7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Passive Environment Controls

The thermal properties of the building envelopes are within the national and international standards. Therefore, the heat gain through the building envelope has no adverse effect on the air-conditioning system. Considering the hot (30° C to 35° C) and humid (Relative Humidity = 80% to 90%) climatic conditions in the island, the thermal properties of the building envelope have to be selected to achieve the required thermal transmission values. The U-values (W/m^2k) in Table 6-3 shows that the cladding type exterior walls with an air gap have better thermal properties than the solid concrete walls.

With reference to Table 6-5, it is conclusive enough to state that majority of the buildings are oriented in the East-West direction. The twin and triplet towers as compound forms rectangular shapes and oriented in the East-West direction and provides a shading effect on each other during Sun rise and Sunset. This has enabled the designers to include more windows in East and West directions (Table 6-4).

7.2 Active Environmental Controls

The light fittings and lighting controls do comply with the relevant standards. The 3rd generation fluorescent lamps emit about 30 % more lumens than the standard lamps and as a result, the number of lamps required was less to achieve required lighting levels and the heat load on the air-conditioning is less. It can be recommended to consider 3rd generation lamps at the time of replacing the existing lamps. The lighting control systems can be incorporated with occupancy and day light sensors such that the unoccupied areas and the areas with sufficient daylight can be operated without artificial lighting.

The indoor air conditions, temperature and relative humidity, are maintained within the acceptable comfort zone (Table 6-10).

The selection of air-conditioning equipment, especially the chillers, was tested against the minimum efficiency levels. The Screw type chillers do comply with the standards but the Centrifugal type chillers do not (Table 6-12). All the new installations are Screw type chillers and that concludes the present trend is towards screw chillers. Screw chillers are more energy efficient and flexible in partial load conditions. Therefore, it can be recommended that priority has to be given to screw type chillers in selecting new equipment.

7.3 Energy Efficient Indices

The results show that all the buildings in the sample fall into the most energy efficient category (Table 6-15). The level of occupation (occupancy rate) is a deterministic factor in the calculation. Table 8-16 shows the density of people in each building varies from building to building. Therefore, a building with 100 % occupancy could have lesser number of occupants and office equipment compared to a building with a low occupancy rate. The density of people has an impact on the energy consumption. Therefore, the occupancy rate in the formula has to be re-defined to include the population density. Therefore, it is not conclusive enough to rank the buildings according to the calculated energy efficiency values.

7.4 Energy Management Processes

Research reveals that there is no management process to evaluate the energy efficiency performances of the facilities. There was no benchmarking method to set energy efficiency targets for the operators to meet in day-to-day operations. The present energy management practices are mainly concentrated on the energy efficient lighting & controls and the power factor correction. However, the largest portion (60%) of the energy is consumed by the air-conditioning system (Fig. 6-1). Therefore, it can be recommended to fine tune the central air-conditioning plants by re-scheduling the operating hours, maintaining appropriate chilled water and condenser water temperatures (Table 6-20), and install variable speed drives in partial load conditions (Chapter 6.2).

The discussion the researcher had with the building managers has concluded that there was no a specific management practice to achieve energy efficiency in their respective buildings. Therefore, it can be strongly recommended to form a continuous improvement team, consist of the key engineering personal and lead by the head of the department to set energy targets, and propose and implement energy management projects.

8 REFERENCES

1. *Energy efficient building code for commercial buildings in Sri Lanka*. 2000. Ceylon Electricity Board, Colombo.
2. *Guidelines for Energy Efficiency in Buildings*. 1999. Ministry of Energy, Malaysia, Malaysia.
3. Burnett, John. 1996. *Conventional Approaches Which Improves the Environmental Performances of Large Buildings*. Hong Kong, Polytechnic University.
4. *Passive Solar Design*. 2001. U.S Department of Energy, U.S.A.
5. Optimization of Building Shape with respect to Building Orientation and Local Climatic Conditions. 2002. Green Building Program, Singapore.
6. *Energy Audit Results*. 2003. Building Energy & Research Information Center, Singapore.
7. *Improving the Efficiency of Chilled Water Plants*. 2001. ASHRAE Journal, May 2001.
8. *Measurement and Verification*. 2001. SPC Procedures Manual, USA.
9. Sam C.M.Hui. 1997. *How to Improve Overall Thermal Transfer Value*, Hong Kong, University of Hong Kong.
10. Perera, K.K.Y.W. 1992. *Energy Status of Sri Lanka*. Colombo: Institute of Policy Studies.
11. Park Alan. 2001. *Facilities Management*. London. Macmillan Press Ltd.
12. *Exemplary Energy Efficient Building*. 2001. Southeast Asia Facility Management, Nov/Dec 2001, p36
13. *Electrical Load Management and Power Factor Correction*. 1999. Energy Audit Manual, SLEMA, Module 7.
14. *Efficient Lighting Systems. Energy Audit Manual*, 1999. SLEMA, Module 9.
15. *Energy Management and Accounting Systems*. 1999. Energy Audit Manual, SLEMA, Module 1.
16. ASHRAE Standard 90-1975, 1975. *Energy Conservation in New Building Design*, ASHRAE, Atlanta.
17. Chan K.T. 1995. *Energy performance criteria for commercial buildings*, The Hong Kong Institution of Engineers Transactions, 2(1): 17-22.

18. 100-1995 *Energy Conservation in Existing buildings.* 1995. ASHRAE Ventilation standards and indoor air quality, USA
19. Bleeker, N.C. 1993. *"Benefits of Energy Efficient Lighting".* Energy Engineering Journal of the Association of Energy Engineers Vol. 90, No.6, USA.
20. *Electric Drives.* 1999. Energy Audit Manual, SLEMA, Module 8, 1999.
21. *City of Colombo Development Plan.* 2000, Urban Development Authority, Volume 2, Colombo.
22. Hegberg, M.C. 2001. *Chilled water plants.* ASHRAE Journal pp10, July 2001
23. Hubbard, R. 2001. *Chilled water plants.* ASHRAE Journal pp12, July 2001
24. Rishel, J.B. 2003. *adaptive control reduces central chilled water plant energy consumption*, Flo-pak technical bulletin, January 2003.
25. Siyambalapitiya, T. 2003."Electricity Tariff and Other Issues Affecting the Private Sector". Seminar on *"How to reduce your energy bill".* The Ceylon Chamber of Commerce, Sri Lanka.
26. *Statistical Digest 2000.* Statistical Unit, Ceylon Electricity Board. Sri Lanka, 2000.
27. Weiss, G. 2000. *"Successful Energy Management".* Civil Engineers Australia, July 2000.
28. Olgyay V. 1963. *"Design with climate"*, London. Macmillan Press Ltd..
29. Jumsai S. 1987. *"Building design with energy factor".* Energy Conservation in Buildings. Asian Institute of Technology. Bangkok.
30. *Solar shading of buildings.* 1999. Construction Research Communications, USA
31. Lui, W.S. 1994. *"building Management System Overview".* Honeywell Pte Ltd. April 1994

Appendix-1

Recommended Lighting Levels

Building space	Illuminance (Lux)		
	Low	Recommended	High
Office area	200	300	500
Lobbies	100	150	200
Staircases	100	150	200
Elevators	100	150	200
Car parks	20	50	100

Appendix-2

Minimum Lamp Efficiencies

Type of Lamp		Minimum lamp efficiency (Lumens /Watt)
Type	**Wattage**	
Fluorescent	18	71
	36	66
	40	59
CFL	9	42
	11	52
	15	57
	20	57
	23	62
Incandescent	40	10.6
	60	12
	75	12.7
	100	13.6

Appendix-3

Building Information

Description	WTC	HNB	BOC	CBSL-EXT.	CBSL-REHAB
Name of Building	World Trade Center-Colombo	Hatton National Bank-Tower	Bank of Ceylon-Head Quarters	Central Bank of Sri Lanka-North (Extension) Building	Central Bank of Sri Lanka-South (Rehabilitation) Building
Name of Owner	Overseas Realty (Cey) Ltd.	Hatton National Bank	Bank of Ceylon	Central Bank of Sri Lanka	Central Bank of Sri Lanka
Address	#18-01, East Tower, WTC, Colombo-01	479, T.B Jayah Mw, Colombo 10.	No. 4, Bank of Ceylon Mawatha, Colombo-01	No. 30, Janadhipathi Mawatha, Colombo-01	No.36, Janadhipathi Mawatha, Colombo-01
Physical Building Background	Office complex with a Podium and a Gallery	Office complex	Office complex with a Shop floor	Office complex	Office complex
Age of Building	08 years	<01 years	18 years	06 years (after refurbishment)	06 years (after refurbishment)

Total Number of Storeys	39 storey twin towers with a 7 storey Gallery	24 storey tower	32 storey tower	12 storey twin towers with a mezzanine floor	12 storey triplet towers with a mezzanine floor
Basement & Car park Floors	9 storey staggered car park with a Basement	10 storey staggered car park with a Basement	3 storey car park with a Basement	Three Basement floors	Basement
Total Gross Floor Area	1,260,000 ft2	420,373 ft2	603,498 ft2	319,557 ft^2	234,946 ft^2
Car Park Area	179,562 ft2	60,740 ft2	81,793 ft2	Nil	Nil
Gross Lettable Area	707,591 ft2	318,926 ft2	399,134 ft2	226,397 ft^2	161,027 ft^2
Air-conditioned Area	1,080,438 ft2	366,782ft2	449,085 ft2	319,557 ft^2	234,946 ft^2
Non-Air Conditioned Area	179,562 ft2	53,591ft2	154,413 ft2	Nil	Nil
Ownership of the Building	Private	Private	State	State	State
Number of occupants	2,440	1200	2000-2200	1000	900

Building Operating Schedule					
Office					
Mon. to Fri.	8.00 hrs .to 18.00 hrs.	8.00 hrs .to 18.00 hrs.	7.00 hrs .to 19.00 hrs.	7.00 hrs .to 17.0 hrs.	8.00 hrs .to 17.00 hrs.
Saturday	8.00 hrs. to 13.00 hrs		7.00 hrs. to 13.00 hrs		8.00 hrs. to 13.30 hrs
Sunday/Mercantile Holiday	Closed	Closed	Closed	Closed	Closed
Restaurant					
Mon. to Fri.	8.00 hrs to 22.00 hrs.				
Saturday	8.00 hrs to 22.00 hrs.				
Sunday/Mercantile Holiday	10.00 hrs. to 22.00 hrs.				

Appendix-4

Research Project-MBA (Management of Technology)

Achieving of Energy Efficiency in high-rise Buildings

DATA SHEET

1 Building Information

Name of Building	
Name of Owner	
Address	
Physical Building Background	
Age of Building	
Total Number of Storeys	
Basement & Car park Floors	
Total Gross Floor Area	ft2
Car Park Area	ft2
Gross Lettable Area	ft2
Air-conditioned Area	ft2
Non-Air Conditioned Area	ft2
Ownership of the Building	
Number of occupants	
Building Operating Schedule	Office: hrs .to hrs. Monday to Friday hrs. to hrs Saturdays Restaurant: hrs to hrs. Monday to Saturday hrs. to hrs. Sundays

2 Building Envelope

2.1 Window (Glazing) details-to calculate OTTV for a Typical Office Floor

- Glass to Wall Ratio of a typical floor, in all four directions
  - North= East= West= South=
- U-Value of Glasses =
- Shading coefficient (SC) of Glasses =
- Glass areas of a typical floor in all four directions
  - North= East= West= South=
- Glass Material
  -

2.2 Walls (perimeter) details-to calculate OTTV

- Wall areas (including glass) of a typical floor in all four directions
  - North= East= West= South=
- U-Value of Walls
- Wall material
  -

3 Building Management Systems

Is there a Building Management System in the building? | Yes

If yes, please provide details

•

4 Lighting Systems

4.1 Heat Load of Office Lighting (Typical Office Floor)

Heat Load on Cooling system (tons)= (Lighting Watts * E * 3.412 Btuh/Watt) / 12000 Btu/ton

Number of Light Fittings per floor =

Number of lamps per fitting =

Type of Lamps = **Fluorescent/ Incandescent**

Wattage of a Lamp =

4.2 Illuminance Level (Lux)

Area	Illuminance (Lux)						
General Office areas							
Lobbies							
Stairs							
Elevators							
Car Parks							

4.3 Lamp Efficiency (lumens/watt)

Lamp Type		Efficiency (Lumens/Watts
Fluorescent	1200 mm	Lumens = Watts = 36
	1200 mm	Lumens = Watts = 40
	600 mm	Lumens = Watts = 18
CFL	9 Watts	Lumens = Watts = 9
	11 Watts	Lumens = Watts = 11
	15 Watts	Lumens = Watts = 15
Ballast Loss	- Single Lamp	Watts =
	- Double Lamp	Watts =
Incandescent	- 40 Watts	Lumens = Watts =40
	- 60 Watts	Lumens = Watts =60
HID Lamps		Lumens =
		Lumens =

4.4 Luminare Efficiency (Light Output Ratio-LOR)

Light Output Ratio (>0.5) = Lumans from the Luminary

Lumens per Lamp * Number of Lamps per Luminary

Lumens from the Luminary							
(Typical office luminary)							

Number of Lamps per Luminary = [ ]

Lumen value of a Lamp = [ ]

4.5 Lighting Power Density (LPD)(W/m2)

LPD is calculated by dividing the total connected load for all lighting systems in the building by the gross lighted floor area of the building (LPD for an Office Building < 16).

• Office Areas • Loading Bays • Car Parks & Drive ways • Common Areas	Office Area (Typical)		Car Parks & Drive ways		Common Area (Typical)	
Total connected lighting load (w)						
Gross lighted floor area (m^2)						

4.6 Lighting Controls

Office areas: Lighting load = W

No. of Switches = Nos.

Car Park areas : Lighting Load = W

No. of Switches = Nos.

5 Air-conditioning and Ventilation

5.1 Indoor / Outdoor Design Conditions

	Indoor	Outdoor
Temperature	°C	
Relative Humidity		

5.2 Indoor/Outdoor Actual Conditions

Date							
Time							
Outdoor	DB						
	WB						
Indoor-	DB						
(Air-conditioned	WB						
Indoor-	DB						
Air-conditioned	WB						

DB = Dry Bulb

WB = Wet Bulb

Date							
Time							
Outdoor	DB						
	WB						
Indoor -	DB						
(Air-conditioned	WB						
Indoor-	DB						
Air-conditioned	WB						

DB = Dry Bulb

WB = Wet Bulb

5.3 Air-conditioning System

Type of A/C System: **Central Air-conditioning system**

Equipment details.

Equipment	Type	Quantity	Capacity (KW)
Chillers			
CWP			
CHWP			
CT			
A.H.U.s			

Sensors

5.4 Fan System (AHU)

- Type of Fan System : CAV / VAV
- Supply Air Volume = L/S
  - Motor Rating = kW

5.5 Controls

- Temperature controls.
  - What are the zone controllers available
- Time control (ON/OFF)

5.6 Equipment Efficiency-Chillers

Equipment Type	Capacity	C. O. P.	$kW/_{kW\ Ref}$	$KW/_{ton}$
Screw	300 ton	4.95	0.19	0.71

C.O.P=12,000 btu / (.71kw/ton*3,413btu/kw)

5.7 Chill Water Plant Efficiency

$$= \frac{\text{Operating } \Delta T(\,^{\circ}C) * \text{Design Capacity (TR)}}{\text{Design } \Delta T\ (^{\circ}c)}$$

- Screw Chillers

Design Capacity = **300 TR** Design ΔT = **6 °C**

Date						
Time						
	CH-1	CH-2	CH-3	CH-1	CH-2	CH-3
Chilled Water Leaving Temp. (°C)						
Chilled Water Entering Temp. (°C)						

Date						
Time						
	CH-1	CH-2	CH-3	CH-1	CH-2	CH-3
Chilled Water Leaving Temp. (°C)						
Chilled Water Entering Temp. (°C)						

Date						
Time						
	CH-1	CH-2	CH-3	CH-1	CH-2	CH-3
Chilled Water Leaving Temp. (°C)						
Chilled Water Entering Temp.(°C)						

6 Electrical Distribution System

6.1 Transformers

TX. Capacity KVA	Type	Quantity	Losses at	
			Full Load	No Load
1600 KVA	Cast Resign			

7 Energy Accounting

7.1 Power Generation

C.E.B. Power:

Metered at = NOT CONNECTED
Tariff Structure applicable to Landlord =

Tariff Structure applicable to Tenants =General purpose
KWh = Rs
Fixed Charge = Rs.
KVA= Rs.

Self-Generation :

Total Capacity =
Operating hours = Daily hrs. to hrs.
hrs. to hrs.-

Unit Cost = Rs. /kWh
Total kWh = kWh
Total energy consumption = gl
Diesel unit cost = Rs.

7.2 Generator metering points

Number of meters | 02 |

Meter numbers

1		2		3		4	

Energy consumption

Year : 2003

Moth	Jan	Feb	March	April	May	June
Days						
Feeder-1						
Feeder-2						
Total						

Year : 2002

Moth	July	Aug	Sep	Oct	Nov	Dec
Days						
Feeder-1						
Feeder-2						
Total						

7.3 Internal Metering / Measuring Points

Number of Measuring points =

Energy Systems

1		2		3		4		5	
6		7		8		9		10	

Energy consumption pattern

System	Energy Consumption per year (kWh)	Percentage (%)
Air-conditioning		
Air Handling Units		
Lighting		
Landlord		

8 Energy Efficiency

8.1 Load Factor (should be around (50-60%))

= (Energy Kwh consumed during the billing period)

(Max. demand during same period) x (hrs. in the period) x (avg. p.f.).

Year : 2003

Moth	Jan	Feb	March	April	May	June
Days or Hrs						

Year : 2002

Moth	July	Aug	Sep	Oct	Nov	Dec
Days or Hrs						

8.2 Total Building Energy Efficiency (kwh/year/m^2)

Parameter	Code	2003	2002
Total Building Energy Consumption (kWh/year)	TEC		
Gross floor area (m^2)	GFA		
Gross lettable area (m^2)	GLA		
Occupancy Rate (%) (E.g. 0.80 for 80%)	OR		
Weekly building operating hours (hours/week)	WBOH		
Building weekly mode operating hours (hours/week)	BWMOH		
Operating hour factor	OHF		
Total Building Energy Efficiency (kWh/year/m^2)			

8.3 Landlord Building Energy Efficiency (kwh/year/m^2)

Parameter	Code	2003	2002
Landlord Building Energy Consumption (kWh/year)	LEC		
Gross floor area (m^2)	GFA		
Gross lettable area (m^2)	GLA		
Occupancy Rate (%) (E.g. 0.80 for 80%)	OR		
Weekly building operating hours (hours/week)	WBOH		
Building weekly mode operating hours (hours/week)	BWMOH		
Operating hour factor	OHF		
Landlord Building Energy Efficiency (kWh/year/m^2)			

8.4 Tenant Building Energy Efficiency (kwh/year/m^2)

Parameter	Code	2003	2002
Tenant Building Energy Consumption (kWh/year)	TeEC		
Gross lettable area (m^2)	GLA		
Occupancy Rate (%) (E.g. 0.80 for 80%)	OR		
Weekly building operating hours (hours/week)	WBOH		
Building weekly mode operating hours (hours/week)	BWMOH		
Operating hour factor	OHF		
Landlord Building Energy Efficiency (kWh/year/m^2)			

9 Maximum Demand Management

What is the Max. Demand metering system

- **Metered at 400 V**

Year 2003

	Month	Jan.	Feb.	Mar.	April	May	June
	Meter no.						
Meter-1							
Meter-2							
Total							

Yea 2002

	Month	Jan.	Feb.	Mar.	April	May	June
	Meter no.						
Meter-1							
Meter-2							
Total							

Year 2002

	Month	July	Aug.	Sep.	Oct.	Nov.	Dec.
	Meter no.						
Meter-1							
Meter-2							
Total							

10 Power Factor Correction

Number of Capacitor Banks

Location: Main Switch **Board**

Type: **Oil impregnated**

Number of steps						
Capacity of the bank (KVAr)						

Overall power factor

Date							
Time							
KWh							
KVArh							