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# 2. NOL Building, Singapore

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|---|---|
| *Owner:* | *Neptune Orient Lines Ltd* |
| *Architect:* | *Architects 61* |
| *M & E Engineers:* | *Squire Mech Pte Ltd* |
| *Main Contractor:* | *Ohbayashi Gumi Ltd* |
| *Date of Occupation:* | *December 1983* |

This article presents a brief account of energy efficient design features of building envelope and energy systems of a high-rise office at Singapore. It is an example of Energy Efficient Office Building in a Warm Humid Climate.

### Climate

Perhaps it would be necessary to describe the general climatic characteristics of Singapore (a warm humid equatorial climate) as the building energy usage and climate are closely linked. Singapore is situated very close to equator, (1.3°N Latitude) and experience a warm-humid conditions throughout the year. There are practically no seasons and both diurnal and annual ranges of temperatures are quite small. The mean monthly temperatures do not vary by more than 2 – 3°C from the mean annual value. The average diurnal variation of temperature is 6 to 8°C.

The mean maximum temperature lies between 27 and 33°C, and the mean minimum temperature varies between 22 to 26°C. High humidities prevail throughout the year. The mean relative humidity (RH) is greater than 70 percent and it varies from 60 to almost 100 percent during the course of a day. Rainfall is spread throughout the year. Annual rainfall vary from 2000 to 3000 mm. Wind speeds are low and there are usually one or two dominant directions. Calm periods are frequent. Sky conditions are mostly cloudy throughout the year. Cloud cover varies from 70 to 90 percent of the sky vault for most of the time. Average sunshine hours are less than 6 hours per day. The mean daily total solar radiation on horizontal surface range from 15 to 21 MJ/m$^2$/day. At noon times the solar radiation intensities reach 800 to 1000 W/m$^2$. Diffuse radiation is fairly high and forms 35 to 45 percent of the global radiation. Clouds and high water vapour content prevent longwave radiation from the ground and buildings to the sky.

### Energy Regulations

The building sector is found to account for nearly 49 percent (office and commercial buildings 32 percent and domestic buildings 17 percent) of the total electricity consumed in Singapore.

For office and commercial buildings put up before 1980, energy efficiency was not a consideration in their designs. The average electrical energy use of these type buildings range from 600 to 1400 MJ/m$^2$/yr.

This type of climate demands year round airconditioning (cooling) of office and commercial buildings and this forms 50 to 55 percent of the electrical energy used in such buildings. There is no heating requirement at all. Lighting is the next major electrical energy component forming 30 to 35 percent.

The government of Singapore introduced new Building Control (space, light and ventilation) regulations which incorporate energy conservation requirements in August 1979 (See Appendix). The most significant measure that aims at encouraging energy efficient building envelope designs, is the Overall Thermal Transfer Value (OTTV) standard. Both new and existing buildings are required to comply with the new regulations as they are mandatory, and failing which building owners are to pay heavy surcharges on their electricity bills.

To supplement the above energy regulations codes of practice for energy conservation in Building Services (CP 24) was issued by the Singapore Institute for Standards and Industrial Research (SISIR) in 1982.

These developments, have lead to the beginning of an era of energy conscious design of buildings and their mechanical and electrical services, in Singapore. Owners, architects and engineers of new buildings are now taking energy conscious design more seriously. NOL Building is one such example of energy conscious design.

### Building Design

NOL building which is of 26 storeys, shapes like a ship's funnel, with the main tower block rises from a broad hull like podium as can be seen from the Figure 1.

Major orientation is South East-North West.

Gross floor area is 26174 m$^2$.

Exterior wall area (including glass portion) is 8837 m$^2$.

Overall glass area/total exterior wall area is 0.225.

Exterior wall surface area/Building volume is 0.092.

Floor height is 3.65 m.

Energy efficiency of the building was a major consideration in the architectural design. Building configuration, orientation and space planning were given due consideration. For example, plant room, AHU room, stores, toilets, and other service areas are located along the perimeter of the building to act as buffer spaces. The basic energy conscious design principle followed was to reduce the building envelope heat gains, especially solar heat gains through glass area. The total glass area is kept to as small as possible (0.225 of exterior wall area) and special (tinted) glases with reasonably low shading coefficient (S.C.) values (0.46 to 0.69) were used. Fixed continuous sun shading projection (with a horizontal projection of 1.5 m) was installed for all exterior walls. The overall thermal transfer value (OTTV) of the envelope, which is supposed to evaluate the thermal characteristics of the building envelope is 30 Wm$^{-2}$, as against the required (upper limit of 45 Wm$^{-2}$) value in the new building regulations. Exterior opaque wall consists mainly three types of construction, namely

– brick walls (115 mmm to 230 mm) with 19 mm thick cements sand plaster on both sides.

– concrete walls (150 mm to 400 mm) airgap + 12 mm thick gypsum board and

– glass curtain wall, backed by airgap + 12 mm thick gypsum board + 100 mm fibreglass insulation + 12 mm thick gypsum plaster board interior finish.

The U values of these types of wall construction are 2.30 $Wm^{-2}k^{-1}$; –1.82 $Wm^{-2}$–$k^{-1}$; and 0.32 $Wm^{-2}k^{1}$, respectively.

Direct utilization of solar energy for supplementary or replacing purchased commercial energy (electricity) for cooling and heating, which is one of the commonly used energy conservation features of many energy conscious designs of buildings was not considered, as it will be uneconomical at the present stage. However passive solar design features like the use of sun shading devices and low shading coefficient glasses were employed.

## Airconditioning Design

### *Chillers*

A modular system of (4 separate chillers of each 200 ton capacity) CTE Centrifugal chillers with capacity control mechanism and surge protection system were installed. The chillers use R-12 refrigerent and movable diffuser system which is capable of controlling capacity as low as 10 percent. Airconditioning system controls are arranged such that when one chiller is shut down, the associated condenser, cooling tower and chilled water pump are also automatically shut down. The measured coefficient of performance (COP) of the chillers ranged between 4.5 and 5.7, which is higher than the specified value of 4.0 for water cooled systems, in CP 24 (Part 1).

The airconditioning system installed is the variable air volume (VAV) type. The chilled water through the cooling coil is throttled to maintain the desired off coil temperature by the control valves. The chilled water not required by the Air handling unit (AHU) is by passed back into the chiller water recycling, saving cooling energy without affecting the comfort of occupants. The terminal boxes of the VAV system will throttle under thermostatic control to meet the required temperature as well as ventilation requirements. By the use of inlet guide vane control, no excess quantity of air is drawn, resulting in lower energy consumption by the fan motor.

Activities of the same nature are grouped together to simplify the air conditioning design and reduce the wastage of cooling energy. Each floor is served by an AHU and has a timer control for switching on/off at scheduled times.

### *Lighting System Design*

The lighting load for the interior office space was designed to be 11.2 $Wm^{-2}$ which is much below the upper limit requirement of 20 $Wm^{-2}$ of the new building regulations. The task area illuminance is higher than 300 lux while that of the general area is about 50 lux. Energy saving 26 mm dia. 36 watt fluorescent tubes and low loss type ballasts are used. Luminaires are equipped with parabolic mirror reflectors which provide maximum downward light and cover larger areas. This has resulted in less number of light fittings than the conventional fittings, and reduced lighting energy requirements. Recessed air handling luminaires light-fitting are used in offices and service areas, to reduce cooling load due to the heat from the light sources in the occupied spaces. Switching of lighting are designed to allow small groups


*Fig. 1. NOL Building*

of luminaires to be switched off in unoccupied areas with a view to conserve lighting energy. The walls, ceiling, carpets and curtains used are of light colour, so that the internal reflection coefficient and the utilisation factor of the rooms are increased.

### *Control Systems*

A microprocessor based building automation system is installed to centrally monitor and control all the building services systems. This would provide precise automatic time start-stop of lights, air conditioning equipment supply and exhaust air fan motors, peak power demand programme, limiting the power consumption of the plants during the peak period, duty cycling of equipment, chiller optimisation by operating the correct number of chillers at any one time to meet the fluctuating airconditioning loads.

This building automation system also monitor chilled water supply and return temperatures, air handling unit supply and return air temperatures, outside air temperature and humidity with a provision for an alarm when the outside air temperature falls below a preset minimum, the traffic demand of lifts and control lifts with a solid state control systems photocell control of light fittings in perimeter zone, for maximising the use of daylight and reduce the lighting energy, are under consideration.

With the above control systems in operation the indoor temperature and relative humidity conditioned are observed to be between 23°C to 25°C dry bulb temperature and 50 to 60 percent Relative Humidity.

## Energy Use Profile

Typical monthly energy use (August 1985) of the NOL Buildidng was as below:

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|---|---|
| Airconditioning | 200 MWhrs – 56.4% |
| Lighting | 55 MWhrs – 15.5% |
| Lifts and water pumps | 20 MWhrs – 5.6% |
| Office equipment and Others | 80 MWhrs – 22.5% |

In 1985 Gross annual electrical energy consumptions was 3750 MWhrs. i.e. 13500 GJ/year and the electrical energy use per unit floor area was 135 KWhr/m²/year i.e. 485 MJ/m²/year, as compared to 600 to 1400 MJ/m²/year for pre 1980 buildings.

*(K. Rao)*

## Appendix

### *Building Control Regulations*

The Building Control (Space, Light and Ventilation) Regulations which incorporate energy conservation requirements as part of the building bylaws, was gazetted in August 1979. These requirements for office buildings are summarized below:

1. The maximum permissible OTTV (Overall Thermal Transfer Value) of Building envelope is 45 W/m².
2. Effective means of Weatherstripping should be incorporated to windows and doors to limit the infiltration or exfiltration of air to
   - 2.77 m³/h per meter of sash crack of window
   - 61.2 m³/h per linear meter of door crack for swinging, revolving or sliding doors, when tested under a pressure differential of 75 Pa.
3. Minimum fresh air supply for comfort airconditining should be 13 m³/h per person or 1.2 m³/h per m² of floor and as a rule under normal conditions the provision of outside air to airconditioned space should not exceed more than 30% of these values.
4. The indoor air conditions should be maintained within the following limits:
   - Minimum dry bulb temperature 23°C
   - Maximum dry bulb temperature 27°C
   - Maximum relative humidity 75%
   - Maximum air movement 75 m/min.
5. Roof insulation standard for air conditioned buildings state that the thermal transmittance (U-value) of the roof, depending on its specific weight should not have greater than the values tabulated below:
   - Light Weight (under 50 Kg/m²) 0.5 W/m² °k
   - Medium Weight (50 to 230 Kg/m²) 0.8 W/m² °k
   - Heavy Weight (Over 230 Kg/m²) 1.2 W/m² °k
6. The maximum permissible lighting load is specified as 20 W/m² for offices.

   The mathematical expression for the calculation of OTTV of an external wall is als follows:

$$OTTV = \frac{(A_w \times U_w \times TD_{EQ}) + (A_f \times U_f \times \Delta T) + (A_f \times SC \times SF)}{A_0}$$

where
- $A_w$ : opaque wall area (m²)
- $U_w$ : thermal transmittance of opaque wall area (W/m² °k)
- $TD_{EQ}$ : equivalent temperature difference (°k)
- $A_f$ : fenestration area (m²)
- $U_f$ : thermal transmittance of fenestration (W/m² °k)
- T : temperature difference between extension and interior design conditions (°k)
- SC : shading coefficient of fenestration
- SF : solar factor (W/m²) to be established for the place and varies with orientation
- $A_0$ : gross area of exterior wall (m²) and is equal to $(A_w + A_f)$

To calculate the OTTV for the envelope of the whole building, the weighted average of all the exterior walls is to be determined. i.e.

$$OTTV = \frac{A_{0_2} \times OTTV_1 + A_{0_2} \times OTTV_2 + \dots\dots\dots + A_n \times OTTV_n}{A_{0_1} + A_{0_2} \dots\dots\dots + A_{0n}}$$

where more than ne type of material and/or fenestration is used the respective term or terms to be expanded into subelements.