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**Photo 1: External view of a large data processing centre in Visakapatnam. Notice all the VRF units and chillers mounted on the terrace.**

# VRF Units for Perimeter Zone Control

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Until a decade back – a good office building in Chennai had statistics of say 500 – 600m² per floor. Architects worked with building widths of 12-15 meters and argued that at times of power cuts and power failures – with the air conditioning plant not working – one would have the option of opening windows to get cross ventilation. The IT sector's huge space requirements have changed all this.

Today, buildings of 50 m x 50 m – 2500m$^2$ per floor have become the order of the day rather than the exception. As a matter of fact this is an average sized building and bigger buildings go up to 4 to 6 times this size. The requirement for such large areas per floor is dictated by the large work force which needs to be housed together under minimal supervision and surveillance. These new offices are largely open plan work spaces. They are cooled by simple constant volume air conditioning systems.

## New Building Trends Today

Commercial undertakings who sponsor beauty pageants have got beauty defined as a person who is 1.8 m tall and does not weigh more than 55 kg. This is a far cry from the standards of beauty carved on our temple walls. Likewise, interested commercial units have successfully packaged glass as a proper facia in lieu of the older, more energy efficient verandah.

Proper architectural authority describes a man who builds with curtain wall glazing in the tropics, as a man who pays to get himself roasted.

Designers perhaps feel that the larger foot print of the new spaces will get better day lighting from the larger glass facades. These glass facades bring in tremendous quantities of heat and worse still an element of variation in the "local" heat load. With the glass sunlit, the solar gain is 15 times more than when it is shaded. In other words for 3 to 4 hours when the glass is sunlit, its solar gain is 15 times more than when it is shaded. For the few hours that the glass is sunlit, occupants within 2 m –3 m of the glass tend to feel very uncomfortable. The space temperature may barely go up by a degree, but that degree of discomfort is intense. The reason is that with sunlit glass the MRT (Mean Radiation Temperature) of the room climbs up and is the same as the outside DB temperature viz. 40°C. To ensure equivalent comfort to the shaded glass, with MRT being 24°C, one has to drop the space temperature by 10°C to 12°C. How does one achieve this in a constant - volume air conditioning system? A local temperature drop in a small pocket of the total space, just for three hours? Impossible!

## How VRF Systems Can Help

What is possible – is to add local air conditioning equipment for the hot "zone". Perhaps, even high wall splits. Buildings with large foot prints and a full glass facia will not permit proper condenser placement for such split air conditioning equipment. VRF systems permit remote locations of condensers as they can work with long lengths of refrigerant piping. This affords a simple solution to a very burning problem. Costs of VRF systems have come down from a whopping Rs.1,00,000 per ton to barely Rs.60,000 per ton and one can install proper cassette type indoor units with pumped drain lines in place of the simple high wall splits. The cassette unit is immensely suited for glass facia applications (as there is no masonary wall, at all, in such cases for mounting the high wall unit).

The benefit of the new micro environment created on the periphery of the building goes to the occupants on the periphery. These peripheral areas generally house senior staff, who work extended hours and necessarily these are before or after the normal working hours. Provision of the additional VRF units on the periphery permits their independent usage even after office hours and provides local comfort when the main central system for the core area has been switched off.

This factor saves a lot of energy as the main system usage gets restricted to fewer hours / day than it would have been otherwise.

Multiple VRF units along the periphery now permit the user to locally set the temperature desired. The complainant actually enjoys the benefit of going to a local switching station and calling for the control he/she desires – all by himself / herself. This helps to reduce the number of complaints, which in turn increases the degree of satisfaction and which lends to greater productivity. Salaries per sq.ft. far outstrip the cost of services per sq.ft., thus ensuring user satisfaction and comfort which has become very important. Property managers will readily agree that a large percentage of their complaints from employees are centered around thermal comfort – for a typical enclosure even with a constant temperature of 24°C, barely 8 out of 10 people are happy, one is too cold and one is too hot. VRF systems empower the manager with a possible solution, and make 10 people out of 10 happy.

As an alternate to the above, chilled water fan coil units can be considered. However, chilled water fan coil units will need massive chilled water lines with a greater chance of condensation on poorly insulated portions of the chilled water lines. False ceiling voids, in the past, were "empty", as they carried only return air and hence appeared to be totally "To let". Today they are occupied by items like: -

- Fire pipes
- Data cables
- Voice cables

- Music / Public address system.
- Sprinklers
- Smoke detectors.
- Fire alarm components
- Power wiring (raw power)
- UPS wiring (corrected power)
- Emergency lights.
- Rodent repellents and pest control items

The standard false ceiling void which was not more than 450 mm high, is now over a 1000 mm high but yet this space is too small for what it is required to contain. Small VRF pipes, and pumped drains for the Indoor Units (IDUs) have a better chance of being squeezed in rather than the other alternates of chilled water lines.

## What is a VRF System?

**Load Variation.** In tropical climates like India an inside temperature of 24°C is maintainable only by mechanical cooling systems. The cooling load of a space is not a constant entity and can be as low as a very small percentage of its peak load (in some instances it can even become a negative load warranting heating in place of cooling). To meet this variation in cooling demand i.e. from a small percentage to 100 percent a designer has to put into his cooling circuit a capability of metering and varying the amount of cooling that is possible from the refrigerant circuit. In other words, ideally the flow of refrigerant through the circuit should vary linearly to suit the cooling requirement. Such a wide variation in refrigerant flow variation is not easily possible. The mismatch in the ability of a cooling circuit to follow a load curve with full fidelity is a "shortcoming" which has been on the unsolved list of designs.

**Mechanical Cooling** is achievable by various cooling cycles. The vapor compression cycle, is the most efficient cooling cycle for comfort cooling applications. The vapour compression cycle configured around high efficiency compressors gives COP (Coefficient of Performance) and EER (Energy Efficiency Ratio) figures which are unmatched. In the vapour compression cycle the compressor with the help of a proper refrigerant maintains the evaporator and the condenser at pressures which are adequate for one to absorb heat from the air conditioned space and the other to reject heat into the atmosphere - the mass flow of refrigerant determines the quantum of cooling that is available. The vapour compression cycle when equipped with sophisticated expansion devices on the evaporator and proper speed control on the compressor has been able to meet this requirement of setting out a cooling capability to follow the cooling load variation with a fair degree of fidelity for a single evaporator, i.e. of a single zone system.

When it comes to multi-zone capability the vapour compression cycle starts exhibiting weaknesses from the point of view of being able to distribute refrigerant from common headers into multiple small lines - the basic problem centres around the fact that the compressor handles both refrigerant vapour and lubricating oil. The compressor's prime requirement is that refrigerant vapor and oil return to it, in the same quantity as they leave it. This constraint has not been easy to overcome and where not overcome, - it leads to instant failure of mechanical equipment. In light of this the vapour compression cycle has, generally, been well used as a "constant" flow circuit. Designers here then enjoy the advantage that refrigerant velocities in the lines can be maintained to design levels to ensure proper oil return.

VRF systems aim to offer a solution by permitting variable flow - as many as 16 or more evaporators are connected to a set of condensing units - with an ability of operating even one evaporator working at part load along with a graduated portion of the condensing unit being in operation.

## Application Data

Featured in the drawing **Figure 1** is the typical floor of a 5-storey building for a large data processing centre at Visakapatnam. The floor is a square –54 m×54 m – made up of 5 grids of 10 m each in both directions with a 2 m cantilever on both sides. One of the diagonals of this square points due North cutting the building in two distinct halves - an Eastern half and a Western half. The Southern end of the diagonal forms a service core close to 300m$^2$. This service core houses all the lifts, toilets and the general needs of a good entry module - each side of the square floor has a triangular extension out of the square to make for additional proper service staircases (fire escape) etc.

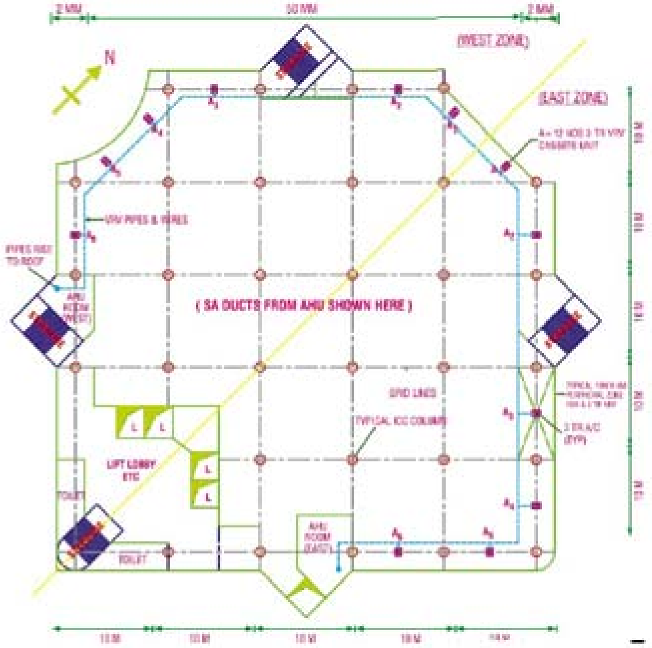


Figure 1: Key plan of a typical floor at HDPI.

The service core houses two AHU rooms – one at each corner – one each for the Eastern half and the Western half. All air distribution ducts are concealed by a false ceiling, the void between the main slab and the false ceiling acts as a RA plenum. The external walls have floor to floor glass in select areas of the facade - high performance glass has been used (low "U" value and low conductivity). Each full floor with an overall area of 3000m$^2$ provides for about 2500m$^2$ of air conditioned space and seats over 300 people. The cooling load works out close to 150 tons.

Each 10 m × 4 m of the floor along the periphery (with an external wall) has a load of just over 3 tons. Each of these 10 m × 4 m areas is set out to form a zone, which is equipped with a 3 ton, two-way cassette indoor DX evaporator - set right in the middle of the zone it controls with its control switch fitted on the column closest to the unit. The Eastern 6 × 3 ton units connect to a 15 ton VRF unit, likewise the Western 6 × 3 ton unit connect to another 15 ton VRF unit. The condensing units are located on the roof top, virtually, directly over the AHU rooms. See ***Photo 1***. VRF refrigerant lines rise to the roof through the AHU room pipe shaft. The most distant 3 ton unit is over 100 m away from the condensing unit i.e. 80 m horizontal run and 20 m vertical lift. Thus the building has 10 x 15 ton VRF systems (two per floor) for peripheral cooling duty only and all senior executives seated along the glass perimeter have individual temperature control facilities, a feature they could not have enjoyed with the central ducted system feeding the internal core area.

Each AHU room houses - twin 30 ton vertical AHUs. All ten AHU rooms in two stacks of five each link to a rooftop air cooled chilled water plant made up of 2 x 300 ton screw chillers. The system is supported by an additional 300 ton standby screw chiller. The AHUs have a simple 2 - way chilled water control valve on the return line. The AHUs, water chillers, pumps, and the VRFs are all controlled by a simple coherent Bacnet speaking BMS system. The BMS also integrates all the other needs of the building from security, to control of power.

## Unplanned Benefits

- Vizag has a mean maximum summer design DB temperature of 34°C only. Thanks to this the exposed walls rarely exceed a temperature beyond the skin temperature of 34°C. With this automatic restriction on MRT (Mean Radiation Temperature) - there have been situations, particularly at nights, when a whole floor has been "comfortable" for say 15% or 20% occupancy usage with only the peripheral VRF systems working and the AHU / chillers switched off.

- It has been a guess – not yet substantiated that on winter nights, with black sky radiation at full force, one will be able to switch off the peripheral VRV and run only the AHUs.