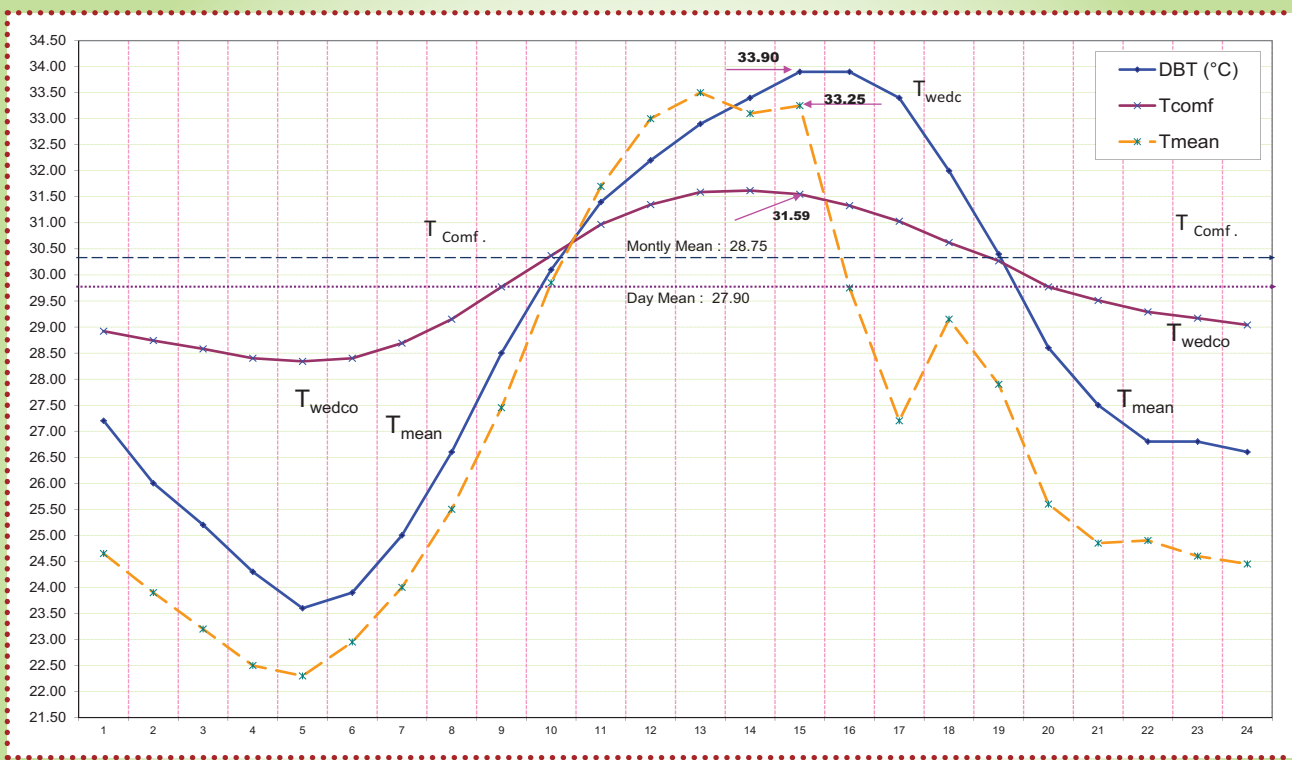


Figure 1: Bangalore temperatures on April 21 including T_{comf}



T_{comf} for Adaptive Comfort Approach, Nicol's Chart and Related Issues

R. V. Simha Director, Airtron Consulting Engineers Private Limited, Bengaluru

HVAC engineers have different levels of familiarity with and understanding of Adaptive Comfort. Many of them are not happy about multiple values of T_{comf} for the same project; having to make so many calculations is probably regarded as an unwanted burden. This article presents a methodology using a new concept about this important aspect of the topic of Adaptive Comfort – which will do away with lengthy and repeated calculations for determining multiple comfort temperatures for various ambient temperatures. Adaptive Comfort is a part of the overall concept of Adaptive Comfort Approach. This approach comprises Adaptive Comfort Temperature (ACT) – also known as Acceptable Operative Temperature and T_{comf} + Air Movement (AM) + Passive Technologies (P). The name for this mixture can be conveniently condensed to 'Actamp'. The word T_{comf} is in widespread use in literature and will be generally used in this article. Obviously, ACT, AM and P can be applied – and in fact, are being already implemented in projects, all of them together and separately as well.

It is also suggested that readers review an article of this author (*Air Conditioning and Refrigeration Journal* issues October - December 2011 and January - March 2012) to relate themselves to the old and new methods, which will help to gain an understanding of the new method.

About the Author

R. V. Simha is a graduate in both electrical and mechanical engineering with over 43 years experience in HVAC. He is a past president of ISHRAE and ASHRAE India Chapter, founder president of ASHRAE South India chapter and ISHRAE and ASHRAE Fellow. He served as a corresponding member of several ASHRAE technical committees and his current interests are climate, comfort, room air movement, natural cooling and related topics. He can be contacted at simha@airtron.in

The Scenario

Adapting to the environment is not a newly acquired virtue of mankind and, in fact, for all living beings. It has been in abundant display and use over a long period of centuries, even millennia. Man is no exception; he has learnt to survive by adapting himself to the environment with minimum effort and admirable elegance to the range of temperatures, as a part of the basket of gifts bestowed by nature. Also tempting are the higher and larger range of T_{comf} available to living beings for various values of outside temperatures. Additionally and typically, they are characterized by resort to 100% outside air (T_o). The Actamp we are talking about has entered the scene at the right

continued on page 38

continued from page 36

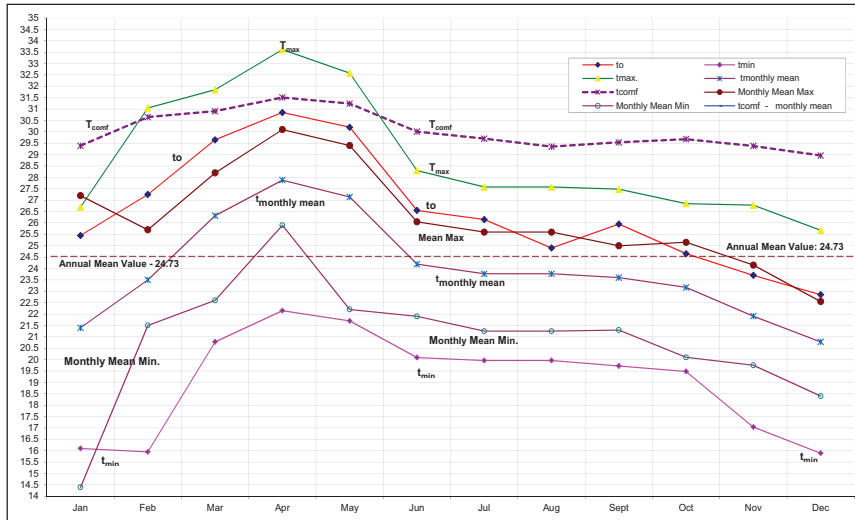


Figure 2: Monthly and annual temperature values

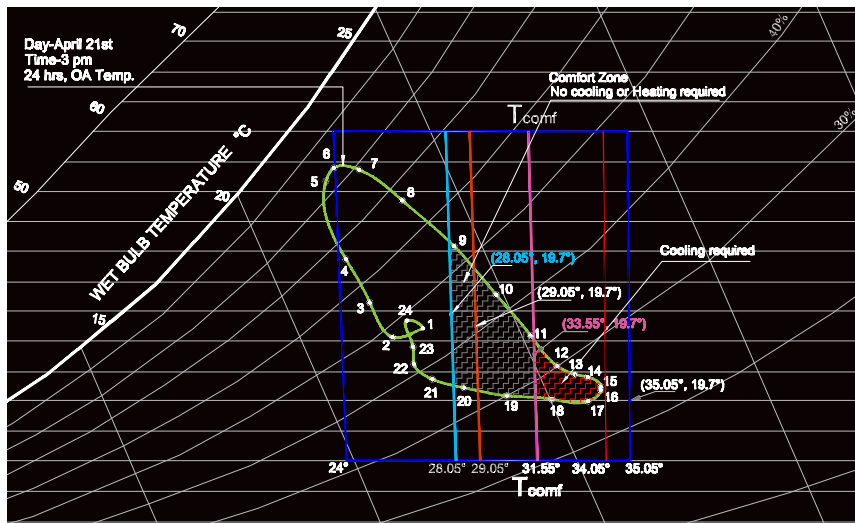


Figure 3: The comfort zone

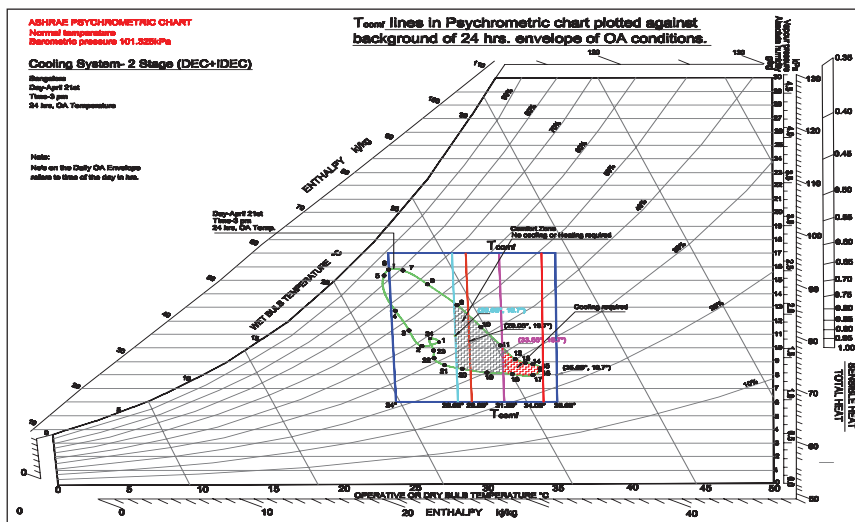


Figure 4: T_{comf} plotted on psychrometric chart

time, though it had been in hibernation and has experienced relatively tardy growth for a long period. It is now merely a revival, starting from around the 1930s – and has been gathering pace for a number of decades from the 1970s. It is now apparently a concept whose time has arrived. A word of caution, however, before we proceed further.

It should be realized that however strong the arguments and attractions in adaptive comfort systems, not all applications can be served by Acaamp; forbidding the use of air conditioning and refrigeration is a voluntary restraint. The scope of mainstream HVAC (msHVAC) will remain far larger than the scope of Acaamp. The latter cannot cope with stricter requirements in a large body of applications, namely industrial air conditioning, manufacturing, health care, pharmaceutical manufacturing, precision engineering, process cooling and heating and a host of others. In fact, there are applications of even just comfort that cannot be met by Acaamp. Let not the msHVAC sector apprehend any serious competition from this nascent strategy.

The ACA, by virtue of its several attractions – the most crucial of which is the strict ban on the use of refrigeration – is set for significant growth.

This brief introduction to the topic of this article should suffice for us to proceed.

The Two Approaches – FTA and ACA

To begin with let us, for the record, list some of the reasons that encouraged scientists and engineers to think of alternate ways of providing thermal comfort.

There are two approaches that characterize the current scenario. The *Fixed Temperature Approach* (FTA: 23°C) represents a well-entrenched trend of thought. The other is the *Adaptive Comfort Approach* – also called the *Variable Temperature Approach* in this context. Obviously, ACA invariably goes with AM and P; this way makes a formidable combination.

The FTA is familiar to all of us. The tolerance is usually $\pm 1^\circ\text{C}$ (RH range: 40% to 60%). Although, under FTA, temperatures up to 25°C and 26°C are now in use, such elevated temperatures have not won popularity as yet.

continued on page 40

continued from page 38

Dissatisfaction with FTA

More specifically, a listing of points of dissatisfaction with the FTA can be presented in a few sentences:

- a) Air conditioned buildings are *either too hot in winter or too cold in summer* most of the time and that translates into *energy penalties*.
- b) Expensive to run.
- c) FTA's laboratories and Climate Chamber approach are too restrictive.
- d) The approach is based on steady state.
- e) Differing comfort requirements or preferences of occupants cannot be met.
- f) It presupposes fixed workstations and seating positions.
- g) No individual controlling devices are considered – operable windows, facility to draw blinds and close them, adjustable speed desk fans, ceiling fans, etc.
- h) Negligible air movement is considered.
- i) It results in monotony of fixed temperature – thermal monotony, so to speak!

ACA Features

A list of features of ACA follows: a) A single Fixed Temperature is not necessary for comfort; b) people react to changes in the surrounding Thermal Environment; c) changes can be in activity level (M) and heat loss (H) from the body; d) clothing; e) posture; f) windows; g) blinds; h) doors; i) change of position; j) fans; and k) thermostat adjustments.

There will, no doubt, be other adjustments carried out by the occupants; likewise there may be some favourable features listed, which cannot be implemented for some reason or the other in some projects.

Concepts of ACA

The focus of this article is, however, on comfort temperature in the Adaptive Approach. So, we go into some of the interesting thoughts, concepts and impacts involved more comprehensively.

Comfort can be found over a *wide* range of temperatures. With the ability of the occupant to meddle with the adaptive variables *themselves*, the wide range of temperatures can be an even *wider range of temperatures*. Every time a change in Thermal Environment is made, the occupant will find himself/herself in a position to accept a different temperature for comfort. The comfort temperature becomes a *bargain* (interaction) between the occupant and the environment. When the occupants have the *adaptive variables* under their control, they are more *forgiving*. Extending *forgiveness* for one's own deficiencies is an integral part of human character and nature.

Occupants should feel *at home* ('at home' used in this context does not imply home, but 'at ease'). When *at home* and with *adaptive variables* under their own control, they are less sensitive to the environment and find it more conducive to comfort.

Note that it is again the *Variable Temperature Approach* or *Adaptive Comfort Approach (ACA)* in action.

When those who favour the adaptive approach say they are comfortable even at warm temperatures classified as 'severe' (according to FTA), they are in fact being less than honest. The

possibility that they may, in fact, be comfortable is not accepted by FTA proponents, whose view – that their expectations of comfort level are low – could be shaped by the fact that living in fixed temperature environments impairs their ability to find comfort in variable temperature ambients. In other words, they are *adapted to a fixed temperature*. The possibility that advocates of variable temperature are, in fact, feeling comfortable never crosses their mind. It is probably an indication of the human trait of suspecting the sincerity behind their acceptance of concepts and willingness to promote them.

Having looked at the comfort temperature in ACA, we now go on to the methodology adopted to arrive at the comfort temperatures (T_{comf}), say for a given location over an entire year.

Arriving at T_{comf}

We start with an extract from ASHRAE Standard 55-2013, which gives an elaborate description of the calculation procedure for T_{comf} :

5.4. Determining Acceptable Thermal Conditions in Occupant-controlled Naturally Conditioned Spaces

5.4.1. Applicability: This method defines acceptable thermal environments only for occupant-controlled naturally conditioned spaces that meet all of the following criteria:

- a) There is no mechanical cooling system (e.g.: refrigerated air conditioning, radiant cooling or desiccant cooling) installed. No heating system is in operation.
- b) Representative occupants have metabolic rates ranging from 1.0 to 1.3 met.
- c) Representative occupants are free to adapt their clothing to the indoor and/or outdoor thermal conditions within a range at least as wide as 0.5 to 1.0 clo.
- d) The prevailing mean outdoor temperature is greater than 10°C and less than 33.5°C.

5.4.2. Methodology: The allowable indoor operative temperature (t_o) shall be determined from Figure 5.4.2 using the 80% acceptability limits or the equations in section 5.4.2.2.

Note: The 90% acceptability limits are included for information only. (See Informative Appendix I for further guidance.)

5.4.2.1. The prevailing mean outdoor air temperature $t_{\text{pma(out)}}$ shall be determined in accordance with all of the following:

5.4.2.1.1. It shall be based on no fewer than seven and no more than 30 sequential days prior to the day in question.

5.4.2.1.2. It shall be a simple arithmetic mean of all of the mean daily outdoor air temperatures $t_{\text{mda(out)}}$ of all the sequential days in section 5.4.2.1.1.

Exception: Weighing methods are permitted, provided that the weighting curve continually decreases towards the more distant days such that the weight applied to a day is between 0.6 to 0.9 of that applied to the subsequent day. For this option,

continued on page 38

continued from page 40

the upper limit on the number of days in the sequence does not apply. (See Informative Appendix I for example calculation.)

Mean daily outdoor air temperature $t_{\overline{mda(out)}}$ for each of the sequential days in section 5.4.2.1.1 shall be the simple arithmetic mean of all the outdoor dry-bulb temperature observations for the 24-hour day. The quality of measurements shall be no less than two, and in that case shall be the minimum and maximum for the day. When using 3 or more measurements, the time periods shall be evenly spaced.

5.4.2.1.3. Monthly means for each calendar month. It is permitted to interpolate between monthly means. Observations in section 5.4.2.1 shall be from the nearest approved meteorological station, public or private, or Typical Meteorological Year (TMY) weather file.

Exception: When weather data to calculate the prevailing mean outdoor air temperature $t_{\overline{pma(out)}}$ are not available, it is permitted to use as the prevailing mean the published meteorological data.

5.4.2.2. It shall be permitted to use the following equations, which correspond to the acceptable operative temperature (t_o) ranges in figure 5.4.2: Upper 80% acceptability limit ($^{\circ}\text{C}$) = $0.31 t_{\overline{pma(out)}} + 21.3$

Table 5.4.2.4. Increases in Acceptable Operative Temperature Limits (Δt_o). The above T_{comf} is applicable for air speeds up to 0.3 m/s. For higher velocities, the increments in the comfort zone are listed below:

Average Air Speed (Va) 0.6m/s (118 fpm)	Average Air Speed (Va) 0.9m/s (177 fpm)	Average Air Speed (Va) 1.2m/s (236 fpm)
1.2 $^{\circ}\text{C}$	1.8 $^{\circ}\text{C}$	2.2 $^{\circ}\text{C}$

Lower 80% acceptability limit ($^{\circ}\text{C}$) = $0.31 t_{\overline{pma(out)}} + 14.3$

5.4.2.3. The following effects are already accounted for in Figure 5.4.2 and the equations in Section 5.4.2.2 and therefore it is not required that they be separately evaluated: local thermal discomfort, clothing insulation (I_{cl}), metabolic rate, humidity and air speed.

5.4.2.4. If $t_o > 25^{\circ}\text{C}$, it shall be permitted to increase the upper acceptability temperature limits in Figure 5.4.2 and the equations in Section 5.4.2.2 by the corresponding Δt_o in table 5.4.2.4.

Comments on Standard 55-2013 Provisions – Limitations on Applicability of 5.4.1 (d):

Note the stipulations of limits in this clause. They could prove restrictive at the high end as well as the low ends of the chart. For example, in hot places and in hot seasons, the mean ambient dry bulb temperature can exceed the limit of 33.5 $^{\circ}\text{C}$. This limitation has, of course, nothing to do with the capability of Nicol's chart but instead the reason could be attributable to technical difficulties. In some places, where it is not very hot but the night temperatures

are somewhat low; arriving at the comfort temperature either from Figure 5.4.2 from Standard 55 or from the equation *Upper 80% acceptability limit* ($^{\circ}\text{C}$) = $0.31 t_{\overline{pma(out)}} + 21.3$ may not always be straightforward and easy. It is apparent, though not explicable clearly, that the focus is on hot temperatures (day time) rather than nights – especially winter nights. A glimpse of thinking behind this limitation can be seen from the following quote:

"The decision about what indoor temperature to set a control, or a thermostat, to in periods of heating or cooling will have a big effect on the energy used by the building. In the UK approximately 10% of heating energy is saved for every one degree reduction in indoor temperature (see Section 1.2). It is worth making this clear to occupants, encouraging them to accept free-running operation for as long as possible, and to accept a seasonally varying indoor temperature to save energy. Thus, if the customary temperature in the heating season is 19 $^{\circ}\text{C}$ (not unusual in a house in the UK) the indoor comfort temperature should not normally fall much below this temperature, even in the depths of winter, in a modern centrally heated house. In reality it often does."

This quote is from *Adaptive Thermal Comfort – Principles and Practice* by Fergus Nicol, Michael Humphreys and Susan Roaf. It seems that this thinking is driving our thinking also in the country today. A scheme that will permit reduction of indoor temperature with falling outdoor temperature has great attraction for us also. May be more studies, analyses, intercourse and debate are called for on this topic.

Applying Flexible Approach to Calculation Procedures

The calculations in this article are essentially in line with the above procedure. Some difficulties will be encountered in achieving compliance with several requirements of the Standard. Those are requirements that are impractical from the viewpoint of implementation in our milieu; in such circumstances, the engineer and the customer should discuss and find acceptable solutions.

The essential concept of the adaptive approach is not restrictive; instead it extols flexibility. Accordingly, the aim should be to provide width and space, i.e. more flexibility for occupants, engineers, architects and developers to arrive at appropriate solutions.

It is instructive to note in this context that even without adhering to Standard 55, one can implement its recommendations where they suit us. Engineers are aware that well-engineered systems can provide significantly better performance and produce greater satisfaction, even though they may not be complying strictly with either ASHRAE or any particular standard. This way of handling the situations needs to be debated and ways and means found out to produce solutions.

An Indian Standard may be proposed. Most clauses can be the same as found in the ASHRAE standard, but there should be no hesitation in deviating on details – particularly in respect of those strongly linked with local practices and requirements (clothing, for example). Leaving it to the customer-engineer team for professional advice will, in a sense, be more in keeping with the

continued on page 44

continued from page 42

spirit of the Standard rather than insisting on compliance to all the clauses just to make the system compliant (with it).

On Methodology and Calculations in this Article

T_{comf} has been calculated using the equation:

Upper 80% acceptability limit ($^{\circ}\text{C}$) = $.031t_{\text{pma(out)}} + 21.3$

80% acceptability limit applies for 'typical' applications, while 90% acceptability limits may be used when a higher standard of thermal comfort is desired.

It will be noted that due importance is given to local air movement. Experience shows that air movements up to 0.5m/s are generally acceptable – and even up to 0.8m/s or 1.2m/s, if problems like flying papers or clothing are not encountered or are not objected to.

Table 1: T_{comf} vs T_o

Hours	T_o ($^{\circ}\text{C}$)	T_{comf}	Hours	T_o ($^{\circ}\text{C}$)	T_{comf}
1	27.20	28.92	13	32.90	31.95
2	26.00	28.74	14	33.40	31.62
3	25.20	28.58	15	33.90	31.55
4	24.30	28.40	16	33.90	31.33
5	23.60	28.34	17	33.40	31.03
6	23.90	28.40	18	32.00	30.62
7	25.00	28.69	19	30.40	30.27
8	26.60	29.15	20	28.60	29.77
9	28.50	29.77	21	27.50	29.51
10	30.10	30.37	22	26.80	29.29
11	31.40	30.97	23	26.80	29.17
12	32.20	31.35	24	26.60	29.04

Compared to the minimum P_u of 4°C , this is quite large. The room can be cooled down by an additional $(16.77-4) = 12.77$ below T_{comf} ($31.55 - 12.77$) to a t_{room} 18.77°C . This is over-cooling. Instead, the room temperature can be allowed to rise and airflow rate reduced. This will bring down both power and energy consumption while offering the desired room temperature.

Table 1 also includes a column giving air leaving temperatures, ahead of the column showing T_{comf} . This helps in the calculation of t_{rm} from the equation $P_u = t_{\text{rm}} - t_{\text{sa}} + 1$. (P_u is t_{rm} ; room temperature and t_{lvgr} air leaving temperature). P_u should not be lower than 4°C . The addition of 1°C already made above is a provision for the temperature rise between $t_{\text{rm}} - t_{\text{lvgr}}$.

Also note that when comfort temperature is achieved, T_{comf} is equal to t_{rm} . Thereafter the required air flow rate can be calculated, and further design work on the plant can be proceeded with.

In the event the limit and P_u turn out to be too small, solutions can be found like increasing the air flow rate and providing lower t_{sa} . This may mean introduction of chillers and cooling coils. If employed, the chiller and cooling coil capacities will be less than

if Acaamp were not employed; moreover, they will run for fewer hours a year, ensuring that the opportunity to achieve savings is not overlooked.

About Data Used for Bengaluru

Some related information regarding the procedure and assumptions made in the calculations for Bengaluru are furnished below:

- a) Maximum t_o (dbt for ambient temperature) for the month of April on 21st day at 15 hours: 33.9°C .
- b) Wet bulb (wb) for the month of April on 21st day at 15 hours: 19.70°C .
- c) Efficiency: 1.15°C .
- d) $t_{\text{a-lvg}}$ (air leaving the cooling equipment): 17.17°C .

The applicable equation is: P_u or $t_{\text{a-lvg}} = t_o - 1.15 (t_o - t_{\text{o-wb}})$.

Calculations have been made for t_{max} at 3 PM on 21st day of April using WeDCo data for all temperatures relating to parameters of the ambient. The 21st day has been used for all months in line with the prevailing practice. A high MRT indicates that the effect of solar radiance is high. Providing adequate shading is a method of control. The default assumption for MRT is that $\text{MRT} = \text{DBT}$. If $\text{MRT} - \text{DBT} > 5^{\circ}\text{C}$, go for shading walls and roofs; providing insulation would become necessary in case shading is not possible. In that situation, insulation needs to be determined and applied.

Standard 55-2013 recognizes the vital importance of AM and with AM in Acaamp, the latter becomes, in fact, the *mantra* of ACA today. Senior engineers in the industry will no doubt recall that even up to almost 1970s (and even closer than that to the present), the appearance of a ceiling fan in air conditioned space was looked down upon as a consequence of the under-sizing of the plant. It would be regarded as a black mark on the engineer! (See also the paragraph on 'Extracts from Standards 2010' later in this article.)

Air movement is factored in the calculations by applying values from Table 5.4.2.4 in Standard 55-2013 V_r vs ΔT . V_a in this table stands for V_r .

Usually V_r is checked at 0.2 to 0.3 m/s through 0.6 to 0.9 and ending with a maximum of 1.2 m/s. Sometimes it can go as high as 1.8 m/s. The benefits in any case decline at high V_r . ' t_o ' is the mean of all the outside air temperatures at the hour under consideration (in this case, 15.00 hours) on April 21. Calculations are to be made for a period of 30 days in the month (3 weeks before + 1 week after).

$t_{\text{o-mean}}$ may be calculated as $(t_{\text{o-max}} + t_{\text{o-min}})/2$ or as $t_{\text{ave}} = N1$ to $N30$. $t_{\text{o-mean}}$ and t_{ave} are often used interchangeably. t_{ave} is the total sum of the N values divided by N (30 days in a month). $t_{\text{o-mean}}$ is readily available in climatic atlases. t_{ave} needs to be calculated. The relation between these two, viz. t_{ave} and $t_{\text{o-mean}}$ is $t_{\text{ave}} = t_{\text{o-mean}} + 1$; it will be seen that the difference between the two parameters is quite small.

These calculations can be made for any station, provided hourly data and other related information (as in WeDCo) are available for the station under consideration.

continued on page 46

continued from page 44

Adjusting t_{rm} vs T_{comf} – Comfort Tool

It is possible that the calculated t_{rm} will, on occasions, fall short of the required T_{comf} . Efforts should be made to bring it down to an acceptable temperature (of T_{comf}). It should be remembered that comfort depends upon 6 factors: i) metabolic rate; ii) clothing insulation; iii) air temperature; iv) radiant temperature; v) air speed; vi) humidity. It is the interaction amongst these factors that produces the sensation of comfort. This interaction is complex and does not lend itself to manual calculations. However, Comfort Tools are available – web-based and dynamic. They will allow any of the factors to be reset and then determine whether the resulting conditions are within the comfort zone or not. This procedure can be repeated with different settings of all or any of the 6 factors till the cursor is dragged into the comfort zone. There is an ASHRAE Comfort Tool, CIBSE tool and several others – mostly based, however, on the ASHRAE product.

It may be noted in passing that the tool incorporates a field for humidity input also but its presence is not highlighted; it just happens to be one amongst the 6 factors. Thus, there is no bar on any humidity value that the engineer can enter in the program. Specifically and specially noticeable is that there is no limit as such on humidity in ACA – either upper or lower.

Extracts from ASHRAE Standard on Adaptive Method, Humidity (in ACA) and Air Movement

It is interesting to take a look at the following three extracts from ASHRAE Standards, air movement and ceiling fans, and humidity.

Standard: 2004: and (ii) **the introduction of the Adaptive method**, which relied on recent research to support natural ventilation designs for more sustainable energy efficient and occupant-friendly designs.

Standard: 2010: Clarifies that the upper humidity limit shown on the psychrometric chart in the graphic comfort zone method applies to only that method. Higher humidity limits are allowed if evaluated with computer model method **and no limits are imposed on the adaptive model**.

Standard: 2010: **This change is expected to give clear requirements for application of ceiling fans for comfort cooling.**

Impact of Cooling Water Temperature

In our calculations, it has been assumed, basically, that cooling water is being supplied by a two-stage evaporative cooling system, but this need not be necessarily so. (An engineer should, in any case, be looking for systems that will produce lower cooling water temperatures delivered – without resorting to refrigeration and air conditioning). The resulting lower supply air temperature t_{lvg} by 1°C or 2°C will have an enormous significance and impact on design and calculations.

Nicol's Charts

All the temperatures we are talking about, viz. weather parameters, room parameters, etc. can be displayed like in *Figure 1*. This is called Nicol's Chart (1914–1997).

Figures can display any function of temperature in the graphic on the vertical co-ordinates; the calculation of mean values, viz. mean maximum, mean minimum, also – both in day time and night hours – on an hourly basis. Other parameters like energy can also be displayed provided energy values are available (from other calculations). The curves in the figures are dynamic, i.e., the calculated value on the parameter on y-axis can be read for any hour by placing the cursor on the curve at the required hour.

Nicol's Chart allows us to display variation of temperatures with respect to time including, for example, T_o , $T_o \text{ mean max}$, $T_o \text{ mean}$, and $T_o \text{ min}$ for every hour and for a total of 8760 hours. Apart from helping us to find T_{comf} the graphs allow us to identify cooling periods and hours when no cooling is required. Curves showing hourly energy consumption values can also be displayed. In this case also, the chart can be entered into, though only when hourly values are available (from other calculations). Please see Nicol's Charts (*Figure 1 to 4*) in which many of these features are incorporated.

Nicol's Charts enable examination of a variety of *what if* options, thus offering ample flexibility to the engineer. All that needs to be done to produce a Nicol's Chart is to obtain hourly values of weather parameters for 8760 hours of the year. Just a few routinely used equations applied on spreadsheets will produce the Nicol's Chart. Ability to make such voluminous calculations with such remarkable ease is the key to satisfactory design and related activities and will go a long way to promote ACA and Acaamp in a number of ways.

Energy saving being one of the most important drivers for advocating the *mantra* of Acaamp, it is time to look at some numbers. *Table 2* contains some results of the calculations made by the author. It will be seen that air conditioning consumes 3.81 times as much energy as an IDEC + DEC plant. In other words the energy saving is 74%. This is spectacular savings indeed – by our industry and any standards.

Table 2: Energy and Emission Calculations

Sr. No.	Description	DEC	IDEC + DEC	Air Conditioning
1	Connected Power	225	252	554
2	Consumed Power	178.2	240	514
3	Cooling Energy - KWHc	2877501	2890726	4770756
4	Consumed electrical Energy - KWHe	248786	311731	1187902
5	Electrical energy / Sqm / Year	27	33	128

These calculations have been made by the author and interested readers may refer to the articles and presentations in the *Journal* issues of October-December 2011 and January-March 2012.

The area of the building used for air conditioning calculations in *Table 2* is about 900 sqm, and it is located in Bengaluru. The calculations were made in detail but have not been published.

The same building data was used for calculation for DEC and IDEC for comparison. The location was, however, Hyderabad. In this instance also, calculation were made in detail. See the article *A Fresh Approach to Evaporative Cooling* published in two parts in the *Journal* issues of October-December 2011 and January-March 2012.

The article deals with bulky calculations – not merely about temperatures, but also about energy. Inevitably, some errors would have crept in. Readers should realize that the purpose of this article is not to present accurate values only; rather, the focus is as much or even more on concepts and methodologies. They are welcome to address their comments either to the *Journal* or to the author.

Conclusion

The author has time and again been observing in his articles and presentations that a large number of case histories and examples are essential to arrive at credible numbers for energy consumption, if they are to help us build a really effective data bank. Complex and bulky calculations are required; such situations can be tackled only by competent and strongly motivated committees, groups, teams and task groups over a period of time. Concepts of this kind and their implementation need to be debated at various levels.

Notwithstanding these remarks, the obvious attraction of the alternate comfort systems as compared to mSHVAC remains. The energy savings are huge by any reckoning. Over-estimates, flawed designs, substandard installation work and such other discrepancies can and do arise due to other reasons also, which are too numerous to narrate here. The consequent reduction in the value of savings achieved will not be significant. In any case, a conservative estimate is that savings can be taken as somewhere between 40% and 70%. This is the kind of figures one comes across in articles, presentations and other literature in this field.

Coming back to the value of Nicol's Charts – the theme of this article – it seems reasonable to say that it goes beyond the selection of comfort temperatures in ACA and Acaamp, and that it could play a crucial role in other ways too, like in energy consumption calculations. ❁