ASHRAE: Historical and Contextual notes

By Professor Ian Bitterlin, Chair, techUK Data Centres Technical Committee, March 2017

The American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) and their influence on data centre cooling

Machine room cooling started in the mid-50s when IBM published their first Planning Manual for the first generation commercial main-frame computers. Although the processor itself was water cooled (an A & B redundant system with flexible hoses and quick-release, non-drip, connectors) they set strict limits for ambient temperature and humidity.

The limits were 21°C ±1°K and 50%RH ±5% with limits on rate-of-change over time. Still today, you will find that 'legacy' condition being specified by some users despite this being remarkable because the temperature limit referred to magnetic-tape read/write heads whilst the humidity limit was imposed because punched-card sorting machines neither liked the air too dry (static charge) nor too damp (jamming). This remained the ipso facto 'standard' for 50 years until ASHRAE came along with their Thermal Guidelines document in 2004 which rapidly (through revisions) widened the temperature and humidity set-point window.

Perhaps more importantly, ASHRAE specified 'where' the set-points should apply. Previously, the IBM requirement did not actually state where the air had to be within those limits and, as the air exhausting the machine has different temperature (increased by the load) and relative humidity from that entering, machine operators, for reasons of fear of overheating more than anything else, chose to apply the limits to the return-air intake of the air-conditioning system. Hence was born the 'cold' data centre as, if you wanted 21°C return air, with all the air-mixing and load-bypass air the air-conditioning system was set to push 9-12°C cold air into the raised floor. As it happens this set the typical chilled water flow temperatures to be 6/12°C (flow/return) and the opportunities to be gained for 'free-cooling' using the external ambient rather than a compressor for refrigeration were minimal. ASHRAE changed all that by dictating that the server inlet to be the controlled point and, potentially, the data centre has become a much warmer environment.

The advantages gained by ASHRAE defining the 'where' the conditioned air is controlled cannot be overstated:

- With a legacy system of poor air-management (no containment) and controlling the hot return air to 21°C you could not achieve any free-cooling until the external temperature fell to below 10°C and no pay-back was viable unless the ambient was below 5°C. In the UK, this resulted in <15% of free-cooling per year
- With good air-management and controlling to 27°C inlet air the hot exhaust air is in the order of 35°C. In the UK, this can result in >98% of free-cooling per year and 100% if you use an evaporative or adiabatic external coil. In other words, there is no justification for compressor cooling in the UK if the full range of ASHRAE TC9.9 Class 1 Allowable (read below) is used

So, who are ASHRAE? ASHRAE are the USA trade association for the HVAC industry. An independent commercial organisation that the members have to pay to belong, ASHRAE now produce ANSI (American National Standards Institution) standards, best practice documents and a wide range of technical handbooks. Within ASHRAE are Technical Committees (TCs) that convene to thrash out new Standards and Guidelines that meet with (USA) industry approval by consensus.

TC9.9 is the committee responsible for the ICT Thermal Guidelines and is composed of many stakeholders but, critically, the ICT OEMs themselves. In this respect it is important to understand the unique and powerful position that TC9.9 has in the data centre world. From a European perspective we have no ICT industry, designers, OEMs or contract manufactures, so all the equipment we purchase and install in our data centres is covered by the requirements set down by the ICT OEMs via the auspices of ASHRAE.

Thankfully the power that ASHRAE wields they do so in a, so far, never ending pursuit of lower energy cooling. At each revision, 2004, 2011, 2016, they have widened the temperature limits and, in the last revision, virtually removed any need for humidity control whatsoever. That is not to say that hotter, humid, environments with poor air-quality is risk-free. Far from it, and the ASHRAE texts clearly spell out the potentially shorter life expectancy from running a hotter inlet or premature failure from corrosion caused by a mixture of temperature, humidity, chlorides and sulphides etc. It is a fact that running electronics cold will lengthen their service life but how much the change from 21^{o}C to 32^{o}C would be is debateable – although, in the presence of air-borne contaminants, **Svante Arrhenius** (1859–1927 author of Arrhenius's Theorem) would suggest halving the achievable service life, from 6-8 to 3-4 years, due to accelerated corrosion in the lead-free solder joints.

ASHRAE (i.e. the server OEMs) also have defined four classes of hardware, A1 to A4, in line with environments from critical conditioned spaces to roadside street furniture cabinets for FTTH etc. As you move from A1 upwards the temperature and humidity window widens until the hardware at class A4 can accept an inlet condition of 45^{o}C ambient, although there is some debate about the true availability of A3 & A4 equipment that would be suitable for data centre loads. Most (if not nearly all) users/operators stick to Class A1 hardware for data centre servers.

In each class of equipment there is a 'Recommended' range of temperature/humidity and an 'Allowable' range. The Recommended range is the lowest-common-denominator that all the OEMs will agree to, that;

- Applies to all equipment already in service and newly purchased
- In theory, will not infringe any warranties that may be supported by the ICT sales channel

That said, the Allowable range is there to be used but the complete ASHRAE Thermal Guidelines detail why you would NOT want to extend temperature upwards due to increased failure rates of the server hardware. The key is to enter the Allowable range for short periods to save energy whilst minimising risk. Since peak summer temperatures in the UK only apply for a few hours per year running in the Allowable range for up to 100 hours/year makes engineering and commercial sense.

However, we cannot ignore the conservative nature of the bulk of data centre users. That conservatism results in a time lag between what ASHRAE publish and what is regarded as 'normal practice'. For example, the latest (2015) Guidelines show that humidification is not required in the UK (and virtually all of Europe) yet most user/operators still regard the 2011 edition as cutting edge behaviour.

There are also practical limits to increasing the hardware inlet temperature above the current Recommended 27°C due to the variable-speed cooling fans in the hardware itself:

- Above 30-32°C the server fans speed up considerably to maintain cooling and the energy potentially saved by supplying warmer (less-cooled) air is negated by the increasing server fan energy consumption because the power consumed by a fan is a function of the cube-power (n^3) of the fan speed
- Above 27°C the fan noise increases rapidly because the sound pressure level is a function of the fifth-power (n^5) of the fan speed. When hundreds of servers are within a small radius the combined fan noise will often infringe H&S legislation and the area should be classified as hazardous and ear-protection is made mandatory
- Additionally there is a long-held and not uncommon view that raising the temperature decreases the time safety margin if the cooling system fails or the generator start is delayed on utility failure. This is increasingly 'true' as power density increases…

In conclusion, ASHRAE TC9.9 has advanced energy effectiveness dramatically and they (the server OEMs) will continue to do so, albeit in a law-of-diminishing-returns as Recommended temperatures exceed the external ambient temperature. This is balanced by the conservative nature of many user/operators who regard ICT service as paramount as opposed to taking risks, either real or perceived.