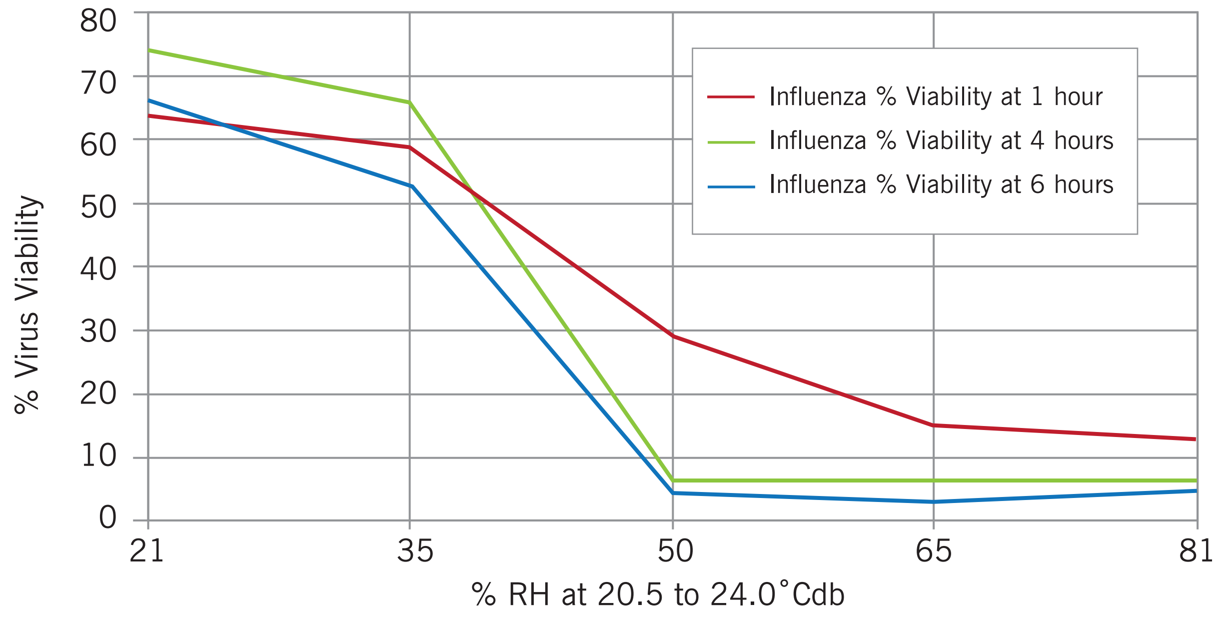

Figure 2: Tests on aerosol transmission of Influenza A show that the virus lives longer in dry atmospheres.[6]

dioxide at humidities of 20% to 30%, but all spores were killed after a 15-minute exposure at a relative humidity of 70%.[17] We noted above that, as relative humidity increases, bacterial surface contamination decreases, and the survival of MRSA was reduced when contaminated surfaces were stored in 45% to 55% RH compared with 16% RH,[14] all of which supports the fact that a controlled humidification environment can also help with cleaning regimes.

Guidance and regulations

It is generally accepted that good design practice for comfort and well-being in general building environments is between 19˚C-23˚C dry bulb temperature and 45% to 55% relative humidity. For detail, we would note the following:

CIBSE Design Guide Volume A, Section 1.3.1.3 – Environmental criteria for design,[18] notes that humidity in the range between 40% and 70% RH is generally acceptable. Section 8.3 – Health issues,[18] also suggests an optimum of 65% at comfort temperatures. It further notes that, at design temperatures normally appropriate to sedentary occupation, the room humidity should be above 40% RH, and warns that in heated only buildings in the UK, the humidity can remain below that 40% RH minimum during periods of sustained cold weather.

CIBSE Knowledge Series KS19 – Humidification, 2012[5] also refers to the above.

Other statutory instruments

There are other relevant statutory instruments, relating to the built environment. For example, the Health & Safety Executive, in its Document OC 311/2 of 2004, *Sick Building Syndrome – Guidance For Specialist Inspectors*,[19] notes, under Clause 17, that levels of relative humidity in the range of 40% to 70% are recommended for the workplace environment, and at higher temperatures, the relative humidity should be at the lower end of this range.

In 1993, The London Hazards Centre published *VDU Work & the Hazards to Health*,[20] which concluded that there are three main factors governing the link between VDU work and skin issues – static electricity, stress, and environmental factors. On the latter factor, The Workplace (Health, Safety and Welfare) Regulations 1992 are quoted. The guidance to these regulations also refers to recommendations produced by the Chartered Institution of Building Service Engineers (CIBSE), noting that CIBSE suggests a relative humidity level of 40% to 70% to produce a comfortable atmosphere.

In the Health & Safety Executive's Display Screen Equipment (DSE) Regulations 1992,[21] CIBSE design guidelines are again quoted as a reference point. There is also plenty of guidance relating specifically to the healthcare sector; note that the examples that follow may not be extensive.

Water for Health – A Hydration Best Practice Toolkit for Hospitals and Healthcare (www.waterforhealth.org.uk August 2007),[22] by the Royal College of Nursing and the National Patient Safety Agency, again notes that the relative humidity for an office should be between 40% and 70%, with the lower end being the most comfortable in warmer offices.

Moving on to hospital buildings, and, more specifically, operating theatre design, ophthalmic surgery accounts for almost 7% of all NHS operations.[23] The Royal College of Ophthalmologists stipulates control of the environment at between 16˚C and 25˚C and 50% to 60% RH as regards operating theatre design.[23]

Importance of the HTMs

The key design guideline tools used in hospital building specifications are, of course, HTMs – or Health Technical Memoranda. The previously used *Ventilation in healthcare premises – Design considerations*, HTM 2025, 1994,[24] noted, under guideline 6.10, that a minimum of 50% humidity must be maintained within the operating room if flammable anaesthetic gases could be used. This

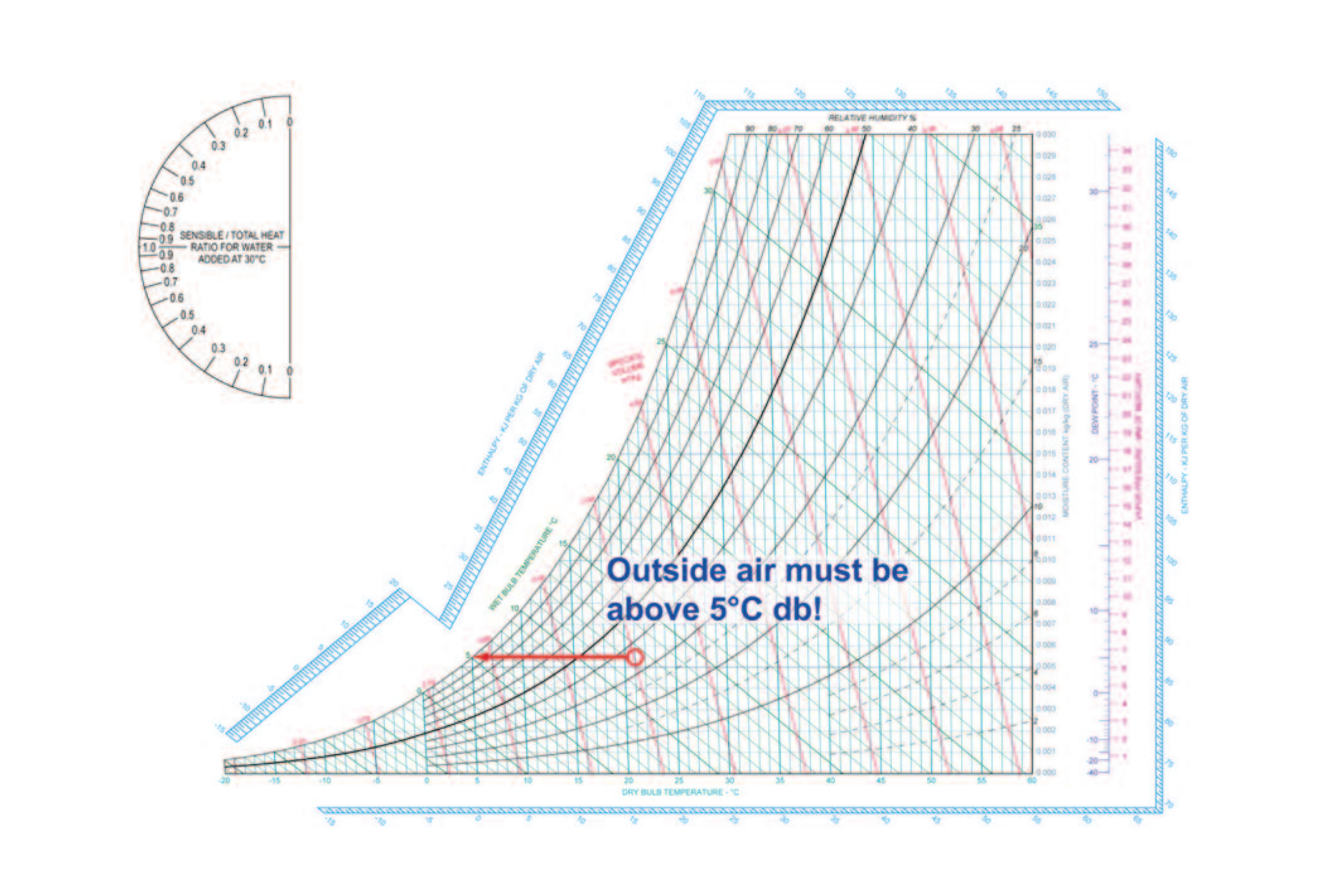

Figure 3: For a minimum 35% RH to be achieved without humidification, outdoor air would need to be above 5˚Cdb.

document has now been superseded by HTM 03-01, Part A, [25,27] which categorically states that as flammable gases are no longer used, humidification is not necessary in operating rooms.

While it may be possible to postulate that some flammable gases may still be in use, let us consider the current HTM, Heating and Ventilation Systems – Health Technical Memorandum 03-01': *Specialised ventilation for healthcare premises* 2007, in detail: HTM 03-01 Part B,[26,28] makes the comment that humidifiers are not generally required, which is often quoted, but not the intent of the document. HTM 03-01 Part A[25,27] guidelines 3.14 and 3.15, for example, note that humidity control use is to be restricted to where it is necessary for physiological or operational reasons. Furthermore, HTM 03-01 Part A, guideline 1.24, notes that for full air-conditioning, humidification may be provided.

Areas warranting full air-conditioning

Guideline 2.19[25] suggests that areas warranting installation of full air-conditioning systems (i.e. possible humidification control) as being operating departments, critical care areas, manufacturing pharmacies, and areas with sensitive equipment, and HTM 03-01 Part A, guideline 7.2, specifically defines those areas and required conditions. HTM 03-01 Part A guideline 7.19[25] and guideline 7.20,[27] state that, for 'specialist' areas (such as obstetrics, critical care areas, isolation facilities, sterile services departments, pharmacies, pathology, and burns units), it is acceptable for supply air humidity to swing uncontrolled between 35% and 70% saturation. Furthermore, in operating theatres, (guideline 7.50,[25] and guideline 7.48[27], the acceptable range of humidity is defined as being between 35% and 60% saturation.

Where 'no humidifiers are required'

If 'No humidifiers are required', the key question that HTM 03-01 raises is 'Is no humidification control compatible with a minimum saturation condition of 35% RH?' For tempered air alone to have any chance of reaching that minimum 35% RH noted, the external air introduced (we are generally dealing with full fresh air plant for operating theatres) must be in excess of 5˚Cdb. Given that average UK winter ambient temperatures are usually well below 5˚C, some kind of humidification control must be required.

As if to help reinforce the need for humidification, HTM 03-01 Part A (guidelines 3.55 and 3.56,[25] and guidelines 3.59 and 3.60[27]) prefer clean, dry (central plant) steam for humidification; however, if that is not available, a steam generator should be provided locally. The HTM also states (guidelines 4.91 to 4.115[25] and guidelines 4.91 to 4.114[27]) that only steam injection systems are permissible for humidification, and that water curtain, spray, or mist humidifiers, should not be used. Finally, HTM 03-01 Part A (Item 7.80[25] and Item 7.77[29]) states that humidifiers should be selected to humidify to 40% saturation at 20˚C during external winter design conditions.

Reinforcing the argument for humidity control

There are other healthcare documents that help reinforce the argument for humidity control. For example, Scottish Health Facilities Note 30 – *Infection Control in The Built Environment* (Item 9.61[29]), looks at controlling infection primarily by maintaining sufficient space for activities to take place so as to avoid transmission of organisms either by air, or by contact with blood or body fluid or equipment. It goes on say that the space needed will vary according to numbers and activity of staff, type of patient, and environmental factors such as ventilation and humidity. Furthermore, it notes that (Items 10.27, 11.93 and 11.167[29]) control of, and physical monitoring of, humidity can help ensure that environmental conditions do not contribute to the spread of infection.

Finally, there is currently a working party involved in a draft European Standard.

The August 2009, Draft EN – CEN/TC 156, Ventilation for hospitals (Clause 6.2.2.1.1[30]) ascribes rooms of a specific 'class' against a function type. For example, operating rooms of 'Class H1a' are for surgeries noted as requiring humidity control, such as orthopaedic and trauma, neurosurgery, thoracic, transplantations, cardiovascular, gynaecology, general surgery (hernia), burns, and those of several hours' duration. There are other classes of spaces – H1a, b & c are all 'protected' operating zones; H2 are areas with a risk of infection, and H3 are for areas with infectious patients.

Specific design conditions

Specific design conditions are then quoted in Table 2 (Versions A & B) for these classes of space. Significantly, a minimum absolute humidity (i.e. moisture content) of 6.5 g/kg is quoted throughout. The detail can be briefly summarised as:

- Table 2 Version A, Classes H1 and H2: Heating – 20˚C to 24˚C supply air temperature, and absolute humidity of 6.5g/kg, i.e. minimum RH of 44% at 20˚Cdb and 35% at 24˚Cdb.
- Table 2 Version B, Classes H3 and H4: Heating – 22˚C to 26˚C room air temperature, and absolute humidity of 6.5g/kg, i.e. minimum RH of 40% at 22˚Cdb and 30% at 26˚Cdb.

These are not dissimilar to the minimum RH conditions noted in the current HTM, although, whereas the HTM is a design guide, any European Standard will be mandatory.

> Dry air favours the transmission of bacteria and viruses; it helps viruses survive, as well as increasing their 'infectivity'

Conclusion

We have seen the impact of dry air conditions on people's health. Dry air favours the transmission of bacteria and viruses; it helps viruses survive, as well as increasing their 'infectivity'. Dry air also has a direct effect on people themselves – mucous membranes dry out in sustained dry conditions, increasing the risk of infection. An intermediate range of relative humidity conditions has been shown to be vital in negating these effects, i.e. it is clear that humidification control at between 40% and 60% RH has a positive impact on infection control.

We have tabled a number of guidance documents that support this assertion. It would seem, particularly as regards healthcare premises, that such advice may be being overlooked. There would appear to be a trend towards either not installing new, or switching off or not replacing, existing humidification equipment. In many instances, the air-handling systems concerned handle a high proportion of fresh outdoor air. That air, if heated from –5˚C saturated to 21˚Cdb, has an RH equivalent to 18% RH. This figure is nowhere near any reasonable recommended minimum RH; hence humidification must be deemed to be essential. ✚

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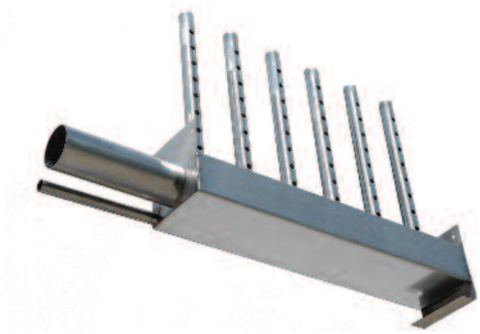

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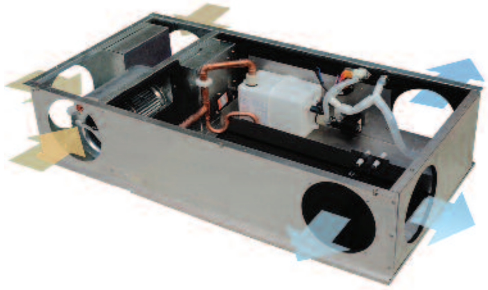

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