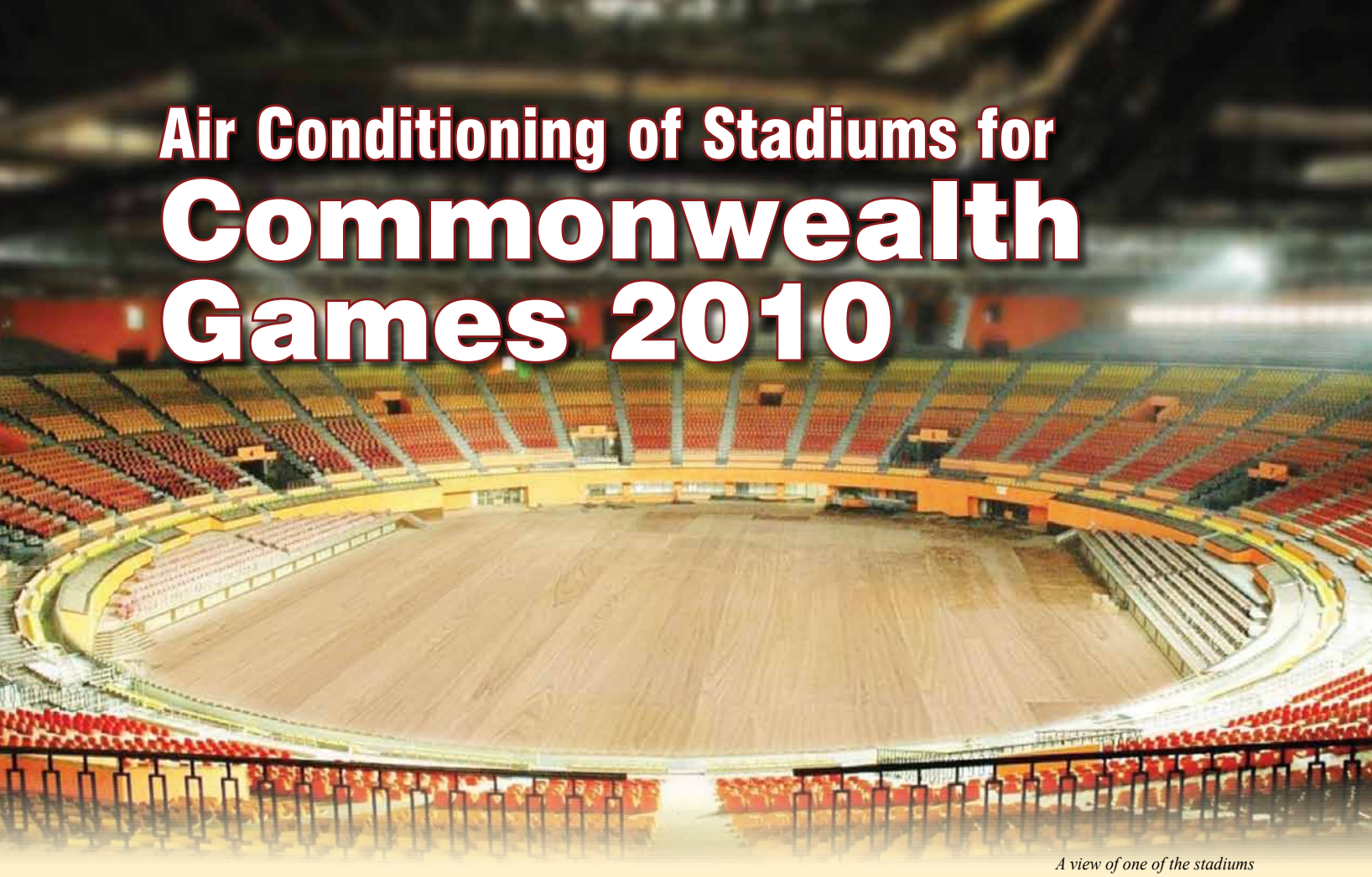
Air Conditioning of Stadiums for Commonwealth Games 2010



A view of one of the stadiums

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The 2010 Commonwealth Games officially known as the XIX Commonwealth Games were held in Delhi, from 3 to 14 October 2010. A total of 6081 athletes from 71 Commonwealth nations and dependencies competed in 21 sports and 272 events. It was the largest international multi-sport event to be staged in India, eclipsing the Asian Games in 1951 and 1982. It was the first time that these games were held in India and the second time in Asia after Kuala Lumpur, Malaysia in 1998.

The opening and closing ceremonies were held in Jawaharlal Nehru Stadium, the main stadium of the event and were widely praised by all, thereby improving the image of the games.

The Delhi Government built / renovated a number of stadiums for various disciplines and these were air conditioned or ventilated depending upon the construction of the facility and type of game to be played.

Some of the major stadiums renovated/ air conditioned during this period were :

Major Dhyan Chand Stadium

This is a hockey stadium consisting of spectator galleries at basement, ground and first floor levels in the existing and new buildings. The total area air conditioned was 158,312 sq.ft with a total AC load of 900 TR. Water cooled screw chillers of 285TR x 4#(3W + 1S) were used.

Talkatora Stadium

This is an indoor stadium for boxing

discipline consisting of stadium and office buildings. The total area air conditioned was 146,300 sq.ft with a total AC load of 966 TR. Water cooled screw chillers of 275 TR x 4# (all working) were used.

About the Author

Sanjeev Malhotra is a post graduate (M.E.) in mechanical engineering from Delhi College of Engg., Delhi University. He has a rich experience of 18 years in designing HVAC systems for various applications like malls, hotels, hospitals, clean rooms, stadiums, under floor cooling etc. He is presently heading the design operations of the Projects division for the northern region of Blue Star and is a member of ISHRAE & ASHRAE.

Sirifort Sports Complex

This is an indoor stadium for badminton and squash events consisting of main and practice courts for both badminton and squash along with a central arena and a main entrance gallery. The total area air conditioned was 140,000 sq.ft with a total AC load of 1750 TR. Water cooled screw chillers of 350TR x 5# (all working) were used.

R. K. Khanna Stadium

This is an outdoor stadium for playing lawn tennis consisting of main and practice courts, media centre, guest rooms, lounges, office block etc. The total area conditioned was 154,000sq.ft with a total AC load of 330 TR. Water cooled screw chillers of 165 TR x 2# were used.

Chatrasal Stadium

This is a training stadium for athelet-ics consisting of administrative building for various offices at ground and first floor and parking at basement level. The total air conditioned area was 25,000 sq.ft with a total AC load of around 270 TR. Air cooled screw chillers of 135TR x 3# (2W + 1S) were used.

Since the AC system required for an indoor stadium has to fulfil the requirements of both spectators and players, it is more critical and requires a thorough understanding and careful implementation of system design as per site constraints and actual application.

The Sirifort sports complex is an indoor stadium built by DDA for disciplines like badminton and squash comes under this category.Since it has the maximum number of playing courts which are air conditioned resulting in higher tonnage requirement(1750 TR), the HVAC system designed for this stadium is explained in the following paragraphs:

Building Description

The main building of Sirifort sports complex is divided into four parts :

1) Badminton Court: It consists of both main court as well as practice courts. The total area of the main court is 65,000 sq.ft with a height of 12m. It has been designed to accomodate a total of 4450 people.
2) Squash Court: It also consists of main court as well as two practice courts. The total area of the main court is 47,000 sq.ft with a height of 12m. It has been designed with a total seating capacity of 2300 people.
3) Central Arena: It divides the Badminton and Squash court and is a single height area with offices on ground and first floor and AHU rooms on the second floor.
4) Main Entrance or Gallery: It is a double height area at the entrance of the stadium with trusses at the top.

All the playing courts have trusses/perlins at the top which are covered with a curved type sandwitch ceiling made of polycarbonate sheet. The sheet is covered with 50mm thick fiberglass with G.I sheet covering.This ceiling has a height of 18m in the centre and 12m height at the ends from the ground floor level.

Design Considerations for AC System

1) Low capital cost
2) Energy efficient at varying load conditions.
3) Minimum power requirements
4) Improved IAQ (indoor air quality) with reduced operating cost.
5) Maximum flexibility of operation
6) Use of automatic control system (BMS) to optimize functioning of system.

System Highlights

- The latest technology systems design has been used to make the HVAC system flexible and efficient at part load conditions.
- Multiple screw chillers with low IKW and having good part load performance have been provided for better flexibility.
- Energy saving devices such as heat recovery wheels and variable frequency drives have been used to make the system very energy efficient.
- Heat recovery units have been used to reduce the plant capacity and to maintain high indoor air quality.
- Improved IAQ is achieved by supplying fresh air quantity of 17 cfm per person or one air change per hour which ever is higher.
- Individual air handling units have been used for each area with common treated fresh air units with heat recovery wheels.
- The main courts 1 & 2 have 5# AHU's with supply air ducting at roof level and return air ducting at basement level.

- The games / practice courts have been divided into two parts by an acoustic curtain to get maximum saving if any area is not in use.
- Provision for smoke exhaust has also been provided for show courts / games / practice courts in case of fire.
- Winter heating has not been considered as building had to be operational in the month ofOctober.

System Design

Airconditioning Loads:

Badminton Court

Floor area - 65000 sq.ft (approx.)

Occupancy - 4450

Capacity of recirculated AHU = 40800 CMH x 4# + 34000 CMH x 1#

Capacity of AHU with HRW = 44200 CMH x 2#

Squash Court

Floor area - 47000 sq.ft (approx.)

Occupancy - 2300

Capacity of recirculated AHU = 34000 CMH x 3#

Capacity of AHU with HRW = 34000 CMH x 2 # + 23800CMH x 2#

The total air conditioning load as calculated was 1750 TR. Hence 350 TR X 5# chiller combination was selected.

Basis of Design

The HVAC system has been designed for the following parameters which are based on the data from the metrological department, ISHRAE and ASHRAE.

Outside Conditions	Summer	:	43.4°C DB ; 23.9°C WB
	Monsoon	:	35.0°C DB ; 28.3°C WB
Inside Conditions	All habitable spaces	:	22.0°C ± 01.5°C DB
	Summer & Monsoon	:	RH not exceeding 60% in all areas.
	Field of Play Spectator area. Warm up areas. Change rooms etc Summer & Monsoon	:	25.0°C ± 01.5°C DB RH not exceeding 60% in all areas.
Lighting Load	Office areas	:	20 W/sqm.
	Indoor Playing Area	:	50 W/sqm.
	Equipment Load	:	20 W/sqm.
Occupancy	Seating Area	:	As per seating plan
	Media Centers	:	3 sq. m per person
	Office	:	6 sq. m per person
Fresh Air		:	29 CMH/person or
		:	1 air change/hour, whichever is higher
Roof Insulation		:	All the exposed roofs shall be insulated with 50mm thick fibreglass or equivalent insulation.
Glazing		:	All windows will have single glass in air tight frames.
General Ventilation	Service Areas	:	10 air changes per hour
	Toilets	:	10 air changes per hour
	D.G. Room	:	As per D.G. set capacity approx. 50 CMH per KVA.
	Basement Ventilation	:	12 air changes per hour
	Emergency Exhaust	:	30 air changes per hour
	Kitchen Ventilation	:	30 air changes per hour

System Description

The HVAC system for the sports complex consisted of following:

- Water cooled screw chillers of 350 TR capacity each – 5#
- Primary CHW Pumps - 6# (5# working + 1# standby)
- Secondary CHW Pumps with variable speed drives – 3# (2# working + 1# standby)
- Condenser water Pumps - 6# (5# working + 1# standby)
- Cooling Towers of 425 TR capacity each - 5#
- Double Skin Air Handling units with imported fans
- Treated fresh air units with heat recovery wheel.
- Building Management System
- Centrifugal fans for normal ventilation of car parking areas and axial flow fans for smoke exhaust of basement and playing areas in case of fire.
- Air washers and exhaust fans for DG room ventilation

The chilling units selected are suitable for an environment friendly refrigerant as per Montreal Protocol on CFCs. Hence screw chillers with R 134A refrigerant have been used. R134a is a stable

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gas, is readily available and has no phase out date.

Screw chillers have been selected due to their price competetiveness in a capacity range of 300 – 400 TR as compared to centrifugal chillers. Further, their part load performance is much better than centrifugal chillers at loads less than 60% of chiller capacity. The screw compressor is provided with an automatic capacity control for infinite steps of capacity control between 40% - 100%. The chillers have a microprocessor-based control panel with following capabilities:

- Self diagnostic facility
- Alpha – numeric display of operating parameters
- Chilled water reset
- Power demand limit & its reset
- Capacity control with overload limit control point adjustment
- Suction, oil & discharge pressure indications
- Safety cutouts

The units are certified as per ARI 550 for performance.

Pumping System

Primary and secondary pumping system is provided.Primary pumps are end suction pumps circulating chilled water between the chilling units and secondary pumps.

The secondary pumps are distributing chilled water to various air handling units and fan coil units in the complex.The secondary pumps are variable speed type to regulate the flow of water as per the variation in the load inside the building. These pumps are controlled by a pump logic controller which on receipt of signal from Differential Pressure Transmitter (installed in the piping header at farthest points in the complex) operates the variable speed drives which in turn automatically change the speed of the pumps.

The pump speed reduces or increases as per the load conditions inside the stadium.

These pumps follow the pump laws given as under:

Flow is proportional to speed

Head is proportional to $(speed)^2$

Power is proportional to $(speed)^3$

Hence, due to load variation when the pump speed reduces, its power consumption reduces by the cube of speed resulting in substantial saving in power consumption of the pumps at partial loads.

Secondary pumps are imported pumps capable of operating satisfactorily over a speed range of 30% to 100%. Condenser water pumps are end suction pumps circulating cooling water between condenser of the machine and cooling towers.

All these pumps are located in the plant room provided in the basement.

Cooling Tower

Cooling towers provided are of induced draught counterflow type. Towers consist of single cell with a single motor along with PVC fills and sump. They are located on the terrace of central arena.

Air Handling Units

These units are sectional type with double skin construction. Their casing is made up of G.I sandwitched panels with polyurethane foam insulation and frame work of extruded aluminium. Each AHU consists of following :

- Forward curved DIDW centrifugal fan with TEFC squirrel cage induction motor.
- Chilled water coils of ½ inch dia copper tubes and Al fins with 6 rows deep.
- Stainless steel sandwitch type drain pan.
- Synthetic prefilters of 50mm thickness and 90% efficiency.

Each AHU section is provided with access panel with rubber gaskets for proper sealing.

AHU's are also provided with following accessories:

- Fresh air damper with pre filters.
- Thermometers and pressure gauges at inlet/ outlet.
- Butterfly valve at inlet/ outlet.
- Dynamic balancing valve at outlet for automatic regulation of water flow thru the unit.
- Motorised fire damper with actuator assembly on the supply duct and return air opening.

The chilled water is circulated by secondary pumps to AHU's located on various floors thru insulated MS piping network. Each floor is having multiple AHU's depending upon the requirement. This has resulted in easy subdivision of playing areas so that respective AHU's can be switched off for areas which are not in use resulting in saving in the operation cost. The AHU 's for the main playing courts are located at the second floor level of central arena. Similarly AHU's for the practice courts are located at first floor level inside the courts on one side.

AHU's with HRW are being used to provide 100% treated fresh air in the playing / practice courts along with recirculated AHU's.

Fan Coil Units

These units have been provided in certain small areas like BMS room, security room etc. which require independent control of air conditioning.

The fan coil units are horizontal ceiling suspended type with low noise fans, cooling coil, GI casing and stainless steel drain pan. These units are connected to the supply air grill through an acoustically lined G.I duct connection piece to achieve silent operation.

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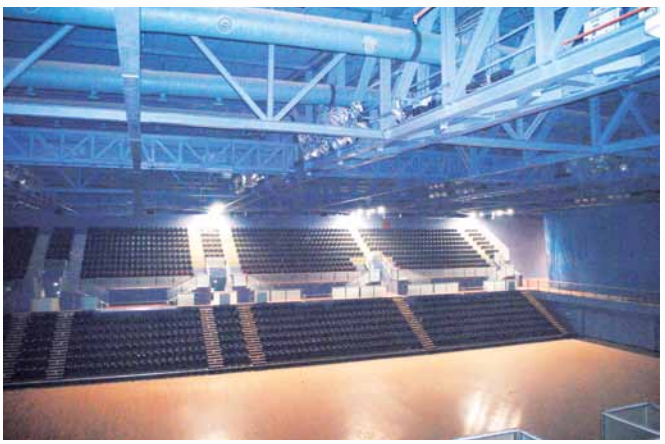

Inside view of the badminton court with exposed ductwork

Piping Network & Fittings

The chilled/condenser water is circulated thru mild steel heavy class pipes as per IS 1239 for pipe dia upto 150mm and pipe sizes of 200mm dia and above are provided as per IS 3589 with wall thickness of 6mm.

All equipment is provided with butterfly valves for shut off and isolation. The chillers, pumps and AHU's are also provided with balancing valves on the outlet for balancing and flow measurement of water.

The chilled water pumps are provided with inlet Y – strainer for laminar flow of water and condenser water pumps are provided additionally with a pot strainer with a bypass arrangement.

Pressure gauges are provided at inlet and outlet of all equipment where as thermometers are provided at inlet and outlet of heat exchangers like chillers and AHU's.

The chilled water pipes are insulated with preformed sections of polyurethane foam.

The pipe insulation in the plant room and AHU room is covered with aluminium cladding to provide smooth and uniform finish and avoid damage to the insulation.

Ductwork

The conditioned air from AHUs is circulated to various areas of the complex thru G.I ducts. These ducts are factory fabricated from G.I sheets in coil form to reduce the number of longitudinal joints. The ducts have been fabricated as per SMACNA standards. The duct connectors are of preformed G.I. C&S cleats, 4 bolt slip-on flange or TDC flange with built in sealant. The main duct branches are provided with motorized fire dampers and opposed blade volume control dampers and smaller branches with splitter dampers to adjust the flow rate during commissioning.

Since in the playing/ practice courts there is no false ceiling, insulated round spiral ducts have been used for providing supply air. The distinctive feature of these round ducts is their supporting arrangement. Wire ropes have been used to support these ducts from the trusses at the top level.

The main playing courts due to their greater heights have been provided with jet nozzles at the top to supply the conditioned air and return is being taken thru openings provided at the bottom of the seats and finally thru grills provided on both sides of the court at lower level. The return air from grills is taken thru ducts till the mixing box of AHU.

Due care has been taken to provide air nozzles at an angle at the top so that the supply air does not cause any interference in the playing area. Round diffusers have been used to supply air just above the playing area so that air flow diffuses slowly without causing any disturbance to the players. The ducts are completely insulated with closed cell elastomeric insulation of 13mm thickness. The supply air ducts are provided with acoustic lining upto 4-5m distance from AHU. Acoustic lining consists of 25mm thick glass wool covered with kraft paper and perforated aluminium sheet.

Ventilation System

Mechanical ventilation system is provided for parking areas in basement, plant room and DG set room and toilets to provide smoke/ fume free environment.

Car Parking

The ventilation system in the basement consists of natural air inlet thru ramps and fresh air fan where as air exhaust is forced by using centrifugal blowers. The exhaust system is partially ducted so that smoke/ foul air is picked up from all areas uniformly. In case of normal ventilation in the basement,centrifugal DIDW fans have been used for both supply and exhaust. As per fire safety norms, the parking areas have been provided with smoke exhaust fans having H – class motor. There are 24# axial flow fans of 68000 CMH each.

In case of fire, they will start automatically on receiving fire signal from the fire panel. In addition to above, 46# roof extractor fans of 34000CMH capacity each have been provided at the roof top for smoke exhaust from playing courts.

DG Room

The DG room is provided with two air washers of 76500CMH capacity to supply cool and filtered air. The use of air washer reduces the air quantity requirement and increases the efficiency of DG sets due to lower air temperature being supplied. The hot air is exhausted out by providing two DIDW centrifugal blowers of 76500 CMH capacity each.

The air washer for the supply air consists of G.I. casing with

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forward curved fan, TEFC motor, cooling pads of cellulose media, stainless steel water tank, heavy duty pumps and filters. The air washer has an efficiency of 90% approximately.

Building Management System (BMS)

This control system has been provided to achieve the following:

- Sequential start/stop of the whole HVAC System.
- Duty cycling to operate all the equipments, including standby equipment, for equal duration.
- Automatic startup of standby equipment in case of failure of operating unit and displaying fault alarm status of the tripped unit.
- Activating/deactivating water valves to start/stop water flow through chiller and condenser circuits.
- Programmed start/stop of individual AHU as per operating requirements.
- Maintaining design inside conditions within specified limits as per designated programs by operating necessary controls and 2-way water valves.
- Automatic change over from the day cycle to night cycle.
- Monitoring the operation of variable speed drives of Secondary pumps.
- Checking water level in cooling tower sumps.
- Water services functions
  - Monitoring the level of water in tanks based on signals of the level switches.
  - Duty cycling of water pumps to ensure equal run time for all pumps.
  - Starting of the standby pump in case of failure of the operating or scheduled pump and displaying fault alarm status of the tripped pump.

The air conditioning system for this stadium has performed very well during the games to the satisfaction of all concerned.The design conditions inside the playing courts have been achieved without any problems.

Conclusion

The Commonwealth Games in Delhi led to wide scale development of stadiums for various disciplines thereby providing excellent infra structure and world class facilities to Indian sportspersons to excel in their respective disciplines. These stadiums came for a special praise by all the foreign dignitaries including international players who performed at these stadiums. In short, they have showcased India's capability of holding international games at world class level. These stadiums have created a new sporting mindset representing our country's efforts in producing world class sportsmen in coming years.

Consultant

Gupta Consultants, New Delhi were the HVAC consultants involved in the design and execution stages of this project. They have provided valuable contributions in the successful completion of this project. ❖