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Air Conditioning of Leisure Centres

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A Bowling Alley with Pool Tables in Mumbai.
Photo courtesy of Buddy's and Blue Star Ltd.

With a higher disposable income, an improved standard of living, and easier credit facilities, the urban Indian consumer is willing to visit, and enjoy the facilities in the new leisure centres that are mushrooming all over the major cities of India. These include Fast Food Outlets, Pizza Parlors, Poolrooms, Bowling Alleys, Music Shops, Department Stores, Shopping Malls, Food Supermarkets and Multiplex Cinemas. All of them have well appointed interiors, piped music, bright colors and are, of course, fully air-conditioned.

Some large international chains such as McDonalds and Dominos have their own standard guidelines for the architecture and interior fit outs. These also include MEP services like air conditioning, ventilation, kitchens and cold rooms, electricals, plumbing, fire alarm, BMS and standards for fresh air requirements, equipment selection guidelines

and installation practices. These must have been developed over years of having constructed hundreds of similar establishments worldwide. In such cases local architects and consultants find it relatively simple to develop similar outlets in India.

However, Indian developers or promoters are building most of the other facilities with little or no experience of the business and who are primarily in it to ride the current boom. There are some exceptions like the larger business houses that appoint reputed architects and consultants to design their establishments. Air conditioning engineers working on such projects will require some guidelines to help design an adequate system. This article aims to lay down some basic principles of design, as well as bring out several other technical issues that must be considered in the design of the HVAC plant for leisure centers. A good starting point for all well designed engineering systems is usually the design brief from the owner or architect.

The Owner's/Architect's Brief

The owner's brief along with the architect's design intent establishes the broad outline of the facility and is the most important starting point of a successful project. The ultimate intended application of the facility will guide the fundamental designs for both the HVAC engineer as well as the rest of the project team. A shopping centre intended for the retailing of economy segment apparel and clothing will have diversely different design requirements as compared to one for jewelry and accessories.

In actual practice the owners brief is probably the most neglected item of documentation and it is often a verbal communication to the HVAC engineer who then tries to establish the broad design outlines based on the perceived intent of the facility.

Ideally the owners brief should make available but not be limited to the following information:

- Size of property.
- Built up area of the facility.
- Specific intended use of the facility.
- Occupancy of each space.
- Working population.
- Estimated population of visitors (peak and average)
- Priority areas for phase-wise development of large projects.
- Current source and quantity of power supply available

- Current source and quantity of water available.
- Administrative and staff facilities required

This helps the designer assess the overall size, scale and level of sophistication of the project and also guides the basic design criteria for airconditioning, which covers the following parameters.

Heat Load Estimates

Determination of the proper heat load is one of the most important issues to confront the HVAC designer and the following items must be carefully considered while estimating the plant capacity.

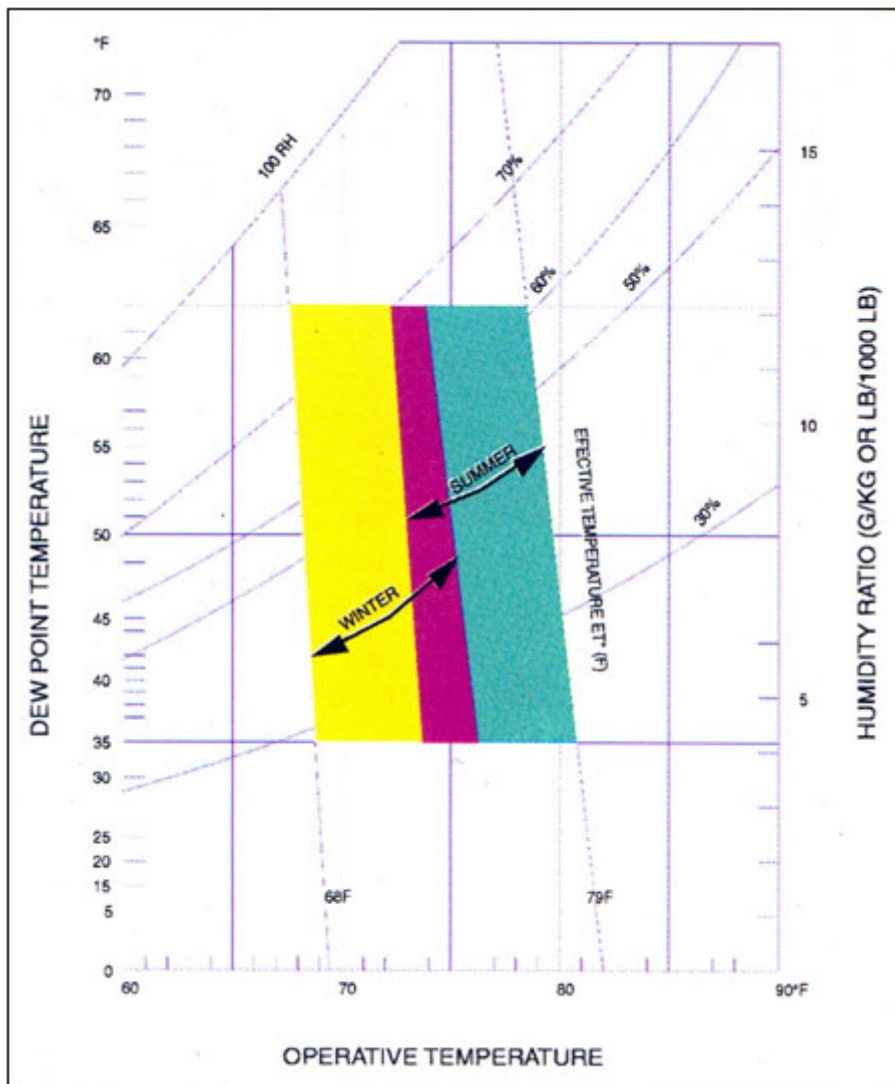


Figure 1 : ASHRAE Comfort Envelope

Design Temperature

Most office and home HVAC systems are designed to maintain a space dry bulb temperature of 74° F. People occupying these spaces do so for long periods of time, maybe

8 to 10 hours a day and are most comfortable with these temperatures. Visits to a small store, supermarket or shopping centre are for a much shorter duration and a slightly higher space dry bulb of 78–79°F may not be noticeable or uncomfortable. This could however translate into significant savings to the business both in terms of lower initial cost of smaller equipment as well as in operational costs. The owners understanding and consent is however a must and only then should the designer proceed on this basis. The ASHRAE comfort envelope (**Figure 1**) shows a band of acceptable comfort conditions.

Relative Humidity

Most comfort applications do not require any specific control over humidity levels and designers aim for anything up to 65 % RH. It may be a good idea though, to aim for humidity levels of around 50 % RH especially in spaces which make extensive use of carpets and drapes and garment stores where musty odors arising due to dampness can be very unpleasant. No special controls are really necessary. Care to ensure that equipment is not oversized is all that is usually required. Oversized equipment results in shorter compressor or cooling coil operating periods and since no dehumidification occurs during the idle period, the space RH tends to rise.

Lighting Levels

Lighting levels in various establishments vary over a large band with average lighting levels in pool parlors at around 0.5 watts/ft² to jewelry stores at as high as 8 to 10 watts/ft². Cursory or careless assumptions could lead to significant over or underdesign both being equally undesirable. A careful selection of lighting levels in the first place is also very desirable as significant savings in energy can be obtained. As a rule of thumb, for every 10 kW of lighting load, 3 tons of refrigeration capacity is required to accommodate this additional load. The use of modern lighting equipment like Compact Fluorescent Lamps, High Intensity Discharge (HID) lamps and electronic ballasts will result in significantly more efficient designs.

Equipment Loads

Equipment such as popcorn machines, softy ice cream units, bottle coolers, freezers and other similar equipment can add significantly to the heat load estimates. A careful evaluation of the proposed equipment being installed will contribute significantly towards optimum estimates of equipment loads.

Occupancy Loads

Occupancy loads can vary for each type of establishment. In cinema halls and restaurants with a fixed number of seats, its simple to estimate the occupancy load but for fast food outlets and shopping centres the decision is more difficult. Be guided by the owner and ASHRAE standard 62–1989 but tempered by the fact that occupancies in Indian cities tend to be higher than in the US.

Ventilation Rates

Estimation of heat loads is a relatively simple exercise if the owners brief is accurate. The decision about fresh air requirements, though, is extremely important as it can mean a variation in plant capacity of upto 25 % and energy consumption of nearly 20 %. ASHRAE standards 62- 1989 specifies minimum standards of outside air requirements for different establishments based on the maximum occupancy levels and varies from 15 cfm per person for most areas like theatres and recreation areas to 60 cfm/person for bars. Retail stores, shopping arcades, malls etc. require a minimum outdoor air of anywhere between 0.15 to 0.30 cfm/ft² of occupied space.

But can we really afford to follow these standards? In Mumbai every thousand cfm of outdoor air requires 7 tons of cooling capacity without the use of heat recovery equipment. Electric power for commercial establishments can cost anywhere between Rs. 4 to Rs. 7 per kWh. Under the circumstances most designers factor outside air intake at 10 cfm/person and sometimes even as low as 7.5 cfm /person. This may result in uncomfortable and 'stuffy' environments during periods when occupancies are high. However, airconditioning energy costs contribute almost 30% of establishment operating costs and start-up businesses, unsure of sales volumes, can ill afford high operating costs.

An efficient and cost effective Building Management System (BMS) can be used to maintain the right amount of outside air intake into the conditioned space. Leisure centers have high peak occupancy but are only intermittently occupied. Varying the outside air intake, rather than always maintaining high ventilation rates needed for peak occupancy makes economic sense. The use of an Internal Air Quality (IAQ) sensor in conjunction with a Variable Air Intake Damper can effectively maintain minimum levels of outside air required, based on the maximum allowable CO₂ level in the conditioned space. Contrary to common perception, BMS comprises only a small percentage of the overall equipment costs, which can usually be recovered over a short period of time.

For spaces that are people load dominated, such as cinemas, theaters and large restaurants, using a Variable Air Volume system that varies the air volume with the cooling

load (and hence indirectly on the basis of occupancy levels) leads to a significant reduction in ventilation demand and energy consumption.



Exposed ducting in a shopping centre. Photo courtesy of Haiko Shopping Centre, Powai, Mumbai

Load Variation Patterns

For accurate selection of turn down ratios (part load capacity) of chillers, a careful analysis of heat load variation over the duty cycle is necessary. This is especially important as it has a bearing on the type of chiller selected. Large installations having higher load variations over the duty cycle are better served by screw or centrifugal chillers. Part load efficiencies of these chillers are very favourable and contribute to significant energy savings. For smaller installations, chillers with multiple compressors (scroll or reciprocating) offer flexibility and ease of operation.

Efficient part load operation benefits may be derived when selecting chillers, by dividing plant capacity into multiple chillers. Chillers having multiple independent circuits serve the same purpose with the added advantage of saving valuable plant room space. This ensures that at least 1 or 2 refrigeration circuits are available as spare and even in the case of breakdowns, spare capacities bring total load available closer to peak demand values.

Variable volume air handling systems may be considered for large shopping centers to keep energy consumption to the minimum. Variable speed drives for AHUs are gaining wider acceptance as equipment prices fall and pay back periods are shortened. This is especially true for larger installations with more pronounced load variations. For example, most shopping centers are very busy during evenings, holidays and during festival seasons. Mornings, afternoons and monsoon seasons are relatively lean periods.

System Selection

Selection of the HVAC system is largely dependent on economics and the first cost of the system.

Small Establishments

Selection on the basis of first cost of equipment is especially true for smaller establishments like retail stores, boutiques, pool and pizza parlors. Such establishments generally opt for several window type, non ducted split or ducted split systems or a combination of such systems. These systems offer flexibility in operation both during light loads and in the case of breakdown or maintenance. Also places with application specification zones (like different areas for video games and pool tables) are better served by these type of systems as airconditioning may only be operated in the areas that are being used. Use of modern high wall mounted split systems offer both a compact and aesthetically appealing indoor unit coupled with very reliable operation. It also affords the architect the flexibility to raise the false ceiling level to the maximum possible height with only the necessary space required to accommodate lighting conduits and fixtures. However these split systems do not have an arrangement for outside air intake and for establishments with high occupation levels maintaining adequate levels of fresh air intakes can prove to be difficult.

Large Facilities

For larger facilities, operation and maintenance costs are also taken into consideration while making equipment selections. Out of the various systems available, a central chilled water plant would be the preferred choice especially when the facility is large and the benefit of combined diversity, part load efficiencies and central monitoring can be availed of. In comparison a decentralized ducted split or packaged type of system would mean a large number of maintenance points and relatively lower part load efficiencies. However, independent functioning of each business entity of the shopping center and lower capital cost are some of the advantages of a decentralized split system.

The decision of using air-cooled or water cooled system is largely related to the availability of clean and clear water at a reasonable price. Most city councils do not allow the use of municipal water for airconditioning purposes. A careful cost analysis must be made prior to deciding on the option of air-cooled or water-cooled systems. Watercooled systems are usually preferred due to perceived lower capital and operating costs. However, a detailed analysis considering all factors such as capital cost of equipment and ancillary

equipment like cooling towers and pumps, annual owning and operating costs has shown that overall cost differential is marginal (see **Table 1**) Added to this, aircooled systems require far less equipment plant room space and can be tucked away inconspicuously on the roof top. This in itself is advantageous as every square foot of space saved is converted into indirect cost savings. Reduced maintenance points, shorter piping, fewer pumps and faster installation are also some of the benefits derived from aircooled systems.

**Table 1 : Air-cooled v/s Water-cooled Chiller Systems
(consisting of 2 x 120 TR units each with 2 x 60 TR Hermetic Screw Compressors)**

	Air Cooled	Water Cooled	Remarks
Capital cost	Rs. 4,120,000	Rs. 3,556,000	Including all ancillaries like cooling towers, pumps, piping, valves etc.
Annual operating cost	Rs. 4,386,744	Rs. 4,389,762	Based on 5298 equivalent full load operating hours at 180 TR peak load. Energy cost @Rs. 4.6/- per kWh
Annual owning & operating costs	Rs. 5,044,955	Rs. 4,957,868	Based on life cycle costing and data per ASHRAE systems handbook 1984

Equipment Noise Levels

Controlling equipment noise levels is becoming critical as environmental awareness increases. Matters are not made any easier with new facilities opening in residential localities and buildings standing cheek by jowl. Local codes specify a maximum permissible equipment noise level of 65 to 70 dB on an A weighted scale (Mumbai municipality permits maximum 65 dB A). Outdoor condensing units of ducted splits, especially of larger capacities of 5, 7.5, 10 and 15 TR, air-cooled chiller plants and cooling towers (for water-cooled installations) must be carefully located to minimize noise transmission to neighboring buildings. This is especially critical in crowded localities where distances between adjacent buildings are at a bare minimum. Noise transmission from a roof mounted screw chiller can be particularly annoying, especially at night when the characteristic whine of the high speed screw rotors is easily apparent. In such cases it is prudent to specify a factory installed acoustic shroud for the compressor and low noise fans. Although this adds approximately 1 – 2 % to the cost of the chiller it is well worth the additional investment. Special care must be exercised while locating chiller equipment on

terraces of shopping centres and buildings with skylights and atriums as noise is easily transmitted through these features to the interior of the building.

Care should be taken to ensure that chillers and other noise generating equipment are not placed too close to sensitive areas in cinema theatres and auditoriums where noise criteria requirements are far more stringent than, say bowling alleys and video game arcades. (See **Figure 2**)

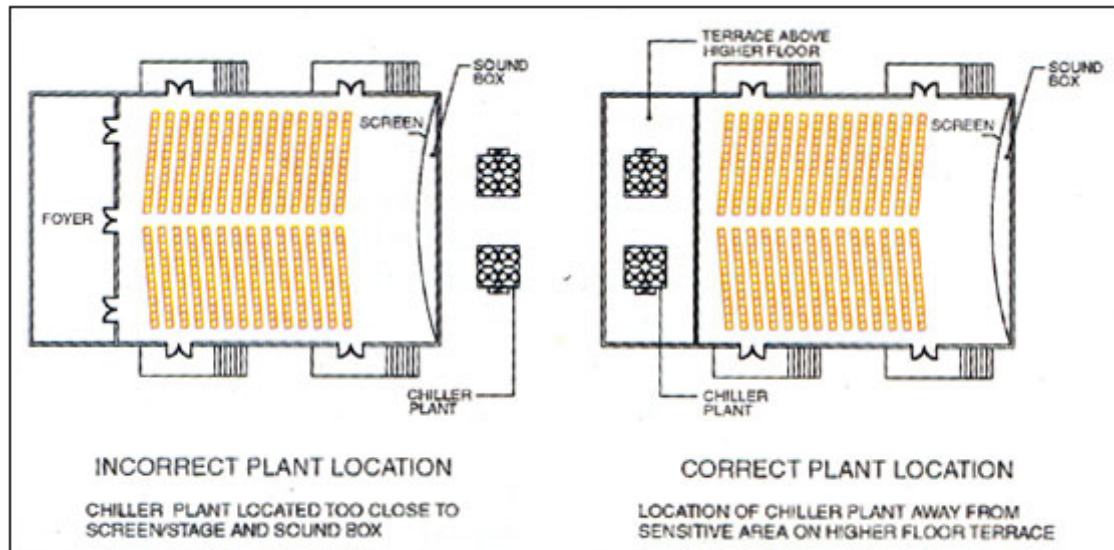


Figure 2 : Cinema Hall showing correct and incorrect location of packaged chiller.

Adequate care must be taken to isolate all roof mounted chiller equipment from the building structure as noise vibrations transmitted through the structure can be very annoying and most difficult to suppress at a later stage.

Some Japanese equipment vendors are now marketing systems having outdoor units with extremely low noise levels (in the range of 58 to 60 dbA), using scroll compressors and low noise condenser fans. These may be particularly useful where outdoor units have to be mounted on parapets and ledges directly in front of neighboring buildings.

Air Distribution Systems

Proper and intelligent selection of air handling and distribution equipment can go a long way in optimizing material and installation costs. For large areas, the selection of one AHU for every 5000 ft² of airconditioned space is an optimum choice. AHU capacities should seldom exceed 10,000 cfm. This restricts indoor equipment noise levels and maximum duct depths between 400 to 600 mm, which helps to maximise false ceiling levels.

Vertical type of air handling units occupy a much smaller foot print area reducing the size of the AHU room required and at the same time having no additional cost implication.

This is especially useful in cities where real estate rates are extremely high and every square foot of usable space saved is converted to a major saving in cost.

Shopping arcades and large retail stores require very flexible air distribution layouts as the floor plans are regularly changed and modified when displaying new merchandise and to impart a new and fresh look to the interiors from time to time. Flexible branch ducting connected to terminal discharge plenums offer flexibility when diffuser and grille locations require to be moved around to accommodate changes in location of light fittings and other ceiling elements.

Cinema theatres, malls and bowling alleys require far less flexibility as these systems will not require changes over much longer periods of time. However, in all these facilities care should be taken to avoid drafts and dumping of air and it is important to select appropriate air terminal devices. Diffusers with anti smudge rings are very useful as they ensure easy cleaning and maintenance of stain free ceilings. This is very pertinent where ceiling height exceeds 4 to 5 metres and access to such ceilings is difficult.

The inherent informal ambience and atmosphere of games and entertainment centers allows the architects a lot more design freedom and they are more inclined to experiment with innovative and cost effective ducting systems like exposed ducts of circular and other shapes. Care should be taken while fabricating such ducts as badly made ducts could lead to higher levels of leakage and noise levels.

Inherently noisy establishments like video game arcades, and bowling alleys allow the system designer to select duct sizes at much higher duct velocities. Duct velocities of upto 1800 fpm may be safely used in such places. This offers considerable saving in duct sizes as well as sheet metal quantities. However, the opposite is true for cinema theatres, auditoriums and high-end stores and boutiques. As cinemas and multiplexes being installed are increasingly adopting stringent international norms like THX (a certification body that sets down minimum design and construction standards for high end cinemas), the reduction in noise levels of airconditioning equipment and distribution systems are of prime importance. In such cases measures to restrict noise levels may include:

- Location of air handling equipment away from the conditioned space.
- Low velocity air distribution equipment.
- System fan selected for maximum efficiency, which yields minimum noise levels.
- Accurate estimation of system static pressure.

Building Management Systems

As all leisure facilities are essentially commercial enterprises, technical maintenance staff is limited to the bare minimum (usually one electrician taking care of all engineering systems), a simple and efficient central monitoring, control and energy management system is very important. Energy optimization has great significance as airconditioning operating costs account for almost 30 % of the overall operating cost of such shopping and entertainment centers and every rupee saved contributes to the overall profitability of the business venture.

An efficient BMS will enable the maintenance staff to efficiently control and monitor all the functions of air conditioning operations as well as other facilities like Water Management, Power Management, D.G Management, Elevator Management and integration with Fire, P.A. and Security Systems.

Fire and Life Safety Systems

All leisure centers are public facilities and the safety and security of patrons and visitors is of utmost importance. Air-conditioning ducts have been increasingly accused of spreading fires within building spaces as the air being circulated by AHUs carry smoke and fire to various parts of the building. Ducts passing between floors must be avoided as far as possible. In designs where it is absolutely necessary for ducts to pass between floors, fire dampers of suitable type and rating must be installed. Supply and return air fire dampers located across the AHU rooms are also mandatory and must be installed correctly as per manufacturers recommendations. Control of the fire dampers wherever motorised must be through a control module of the Fire Alarm system. A fire-mode protocol must be established in totality for the entire system. Running of exhaust fans (smoke extract and car park) at higher speeds than normal operating speeds in the event of a fire emergency are some of the measures that may be adopted to ensure the safety of visitors.

Pressurization of escape staircases and lift shafts in the core of a building are both necessary and mandated by law. Power supply to all fire duty fans and extract systems must be from an alternate source of supply to ensure that these loads are catered to even when the mains supply is shut off in the event of a major fire.

Special Design Requirements for Air Conditioning of Bowling Alleys

Bowling alleys are fast becoming the center of attraction of most leisure centers and the maximum

source of revenue for these centers.

Central to the design of HVAC systems for bowling alleys is the existence of very high concentration of heat load over a very small portion of the bowling alley.

There is a concentration of spectators and bowlers in segment A of the alley, see **Figure 1**. Cooling is primarily required in this area.

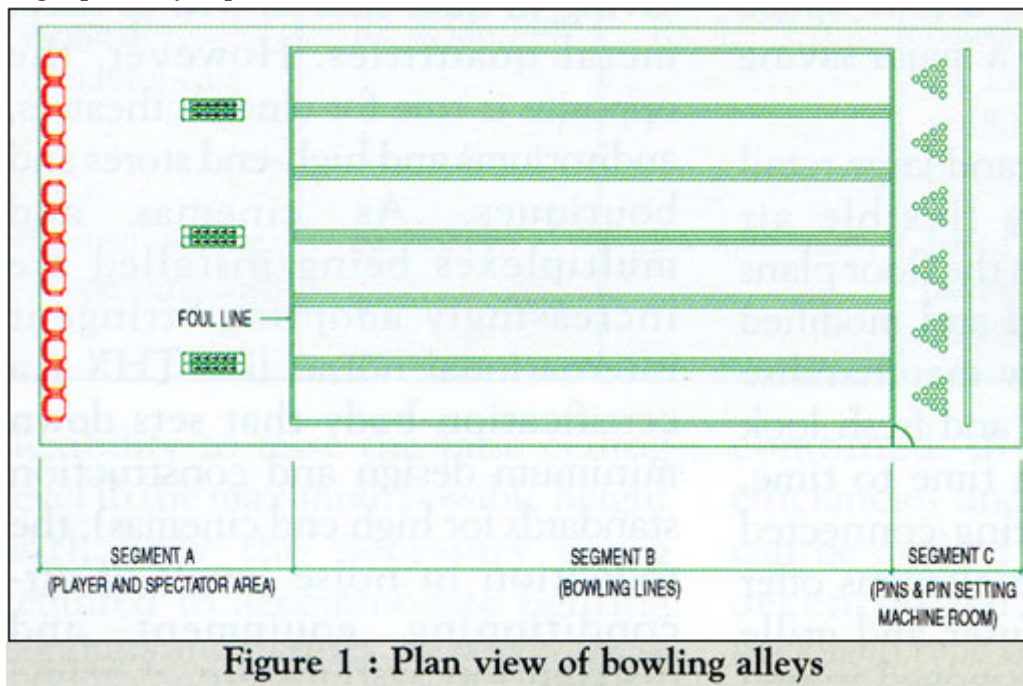


Figure 1 : Plan view of bowling alleys

Segment B has no occupancy and does not require cooling. Segment C which is the pins and pin setting area requires equipment loads to be taken care of only.

Segment A is both an athletic area as well a spectator area. Formerly, the spectator areas used to be high smoking areas requiring very high ventilation rates and sometimes even additional smoke extract systems. Nowadays, however, most of these facilities do not encourage smoking especially bowling alleys in India.

Also bowling in India is still regarded as a leisure activity and not a competition sport. Hence spectator areas are not highly developed and make-shift spectator stands are usually created during tournaments.

Bowling alleys in India are usually part of the leisure center which may include other games areas like pool and billiards, laser tag, video games and also bars, restaurants and cafés. It is a good idea to zone these areas from the bowling area.

While carrying out load calculations emphasis is to be given to segment A, where spot cooling is desirable and segment C where equipment loads are required to be cared for (through a suitable exhaust system). Even though centers are operated during daylight hours too, the peak time of activity is around 2000 hours. A check on the heat loads, considering outside conditions at this time is a must.

The optimum inside condition in segment A is 75°–78° F with 60–65% RH.

Activity	Heat gain / person	
	Sensible	Latent
Bowling	500	1000
Standing	200	300
Sitting	190	185

As a rule of thumb occupancy load may be considered as follows: one person bowling, one standing and six seated (per alley) making a total of 8 people per alley. Heat gain factors from players and spectators are given in the Table below.

Heat gain from non air-conditioned alley areas may be taken as 8 Btu/hr/sq.ft of the width of the lanes times ceiling height. Differential temperature will be approximately 7–10 °F.

It is preferable to maintain a slightly positive pressure in the bowling area with slightly less air being exhausted than intake fresh air.

Equipment selection

For small facilities with only a bowling alley and a restaurant ducted split type air conditioning is preferred. Lower first cost, flexibility in locating indoor units, zoning, and easy operation of equipment are some of the main advantages of this type of system. Disadvantages are rudimentary temperature controls, and increased maintenance points.

Large facilities are better served by central plant based systems which offer advantages like excellent temperature controls, special humidity control where deemed necessary, uniform air distribution and minimum drafts. Better energy efficiency and longer equipment life are added advantages. Disadvantages are higher capital costs, special space requirements to strategically locate large air handling equipment and design difficulties while zoning, especially issues like odor migration from food areas.

Different occupancy levels, temperature conditions and fresh air requirements in different zones may need individual air handlers for each zone.

Air Distribution

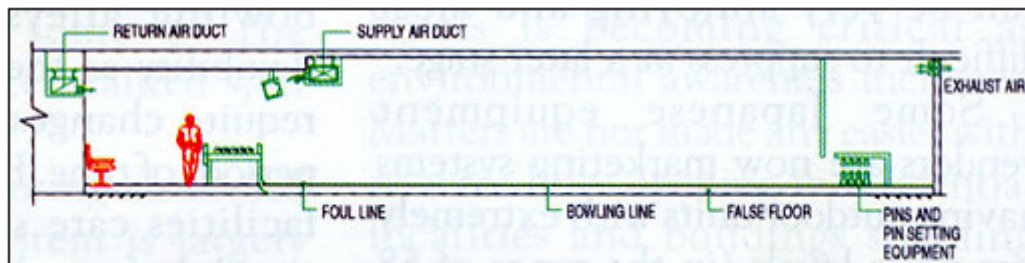


Figure 2 : Air distribution from side outlet registers

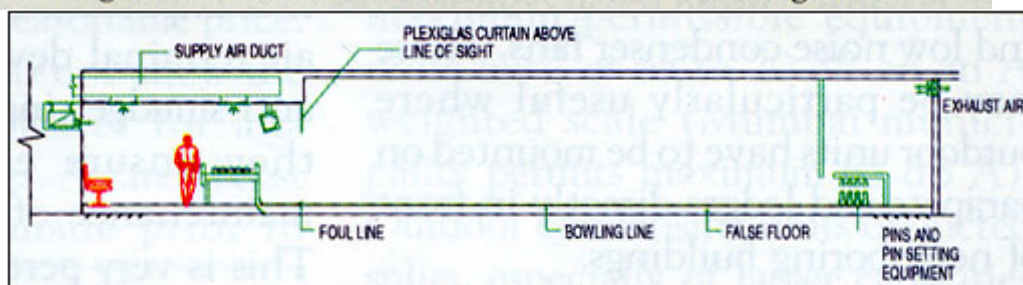


Figure 3 : Air distribution from ceiling diffusers

Air distribution is best done by running a duct just over the foul line at an appropriate height and blowing through side outlet registers towards the player and spectator areas, see **Fig 2**. This prevents migration of air into unoccupied alley areas and allows for excellent spot cooling.

Alternatively, ceiling diffusers may also be used but they tend to induce warm air from the alley area. A vertical barrier made of Plexiglass and suspended from the ceiling may be required to alleviate this problem, see **Fig 3**.

Return air is best taken from the rear of the spectator areas ensuring air is returned from the space uniformly.

Exhaust air is to be drawn over the bowling lanes and from pin machine area and will help in preventing excessive build-up of heat in this area.

Editors Note : The following Cooling Load Check Figures have been collected from various consultants in Mumbai, in order to help readers check their own calculations and to indicate correct practise in the industry

Building	Occupancy ft ² /person	Lights* W/ft ²	AC Load ft ² /ton	Total Air CFM/ft ²	Fresh Air per person
Shoppers Stop, Mumbai (Dept. Store)					
Basement	24	7	160	2.5	10
Main/Upper Floors	35	-	-	-	-
Globus Stores (Dept. Store)					
Mumbai	30	4 to 6	120	2.5	15
Saga, Mumbai (Dept. Store)					
Main Floor	46	6	105	3.5	7.5
Upper Floors	20	-	119	5.3	-
Crossroads, Mumbai (Mall)					
Food Court	50				
Shopping Area	30	5.5	170	N.A.	10
Games Parlor	10	-	-	-	-
Bowling Co., Mumbai (Bowling Alley)					
Public Area	28	2.5	105	N.A.	10
Bowling Lanes	Nil	3.0	275	N.A.	½ AC/HR
Machine Room	Nil	4.0	100	N.A.	½ AC/HR
Pool Room	35	2.0	140	N.A.	10
Buddys, Mumbai (Bowling Alley)					
Public Area	20	2.8	115	N.A.	20
Bowling Lane	Nil	N.A.	Non A/c	-	-
Machine Room	Nil	N.A.	Non A/c	-	-
Fast Food Restaurant, Mumbai					
Restaurant Area	8	2.5	80 to 100	4	10
Kitchen	8	3.5	16 to 20	16	†
* excludes equipment loads † 5 cfm/ft ² fresh air and 6.5 cfm/ft ² exhaust air					
USA check figures – Source : HVAC Systems Estimating Manual by A.M. Kashab, McGraw–Hill					
High (Dept. Stores)					
Basement	20	4	225	1.2	N.A.
Main Floor	16	9	150	2.0	
Upper Floors	40	3.5	280	1.2	
Average (Dept. Stores)					
Basement	25	6.0	245	1.4	N.A.

Main Floor	25	2.5	340	1.0
Upper Floor	55			