Air Conditioning of Hyderabad International Convention Centre

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The Hyderabad International Convention Centre is India's first world-class convention facility. Located on a 15 acre campus, the building design includes 291,000 sq. ft. of primary meeting space, 250,000 sq. ft. of pre-function areas, a 5-Star hotel with shops, restaurants, pool, 1000 car parking area that can handle events with 50 to 5000 delegates. The huge convention hall of 20,000 sq. ft. is column free with moveable acoustically treated partitions to provide different combinations of halls for various occupancy requirements.

Several important concerns were addressed during the design stage and these included power and energy saving features, draftless air distribution in all areas particularly in the main convention hall with a height of 14.5 m, low noise levels and provision for fumigation for contamination control. This article describes such features in detail.

Customer Requirements and Basis of Design

a. Room temperature: db°C = 23 ± 2, rh around 60%

b. Outside design conditions: db°C = 41.11, wb°C = 23

c. Noise level in the convention hall not to exceed NC 30.

d. Multipurpose hall must be suitable for holding trade fairs, exhibitions, sports events, auditorium etc.

e. Adequate flexibility and options for partial utilization of the facility

f. Facility usage - 10 - 12 hrs a day

g. Occupancy - 10 to 12 sq. ft. per person (about 6000 persons)

h. Fresh air: 17 cfm/person (8 l/s per person)

i. Appliance load - 1 watt per sq. ft.

j. Minimum operating & maintenance cost

Estimated Baseline Plant Capacity

The cooling load for the entire facility worked out to around 1500 TR. The summer cooling load break-up during peak conditions for the convention hall is shown in *Table 1*.

Use of Heat Wheels and TSS to Reduce Plant Capacity and Connected Power

Since the occupancy in the convention hall is high and the heat load due to fresh air (ventilation) alone is around 510 TR, as an energy saving measure, heat recovery wheels (HRW) were provided in the design and the

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Sl No.	Description	Watts - W/O HRW	Watts - With HRW
	Room Sensible heat		
1	Glass Load	Nil	Nil
2	Wall Load - 2 side exposed walls & 2 nos. interior walls (double wall with sandwiched insulation & acoustic panel on the interior surface).	48300	48300
3	All - Glass	Nil	Nil
4	Roof - Exposed with insulation, no false ceiling	61230	61230
5	Floor	Nil	Nil
6	OA load due to bypass	52500	21000
7	People	427650	427650
8	Lights	201780	201780
10	Safety Factor	38000	38000
11	Appliances	558000	558000
12	**ATSH**	**1387460**	**1355960**
13	Fan Gain	119000	119000
14	**ERSH**	**1506460**	**1474960**
	Room Latent Heat		
15	OA load due to bypass	38400	15354
16	People	309484	309484
17	Safety Factor	17394	16242
18	**ERLH**	**365278**	**341080**
19	**ERTH**	**1871738**	**1816040**
	Outside Air Load		
20	Sensible	999900	399936
21	Latent	729400	291738
22	RA Heat Gain (Fan Gain)	Nil	Nil
23	**Grand Total Load (GTH)**	**3601038**	**2507714**
	TR	**1017**	**708**
	Saving due to use of HRW	**309 TR**	

Table 1 : Summer cooling load break-up

reduction in capacity due to their use is around 300 tons.

As air conditioning is required for only 10 to 12 hours and that too during the daytime, for optimum utilisation of the plant and to reduce the connected power requirement of the plant, a Thermal Storage System was provided to work during the night hours to build ice and store thermal energy. The TSS can also provide bulk discharge of the stored cooling capacity during events like exhibitions, seminars, sports and other events which require large cooling capacities for a short duration, thus ensuring better utilisation of the plant. Incidentally the storage capacity of 1100 ton hours can also take care of the entire cooling load during power outages.

These two features of the plant, the addition of the HRWs and the TSS help reduce the required plant capacity to just 750 TR from 1500 TR and reduce connected power by 640 kW.

Use of High DT Chiller System to Reduce Capital and Running Costs

Both the chillers and the cooling coils were selected to provide a 9°-10°C (18°F) split between the entering and leaving chilled brine temperature. For the normal DT of 5°C (9°F), the chilled water/brine flow rate is 0.16 l/s (2.5 gpm/TR) while in a high DT system the flow rate comes down to 0.09 l/s (1.5 gpm/TR). The reduction in flow will therefore be in the ratio of (9–5)/9 i.e. about 0.45.

The most important benefit of this reduced flow rate is the reduction in the size and power requirements of the chiller pumps, sizes of pipes, valves, fittings, control valves, balancing valves and insulation. The saving in power due to smaller pumps will be greater than any increase in power requirements of the chillers due to the larger range through which the chillers will be required to work.

Besides the saving in connected power and energy referred to above, an important gain will be that the chillers will be loaded closer to the design capacity at partial loads and often, fewer chillers will run for a given partial load.

Plant Selection

Three numbers 250 TR water cooled R-134a dual mode brine chillers were selected. The chillers use multiple screw compressors and incorporate dual temperature output feature of 6 to 8°C during Normal Mode and – 6°C during the Production Mode (i.e., while building ice). Brine from the chiller outlet as well as from the TSS is pumped to the AHUs during normal working hours to meet the full load requirement. Under partial load conditions, the chilled brine is drawn from the chillers only. Hence, the storage refrigeration in TSS will act as stand-by also.

The air conditioning system plant room has been remotely located in a separate building away from convention hall to minimize transmission of noise and vibration to the conditioned space. Primary and secondary pumping systems are installed. The cooling tower has been located on the terrace of the plant room and the TSS tanks are installed on the ground adjacent to the plant room.

The Importance of the Cooling Coil Selection for High DT Application

Focusing again on the hydronic system, it is obvious that the chilled water flow rate in a variable flow system

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A view of the 20,000 sq ft convention hall.

should decrease as the load decreases - for otherwise; there would be nothing to commend it. This decrease does indeed occur, but how much should be the decrease?

First, we shall note that in a (cross flow) cooling coil, the standard conditions are 7°C entering chilled water temperature, 27°C mixed air entering temperature, 12°C leaving air temperature and a water flow rate of 0.16 l/s (2.5 gpm/TR) at full load. One would assume - simplistically - that when the load falls to say 50%, so would the flow. The performance of such a coil would be "linear". Unfortunately, cross flow coils do not have such characteristics, but instead, their performance is 'non linear'; thus, at 50% flow, the coil capacity is still 80% (and not 50%). Further, the flow required to produce 50% capacity is less than 30%). This can be seen from *Figure 1* - which is taken from ASHRAE Hand Book Application Volume.

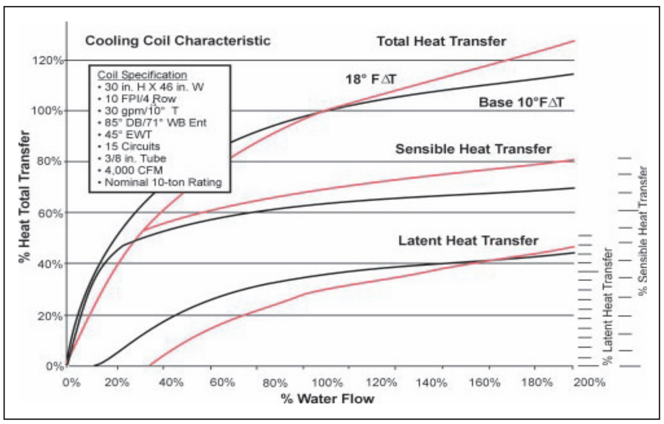

Figure 1 : Characteristics of cooling coils.

Saying that the coil capacity at 50% flow is 80% is the same thing as saying that the DT at 50% capacity should be 80 / 50 = 1.6 times the DT at 100% capacity. Thus if DT at full load is 9°C, it should be 1.6 × 9 = 14.4°C (26°F approx) at 50% capacity. (Incidentally this statement holds for the normal 5°C DT systems also; in this case, the DT at 50% load should be 1.6 × 5 = 8°C).

The point that emerges is that the DT across the coils should increase and go even higher at part loads - than at full load. The high-DT coils are no exception.

Selection of a cooling coil is based on the following equations

$$q_a = q_w = q = \text{coil capacity} \qquad (1)$$

$$q_a = Q_w \times Dh \times C_1 \qquad (2)$$

$$q_w = Q_a \times DT \times C_2 \qquad (3)$$

Where,

q = coil capacity (given)

q_a = coil capacity from air side calculations.

q_w = coil capacity from water side calculations.

Q_a = air flow rate

Q_w = water flow rate

Dh = entering air enthalpy minus leaving air enthalpy.

DT = leaving water temperature minus entering water temperature.

C_1, C_2 - are constants to take care of factors required to obtain results in desired units.

$q = q_w = q_a$

These checks are important, but there is another equation which plays a vital role in understanding the low DT problem.

$$q = q_a = q_w = A \times U \times LMTD \qquad (4)$$

Where,

A = coil surface area.

U = overall heat transfer co-efficient.

LMTD = logarithmic mean temperature difference.

In this equation, A is obviously constant for a given coil.

As the capacity falls to say 50% part load across the coil, if the chilled water flow also falls to 50% of full load flow, the heat balance between air and water would be neatly maintained. This would be simple. Unfortunately this is not how things work.

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As the capacity changes, only U and LMTD can change (since A is constant for a given coil). U does decline with flow, but less rapidly than q, the capacity. Hence, at–say 50% airflow across the coil, the load will be 50% but U × A would have decreased by less than 50% – say about 40%. Thus the deficit must be met by a decrease in LMTD to balance equation (4).

Of the four temperatures that determine the LMTD, three stay essentially constant; the entering and leaving air temperatures do not change much - and likewise, the chilled water supply temperature is nearly constant. It is therefore only the chilled water return temperature that will act to increase (by means of reducing the chilled water flow rate) to reduce the LMTD in response to the reduced load.

LMTD is given by the following equation:

$$\text{LMTD} = \frac{\text{GTD} - \text{LTD}}{2.3\ \text{Log}_{10} \dfrac{\text{GTD}}{\text{LTD}}} \qquad (5)$$

Where,

a. GTD = greatest temperature difference (°F)
= (entering air temp.°F – leaving water temp.°F)

b. LTD = least temperature difference °F
= (leaving water temp.°F – entering air temp.°F)

c. LMTD = log mean temperature difference °F

From an inspection of equation (5), it is apparent that

i. GTD decreases when leaving water temperature rises.

ii. LTD increases as leaving water temperature rises and

iii. Hence, the numerator GTD – LTD becomes smaller when leaving water temperature rises.

iv. When GTD decreases and LTD increases, the denominator will decrease.

Thus, the total effect of an increase in leaving water temperature is to lower the LMTD. This, it will be recalled, is what is required for balancing equation (4).

Sl. No.	% Capacity	Flow -l/S	DT-°C
1	100	8.596	9
2	90	7.234	9.6
3	80	6.177	10
4	70	5.194	10.4
5	60	4.252	10.9
6	50	3.386	11.4
7	40	2.592	11.9
8	30	1.882	12.4
9	20	1.172	13.3

Table 2 : Capacity & flow v/s DT

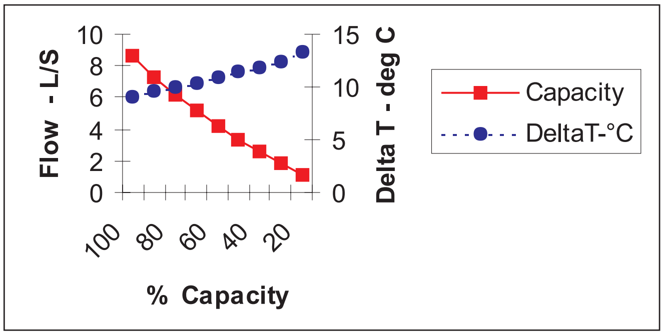

Figure 2 : % Capacity v/s flow & DT

That is how we can see that DT increases at coil part load or alternately, that the chilled water flow is reduced to a greater degree as load falls off.

This is shown in *Table 2* and *Figure 2*.

Because of the low flow rates handled, the coil velocities tend to get low - less than 0.3 m/s. This is the point at which turbulent flow changes to laminar flow as the velocity keeps dropping. Care has to be taken by way of design and circuiting the coils appropriately. It is also necessary to provide 2-way modulating control valves. Due attention has to be paid to the selection of these valves. It should be ensured that the authority of the valves is adequate for effective flow control. The valves should be pressure- independent.

There is no financial impact involved when high-DT coils are selected.

About AHUs

Ten AHUs of capacity 38 to 96 TR with an air flow rate of 7500 lps to 18000 lps each are installed on the service floor to serve the main convention hall. The AHUs feature double skin, sandwich panel construction with thermal break sections. The units comprise backward curved fans, cooling coils, EU-3 and EU-5 filters, heat recovery wheels, supply and return air exhaust plenums and sound attenuators on supply and return airside. The sound attenuators have been designed to minimize the transmission of noise level from supply air-side as well as return air-side. Both supply air and return air are ducted and insulated. The AHUs are selected in such a way that they can serve the convention hall based on the occupancy patterns.

Sheet Metal Work

All sheet metal ducting provided for the project is factory made. This ensures that the ducting is leak-tight. The workmanship is superior and appearance is neater. Time is saved since the work is executed fast.

Heat Recovery Wheels

Heat recovery wheels are installed with supply and exhaust fans. Since occupancy in the convention hall is high and the fresh air requirement is of the order of 8

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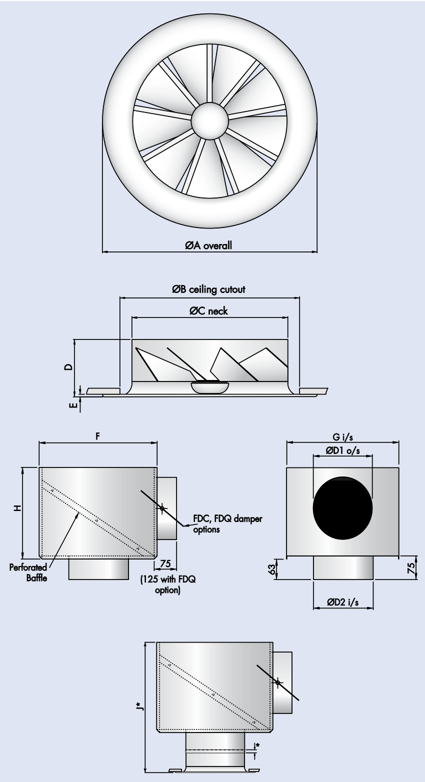

Figure 3 : Swirl diffusers

lps/person (amounting to 48000 lps when fully occupied), as an energy saving measure, heat recovery wheels are installed to recover both sensible and latent heat from the exhaust air.

Swirl Type Diffusers

Large format, high capacity fixed swirl diffusers have been provided for air distribution in the convention hall, which features a high ceiling (12.5m). These diffusers are designed to produce a horizontal radial air pattern with a high induction jet characteristic. They have low noise level ratings. Views of the diffusers are shown in *Figure 3*.

Noise Level Silencer and Acoustic Treatment

Noise level of less than NC 30 is maintained in the convention centre. To meet this requirement, silencers (sound attenuators) are installed on supply and return air-side. Supply air ducts are acoustically lined for a distance of 5 to 6 m. Supply air fans of AHUs are selected for low NC level. Supply air duct is sized for a velocity of 1200 fpm. Walls and ceilings in the conditioned space are also acoustically lined, with details given below:

• External wall treatment consists of stone cladding finish (on the exterior), 200 mm concrete block, 50 mm thick extruded polystyrene slabs, 50 mm air gap, 100 mm concrete block, 400mm air gap and acoustic panel on the interior.

• For roof, the details are - metal cladding finish (exterior), 50mm thick mineral wool, metal cladding, 1400mm air gap, 2 layers of 100 mm thick sound absorbent mat (mineral wool)and grid false ceiling on the interior.

• Movable panels consist of 2 × 100 mm thick mineral wool in cavity, cladding with 12.5 mm thick gypsum board on either side and finished with interior panels.

In fact, all these components such as sound attenuators, fan selection, and acoustic treatment for the ducts were checked and certified by an acoustic consultant.

Provision for Fumigation

One of the AHUs has been configured for fumigation to remove contamination from an occupied zone after the completion of the event. The AHU selected has dual operation mode. In normal mode, it supplies the conditioned air to the hall, while under fumigation mode, by operating dampers, it draws the air from the conditioned space and exhausts it to the outside. (All these AHUs are operated through VFDs). This feature has been incorporated keeping in view that the activities in the conventional hall would involve a large number of people and also that many equipment and devices will be kept running for live demonstrations. In such situations, a fumigation system will help raise the indoor air quality.

Areas like retail, offices, mini meeting rooms are provided with variable air volume (VAV) units for zonal control of temperatures. These AHUs also have VFD drives for the fan motor.

Energy Saving Strategies

The various energy saving strategies implemented for the project are listed below.

A. Total reduction in installed capacity:

	Capacity
• Baseline TR	1500
• Reduction due to heat wheel (less 300 TR)	1200
• Reduction due to TSS (less 450 TR)	750
• Plant capacity selected	750
• Reduction in plant capacity	50%

B. Reduction in connected power will be about 640 kW.

i. The Heat Recovery Wheel gives the following benefits:

• Reduction in plant capacity

• Positive fresh air supply to the conditioned space

• Energy saving due to heat recovery from the exhaust air

• Can be switched on when conditioned space is not in use to remove stale air

• Saving in maintenance cost due to reduction in chiller capacity

As a result, the reduction in connected power is : **265 kW** and energy saved is : **250000 kWh/annum**.

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ii. The Thermal Storage System gives the following benefits :

- Reduction in installed power
- Reduction in chiller capacity
- Optimum utilization of chiller
- Reduction in cooling tower capacity
- Reduction in cooling water pumpset capacity
- Reduction in DG set power
- Storage capacity can be built when power is available

As a result, the reduction in connected power is : **375 kW.**

iii. The use of Primary & Secondary Chilled Water Pumpsets gives the following benefits :

- Chiller will work on the base load independently.
- Fluctuation on the low side will not affect the chiller performance.
- Enhanced chiller performance.
- 2-way valve to regulate the flow of the chilled water in the cooling coils of the AHU.
- Differential pressure sensor(s) installed in the tail end will sense the pressure difference across supply and return piping and send appropriate signals to VFD to regulate the pump speed.
- Lower pumping head for primary pumps.

As the rusult, the energy saved is : **15400 kWh/annum.**

iv. The use of High DT Cooling Coils gives the following benefits :

- High DT coils enable loading of chillers closer to their design capacity at partial loads. Result - fewer chillers will work to deliver the required partial load capacity.
- Reduction in pump capacity
- Reduction in chilled water pipe sizes
- Reduction in pipe insulation
- Reduction in sizes of pipe accessories - butterfly valves, 2-way valves and strainers

As a result, the reduction in connected power is : **21 kW.**
and energy saved is : **32000 kWh/annum.**

v. The use of VFDs for AHUs for the Convention Hall:

- Energy saving under part load condition
- Fan motor starts from the lowest speed; hence starting current is less than operating current
- Improved life of fan belt
- Smooth and silent starting

As a result, the energy saved : **72600 kWh/annum.**

vi. The use of VAVs & VFD for AHUs serving Office areas:

- Energy saving under part load condition
- AHU sized for 85% capacity
- Zonal temperature control
- Variable temperature control in the cabins based on the individual requirement.

As a result, the energy saved is : **27800 kWh/annum.**

Summary of Energy Savings

The total energy savings works out to 397800 kWh per annum as per break-up furnished in the table below.

Sl No.	Description	kWh saved/ annum
1	Heat recovery wheel	250000
2	Primary & secondary chilled water pumpsets	15400
3	High DT cooling coils	32000
4	VFD for AHUs for convention hall	72600
5	VAV & VFD for AHUs serving office areas.	27800
	TOTAL	**397800**

Table 3 : Summary of energy saved - equipment wise

Conclusion

The state-of-art systems and features incorporated will qualify the installation as a benchmark in this country for projects of this kind. The project has demonstrated the benefits of application of high DT systems. Such benefits will be larger, the bigger the plant capacity. The Centre has been attracting international conventions, paving the way for more business for all segments of HVAC services in our industry viz., manufacturers, consultants and contractors. A project of this kind could also open opportunities for Indian consultancy firms to win overseas contracts.

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