1. INTRODUCTION

THE PROJECT

The project is to undertake Energy Audit of Administrative Staff Training College, Khanapara, Assam.

The basic objective of the Energy Audit was to study the operations/performance of both Electrical and Thermal energy intensive equipments/ systems for identification of potential areas wherein energy savings are practically feasible.

BUILDING PROFILE

The building complex is utilized for conducting training programs for various government officials besides arranging of numerous governmental workshops, conferences, seminars etc. The main building is four-storied and about nine numbers of rooms each of different sizes are there in top two floors. The ground floor is housing a library with thousands of books. A hostel of 80 rooms with kitchen, dining hall and lounge is also there to cater the boarding and lodging need of the delegates/ trainees. The institute is headed by **Smt. Samita Das, Director.** And under her **Smt. Kajori Rajkhowa, Administrative Officer** looks after the administrative affairs of it. The maintenance activities are being looked after by **Sri Dwijen Deka, Engineer (Elect)** of **PWD, Guwahati** and assisted by other professional/ technical staff.

The main sources of Energy being used are Electrical Power purchased from M/s. ASEB Limited and HSD for DG set.

Prevailing rates of various Energy Sources

- Purchased Power = Rs 6.34/ unit (last two years avg.)
- HSD = Rs.33.0/ Litre

Tariff Structure

Charges on Billing Demand	@ Rs 145/- per KVA
Energy Charges	@ Rs 4.05/- per unit
Contract Demand	513 KVA
Penalty on P.F. (below 0.85)	@ Consumed unit X (0.85 – P.F.)
Billing Demand	513 KVA

Scope of Work

The study was aimed at identifying the potential for reduction of energy consumption in the following areas:

- **Refrigeration System**: Study and analysis of TR requirement, actual vis-a-vis standard, specific power consumption for each TR, existing refrigeration system compatibility, opportunity to reduce loss and need of refrigeration.
- **Illumination System**: Study of the lighting systems and measures for improvements wherever feasible.
- **Electrical Distribution System**: Study and analysis of contract demand, power factor, performance of transformers and motors above 5 HP, pumps and their flow, and suggestions to improve performance.
- **DG set**: In addition to above, the study also covered the performance of DG set, to suggest measures for Energy Efficiency Improvements.

Methodology

The Methodology adopted for achieving the desired objectives viz: Assessment of the Current operational status and Energy savings included the following:

- Discussions at site with the concerned officials for **identification of**

major areas of focus and other related systems;

- A team of engineers visited the institute and had discussions with the concerned officials/supervisors to collect data/ information on the operations and Load Distribution. The data was analyzed to arrive at a **base line** energy consumption pattern.
- **Measurements and monitoring** with the help of appropriate instruments including continuous and/ or time-lapse recording, as appropriate and visual observations were made to identify the energy usage pattern and losses in the system.
- Computation and **in-depth analysis** of the collected data, including utilization of computerized analysis and other techniques as appropriate to draw inferences and to **evolve suitable energy conservation plans** for improvements/ reduction in specific energy consumption.

PARTICIPATION

Head and all other the working group members of Administrative Staff Training College, Khanapara co-ordinated and helped the Energy Audit Team during the site visits, these include amongst others the following:

- Smt. Samita Das, Director
- Smt. Kajori Rajkhowa, Administrative Officer
- Sri Dwijen Deka, Engineer (Elect) of PWD, Guwahati

A team of PCRA engineers comprising of the following officials were involved in conducting the study.

- Sh. P. Chattoraj, Addl. Director & Chief Regional Coordinator
- Sh. K.L. Bhutia, Deputy Director & SRO Guwahati
- Sh. S. Roychoudhury, Jt. Director
- Sh. Rabindranath Mandal, Jt. Director

2. STUDY OF ELECTRICAL DISTRIBUTION SYSTEM

Administrative Staff Training College, Khanapara is importing power from Assam State Electricity Board through an 11.0 KV supply. The contract demand of the institute is 513 KVA. One 100 KVA DG set meets the emergency power demand during outage of M/s. ASEB.

ANALYSIS OF DEMAND

Monthly electricity bill

Month & Year	KWH (Consumed)	Avg. PF	KWH (PF Penalty)	KWH (Charged)	KVA (Billed Demand)	Energy Charge (Rs.)	Demand Charge (Rs.)	Total Charge (Rs.)
Jan/07	17430	0.5	7844	25274	513	102359.7	74385	176744.7
Feb/07	15470	0.58	4487	19957	513	80825.85	74385	155210.9
Mar/07	14870	0.64	3123	17993	513	72870.44	74385	147255.4
Apr/07	13155	0.59	3552	16707	513	67663.35	74385	142048.4
May/07	36964	0	0	36964	513	149704.2	74385	224089.2
Jun/07	34654	0	0	34654	513	140348.7	74385	214733.7
Jul/07	33499	0	0	33499	513	135671	74385	210056
Aug/07	38902	0.8	1137	40039	513	162158	74385	236543
Sep/07	40570	0.79	2434	43004	513	174167	74385	248552
Oct/07	29200	0.76	2628	31828	513	128903.4	74385	203288.4
Nov/07			0	0		0	0	0
Dec/07	29350	0.79	1761	31111	513	125999.6	74385	200384.6
Jan/08	29860	0.77	2389	32249	513	130607.6	74385	204992.6
Feb/08	29580	0.77	2366	31946	513	129382.9	74385	203767.9
Mar/08	25930	0.74	2852	28782	513	116568.3	74385	190953.3
Apr/08	37920	0.79	2275	40195	513	162790.6	74385	237175.6
May/08	30810	0.85	0	30810	513	124780.5	74385	199165.5
Jun/08						0	0	0
Jul/08						0	0	0
Aug/08	44990	0.85	0	44990	513	182209.5	74385	256594.5
Sep/08	39460	0.85	0	39460	513	159813	74385	234198
Oct/08	32420	0.79	1945	34365	513	139179.1	74385	213564.1
Nov/08	31790	0.74	3497	35287	513	142911.9	74385	217296.9
Total	606824		42290.7	649114.7		2628915	1487700	4116615
Monthly Avg.	**30341.2**		**2114.535**	**32455.735**		**131445.7**	**74385**	**205830.7**

Monthly Demand

Month & Year	KVA (Billed Demand)	MD KVA (Reading)	MD KVA Excess Charged	Demand Charge (Rs.)	Excess Demand Charge (Rs.)
Jan/07	513			74385	0
Feb/07	513			74385	0
Mar/07	513			74385	0
Apr/07	513	127	386	74385	55970
May/07	513	166	347	74385	50315
Jun/07	513	166	347	74385	50315
Jul/07	513	166	347	74385	50315
Aug/07	513			74385	0
Sep/07	513	133	380	74385	55100
Oct/07	513	209	304	74385	44080
Nov/07			0	0	0
Dec/07	513	96	417	74385	60465
Jan/08	513	101	412	74385	59740
Feb/08	513	113	400	74385	58000
Mar/08	513	111	402	74385	58290
Apr/08	513	281	232	74385	33640
May/08	513	174	339	74385	49155
Jun/08			0	0	0
Jul/08			0	0	0
Aug/08	513	199	314	74385	45530
Sep/08	513	193	320	74385	46400
Oct/08	513	167	346	74385	50170
Nov/08	513	117	396	74385	57420
Total		2519	5689	1487700	824905
Monthly Avg.		**157.4**	**355.56**	**74385**	**41245.25**

Observations

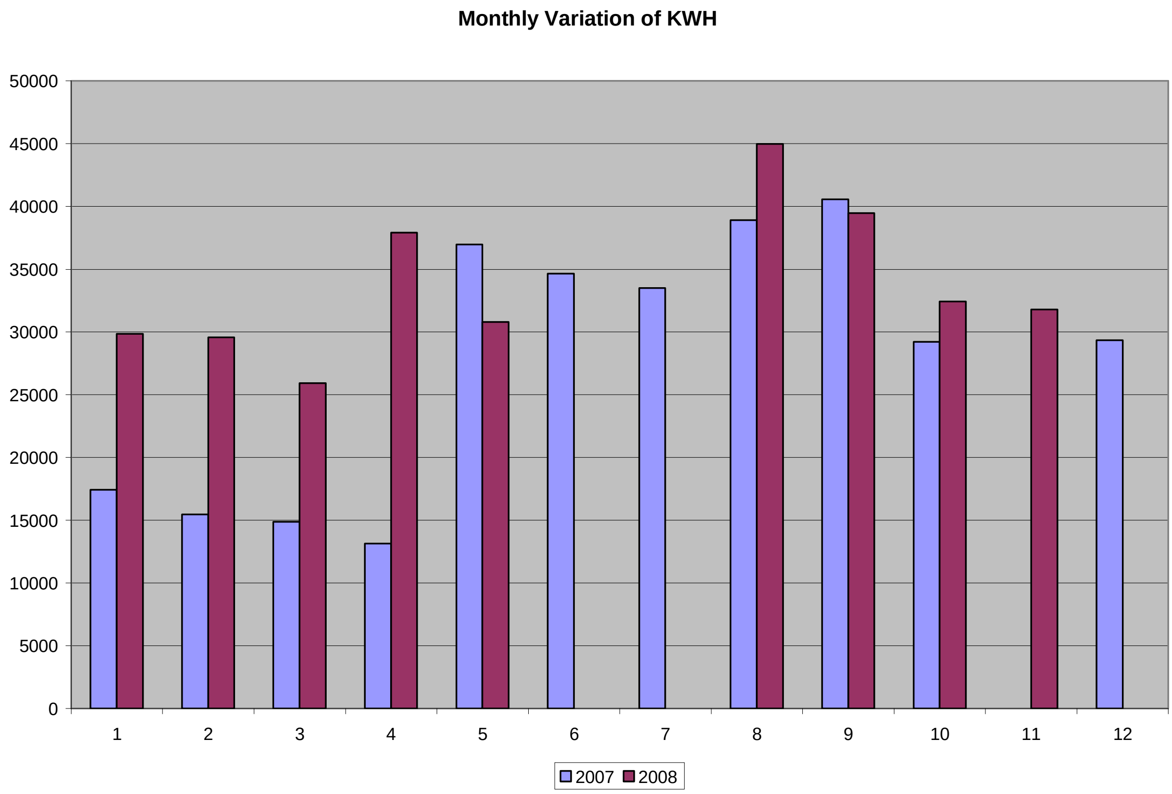
1) Actual demand for all months for the institute is much lower than the contract demand / billed demand and, as a result a monthly average of 355 KVA of additional demand is being charged by the SEB. The management should take up the matter with M/s. ASEB and **reduce the contract demand**. By reducing the contract demand approximately **Rupees Five Lacs (Rs. 5.0 Lacs)** can be saved per year.

2) An average of 2114.5 KWH of electricity has been charged monthly in excess of consumed units for maintaining P. F. below 0.85. This can be

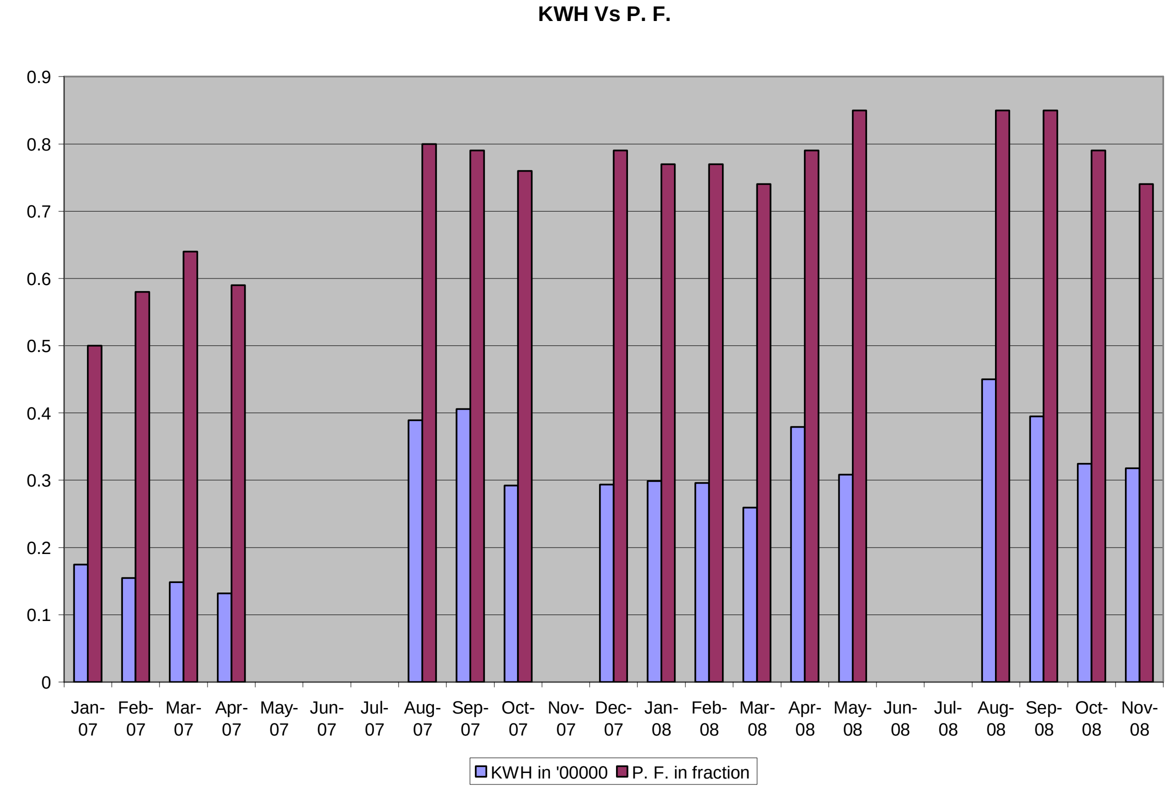
avoided through installation of **Automatic Power Factor Controller (APFC)**. Resultant savings can be calculated as below:

PF Penalty and Savings:	
Average unit as penalty, KWH	2114.5
Monthly avg. penalty, Rs	8563.73
Annual penalty, Rs.	**102764.7**
Average Demand, KVA	157.4
Existing average P. F.	0.75
Improved P. F.	0.99
Required KVAr	87.24
Cost of 90 KVAr APFC, Rs.	49500
Pay back, month	5.8

Bar graph below indicates the monthly variation of power consumption. Due to non availability of data the comparison could not be completed.



The bar graph below shows the comparison between KWH and P. F. However, no relation could be established through it.



TRANSFORMER OPERATIONS

There are three numbers of transformers are installed and operated for the institute. One 500 KVA transformer giving supply to lights, fans lifts, water pump, street light etc. One 250 KVA transformer is supplying power to air conditioners and computers of ground floor, first floor and second floor of the main building. Another 250 KVA is catering the need of a/c's and computers at third floor of main building.

The ratings/ specifications of three nos. transformers are given below:

Transformer Details	Description
Transformer No.	T1
Catering to	All floor Light, Fan, Lift, Water Pumps, Hostel
Make	Prag Electricals Pvt Ltd.
Capacity	500 KVA
HV	11000 Volt
LV	433 Volt
HV	26.24 Amp
LV	666.7 Amp

Impedance Volts	5%
Total Wt.	2025 Kg
Oil Wt.	415 Kg
Year Of Manufacture	2004

Transformer No.	T2
Catering to	Computer & A/c for GF, FF, SF
Make	Prag Electricals Pvt Ltd.
Capacity	250 KVA
HV	11000 Volt
LV	433 Volt
HV	13.2 Amp
LV	333.35 Amp
Impedance Volts	4.16%
Total Wt.	1230Kg
Core & Winding Wt.	400 Kg
Year Of Manufacture	1996

Transformer No.	T3
Catering to	Computer & A/c for Third Floor
Make	Prag Electricals Pvt Ltd.
Capacity	250 KVA
HV	11000 Volt
LV	433 Volt
HV	13.2 Amp
LV	333.3 Amp
Impedance Volts	4.63%
Total Wt.	1110
Core & Winding Wt.	410
Year Of Manufacture	1997

Transformers are extremely efficient devices; however, since the entire power consumption of the plant is through the transformers, some loss does take place. These losses are difficult to measure under site conditions as its magnitude in relation to the actual power consumption of the plant is very small.

Site testing of transformers is not possible without isolation of the transformers.

$$Transformer\ efficiency = \frac{kW}{kW + No\ load\ Losses + (\%loading)^2 \times Load\ losses}$$

<u>Observations & Comments</u>

Distribution transformers generally have full load efficiency around 98.5%. At lower loading levels, the efficiency increases, peaks at a value around 99.1% to 99.5% at about 50% kVA loading and then falls to around 98% to 98.5% at lower loading levels. If the transformer loading is very low i.e. below 10%, the efficiency deteriorates as then the fixed iron losses become the predominant loss.

Higher power factor at the load end helps reduce the current and the resistive losses in electrical distribution and generators.

TECHNIQUES FOR IMPROVING EFFICIENCY OF EXISTING TRANSFORMERS

Reduction of Transformer Losses by Power Factor Improvement

Transformer load losses vary as square of the current. If the power factor is poor, for the same kW load, the current is higher leading to higher losses in transformers and cables; the transformers also reach their limits for kVA loading with smaller kW loads when the power factor is poor. If the power factor is maintained at unity the saving in load losses =

$(\text{Per unit loading as per kW})^2 \times \text{Load losses at full load} \times [(1/PF)^2 - 1]$

At ASTC, Khanapara, there is scope for improvement of power factor as the power factor of the feeder is in the range of 0.74 to 0.85. If the transformers are operated at unity power factor by **installation of capacitor bank (APFC)**, the total transformer losses can be reduced minimum. Capacitors can help in reducing kVA loading on transformers operating close to their rated load.

Transformer No	T1
Transformer Rating, KVA	500
Typical No load Loss, KW	1.03
Typical Full load Loss, KW	6.86
Existing (Average) P. F.	0.75
Expected (Average) P. F.	0.98
Average Power, KW	100
Average Loading, %	0.27
Savings, KW	0.359
Annual Savings, KWH	**1293.49**
Annual Savings, Rs.	**8200.73**

Operation of Transformer close to 50% loading

The peak efficiency of distribution transformers generally occurs near 50% to 60% loading when the fixed losses (iron losses) are equal to the variable (copper losses). Academically speaking, efficiency can be improved by loading some of the transformers to about 50% level, wherever the electrical distribution system permits the same. However, since the electrical distribution of the institute is built on the concept of reliability and zero forced downtime, it is not advisable to attempt any such relocation of loads for the achieving the relatively minor energy savings

Stopping Idle Operation of Transformers

Another important issue is that transformers, even when not loaded, will consume power i.e. no load losses (also called iron losses). To avoid the same, idle transformers will have to be switched off. Switching off transformers for prolonged periods, especially during periods of high humidity, can lead to deterioration of transformer oil, which makes it difficult to energise the transformer at short notice. Keeping in view the very high reliability requirements, we do not recommend any switching off of transformers in case of process plants, since the energy savings are relatively minor.

Switching off two transformers beyond office hours	
Numbers of transformers	2
Ratings, KVA	250
No load loss, KW	0.57
Non Operating Hours per Day (Working day)	14
Non Operating Hours per Day (non-Working day)	24
Annual Savings, KWH	**7011**
Annual Savings, Rs.	**44449.74**

Amorphous Core Transformers

Amorphous core transformers, in comparison to the laminated core transformers, have lower iron losses, and can save energy (refer table below). The thickness of amorphous steel foils is about 0.03 mm compared to 0.18 to 0.23 mm for CRGO laminations, this reduces iron losses by about by about 75% (comparisons are given at a magnetic flux density of 1.5 Tesla). However, since magnetic flux densities in amorphous core transformers are likely to be lower, the volume of the core may be larger, leading to longer winding length and higher copper losses. Hence, at the time of transformer selection, comparison of total losses is preferred at the most probable loading level.

Evolution of Transformer Core Material with Reference to Core Losses

Year (Approx.)	Core Material	Thickness (Mm)	Loss (W/Kg At 50hz)
1910	Warm rolled FeSi	0.35	2 (1.5T)
1950	Cold rolled CRGO	0.35	1 (1.5T)
1960	Cold rolled CRGO	0.3	0.9 (1.5T)
1965	Cold rolled CRGO	0.27	0.84 (1.5T)
1975	Amorphous metal	0.03	0.2 (1.3T)
1980	Cold rolled CRGO	0.23	0.75 (1.5T)
1985	Cold rolled CRGO	0.18	0.67 (1.5T)

These transformers are available up to 2000 kVA rating in India. Considering energy savings and investments (about 40% higher than conventional transformers with laminations), it is not economically viable to replace existing transformers. However, these transformers can be considered for expansion. We suggest that these transformers can be installed for non-critical applications initially till sufficient confidence is gained by the electrical department in the new technology.

3. STUDY OF LIGHTING SYSTEMS

INSTALLED FITTINGS (LOCATION WISE)

Room/Hall No.	No. of FTL (40W)	No. of Ceiling Fan (60W)	No. of wall fans (60W)	No. of ventilation fans (60W)	No. of GLS Bulbs (60W/40W)	No. of reflector lamps	No. of A/c Machines
Library	100	15	20		35		16
002	2	1					
003	2	1					
004	4	1					
005	5	1					
Corridor & Toilet	30	17		4	4		
101	14	7					
102	8	4					
103	16	6					6
104	16	6					6
105	5	2					
106	5	2					
107	5	2					
108	2	1					1
109	18	1					5
110	4	1					
111	4	1					
112	4	1					
114	8	1			2		2
115	4	1					
116	4	1					
117	4	1					
118	4	1					
119	4	1					
120	4	1					
First floor corridor	40	7					
Toilet	12	1		6	12		
Mezzanine floor	12	8			8		
201	15	4					4
202	8	2					1
203	8	2					2
204	8	2					1
205	18	6					6
206	4	1					
207	8	2					
208	7	2					
209	2	1					
210	21	6					
211	20	6					6
212	18	6					6

213	20	6					
Second floor corridor	50						
Toilet	12			6	12		
301	6						4
302 VIP lounge	10						5
VIP Toilet	3						
303	16						6
304	4						
305	5						
306	5						
307	2						
309	60						18
308	72						24
Lift m/c room	6						
Hostel				2 KW Geyser			
Dining Hall	15	8	4		40 CFL		12
Lounge	24	14					6
Rooms 80nos	80	80		80	240		80
Total	**867**	**241**	**24**	**96**	**313**	**0**	**217**
Street light	400w MH	150w SV	250w SV				
	14	13	3				

ILLUMINATION SURVEY OF INSTITUTE & CAMPUS

Illumination survey of institute campus area was carried out in night on 19th Jan 2009. During the survey it was observed that street lights in plant roads are mostly of 150/250 Watt SV. As SVs are one of the most energy efficient lamps, it is appreciated that management has already taken the initiative to fix SV in many parts where Color Rendering index (CRI) are not that important. This has definitely resulted in conservation of energy in illumination.

The readings in Lux as measured with Luxmeter during the study in different rooms of the institute are depicted below.

Sr. no	Room No	Fitting no	Fitting Type	Watts	LUX			
					Point-1	Point-2	Point-3	Point-4
1	201	15	FTL	40	250	176	190	240
2	303	16	FTL	40	198	212	183	318

3	302		FTL	40	124	140	70	75
4	301	4	FTL	40				
5	308	72 10	FTL GLS	40 40	246 174 178	204 171	227 223	275 206
6	309	60 12	FTL GLS	40 40	200 195	153 141	146 152 182	150 170 156
7	Library		FTL	40	176 166	142 120	135 169	148 115
8	103			40	63 61	81	80 89	122 84
9	Hostel Dining hall	15 26	FTL CFL	40 18	44 41	23 52	54 56	53 82
10	Hostel Common room	27	FTL	40	97 88	130 146	460	

Observations

- Illumination levels in different locations of the campus are OK and meet the stipulated limits prescribed except a few places on the road where it needs to be improved. The CFL used for street light can be replaced with metal halide (MH) or specially designed T5 (a set of 4X14w T5).
- In some areas lighting fixtures are covered with dust and insects and needs cleaning.
- In areas of hostel as well as office building quite a no of GSL bulbs of 60/40w were observed. Though GLS bulbs have the best Color rendering index, but it is the worst from energy efficiency point of view.
- The institute has installed conventional tube lights of 40W ratings with

copper choke for lighting purposes. With the advancement in the technology, several energy efficient lighting systems are available today, which would not only reduce the energy consumption but also improve the illumination levels. A comparative study of the average power consumption viz Lux Levels for different tube lights is given herein:

Type	Voltage (Volts)	Current (mA)	Power Factor	Power Drawn (W)	Lux Level
Asian (28 Watt with Electronic Ballast)	235	131.5	0.89	27.50	> 250
Osram (28 Watt with Electronic Ballast)	235	131.0	0.89	27.39	> 250
Philips (36 Watt with Copper Ballast)	235	250.0	0.72	42.30	200-250
Existing Tube lights (40 Watt with Copper Choke)	235	291.0	0.72	49.23	200-250

Recommendations For Energy Savings

- Maintain and clean all lighting fixtures. Maintain record of all lighting fixtures against each location.
- Use natural light wherever feasible. Use translucent sheets at the roofs of Compressor house, Boiler house and other sheds to allow natural light inside. This will allow putting off all the lamps during sunny days.
- In case of single 60w/40w GSL, it should be replaced with 18w CFL at pathways / toilets etc. But it should be avoided in working areas or rooms as color rendering index of CFL is poor.

Savings due to replacement of GLS lamps with CFL:

Nos. of GLS bulbs	313
Power consumption, Watt	50
Running hours	8
Expected Power consumption(18W CFL), Watt	18
Average nos. of day per year	250

Annual savings (50% light on), KWH	**10016**
Annual savings, Rs.	**63501.44**
Investment (@ Rs.125/- per CFL), Rs.	39125
Payback Period, Yr.	0.62

- Replace all 40 watt conventional TFL (T12 & T8) under a failure replacement policy with 28 watt energy efficient TFL (T5). Lamp efficacy (in lumen/watt) of T5 is much higher than T8. Burning hour of T5 is almost 3.5 times of T8. The resultant benefit in terms of Energy Savings has been worked out as follows:

Savings due to replacement of 40W FTL with T5 lamps:

Nos. of FTL	867
Power consumption, Watt	52
Running hours	8
Expected Power consumption, Watt	28
Average nos. of day per year	250
Annual savings (50% light on), KWH	**20808**
Annual savings, Rs.	**131922.72**
Investment (@ Rs.350/- per T5), Rs.	303450
Payback Period, Yr.	2.30

Suppliers:

- ASIAN Electronics Ltd., 12, Aswini Dutta Road, Kolkata-700 029, Phone: (033) 2465 0589/0239, e-mail: aeccal@cal2.vsnl.net.in
- Philips India ltd, Motorola excellence centre, 5th floor, 415/2, Mehrauli Gurgoan Road, Sector 14, Gurgoan-122001
- Linear Technologies India Pvt. Limited, K-37, Green Park, Main Basement, New Delhi-110016
- Eurolight Electricals Limited, 20, Sadashiv Peth, Rahi Chambders, L B S Road, Pune- 411030

Note: The supplier(s) mentioned above is not necessarily the only ones or the best available. Competitive rates, specifications etc. of other suppliers may be obtained for comparisons. Some of the parties are doing business on ESCO concept also.

4. STUDY OF AIR CONDITIONERS

INSTALLED AIR CONDITIONERS

Sl. No	Room No.	Window/ Split	Make	Model	Year of Instln.	Rated TR	L X W X H (ftxftxft)	Remarks
1	205	Split	Carrier	Sierra	1997	1.5	45X32X14	6 Nos a/cs, Window pans need sun filming
2		Split	Carrier	Sierra	1997	1.5		
3		Split	Carrier	Sierra	1997	1.5		
4	201	Split	Carrier	Sierra	1997	1.5	40x40x14	4 Nos a/cs, Window pans need sun filming
5		Split	Carrier	Sierra	1997	1.5		
6	204	Split	Voltas		1992	1.5	14x14x14	Window pans need sun filming
7	303	Split	Amtrex		2002	1	45X32X14	
8		Split	Amtrex		2002	1		
9		Split	Amtrex		2002	1		
10	302	Split	LG	LS-1862CIG	2004	1.5	30x35x14	
11		Split	LG	LS-1862CIG	2004	1.5		
12		Split	LG	LS-1862CIG	2004	1.5		
13	301	Split	LG	LS-1862CIG	2004	1.5	40x40x14	4 Nos a/cs, Window pans need sun filming
14		Split	LG	LS-1862CIG	2004	1.5		
15	308	Split	Carrier	Sierra	1992	1.5	90x45x12	24 Nos a/cs, only 8 nos are working
16		Split	Carrier	Sierra	1992	1.5		
17		Split	Carrier	Sierra	1992	1.5		
18		Split	Carrier	Sierra	1992	1.5		
19		Split	Carrier	Sierra	1992	1.5		
20		Split	Carrier	Sierra	1992	1.5		
21	309	Split	LG	LSA24XWAF1	2008	2	75x45x12	18 Nos 2.0TR

22		Split	LG	LSA24XWAF1	2008	2		a/cs, Most of them are not working
23	Library	Split	LG	LSK-1862CIG	2004	1.5	75x45x11	False ceiling is made
24		Split	LG	LSK-1862CIG	2004	1.5		
25		Split	LG	LSK-1862CIG	2004	1.5		
26		Split	LG	LSK-1862CIG	2004	1.5		
27		Split	LG	LSK-1862CIG	2004	1.5		
28	103	Split	LG	LSK-1862CIG	2004	1.5		Remote was not available
29		Split	LG	LSK-1862CIG	2004	1.5		
30	114	Split	Carrier		2003	1.5	3x1.5Tr a/cs	No sun film, Air filter is clogged.
31		Split	Carrier		2003	1.5		
32	303	Split	LG			1.5		
33		Split	LG			1.5		
34		Window	Voltas		1984	1.5		
Hostel								
1	Dining Hall	Split	LG	LSA24XWAS1	2008	2	Dining room height is more, top ventilation window is kept open, gaps are observed at doors and windows, no sun film on glass.	
2		Split	LG	LSA24XWAS1	2008	2		
3		Split	LG	LSA24XWAS1	2008	2		
4	C-004	Window	LG	LW-N1860CIG	2004	1.5	13x11xx10	Window pans need sun filming, Door, window & ventilation window to be sealed.
5	C-012	Window	LG	LW-N1860CIG	2004	1.5	13x11xx10	
6	B-015	Window	LG	LW-N1860CIG	2004	1.5	13x11xx10	
7	301	Split	Amtrex		2003	1	11x13x10	
8	301	Split	Amtrex		2003	1	16x13x10	

CRITERIA

For Star Rating Analysis

Star Rating	EER (Wc / Wp)	
	Min	Max
1 Star *	2.30	2.49
2 Star **	2.60	2.69
3 Star ***	2.70	2.89
4 Star ****	2.90	3.09
5 Star *****	3.10	

MEASUREMENTS MADE AND ANALYSIS

Sl. No	Room No.	AC No	Window/ Split	Year of Instln.	Rated TR	Amps	Volts	KW	PF	EER Wc/Wp	Operating Star level
1	205	2 (E->W)	Split	1997	1.5	12.5	232	2.01	0.72	2.62	**
2		1 (E->W)	Split	1997	1.5	7.55	238	1.73	0.96	3.05	****
3		3 (E->W)	Split	1997	1.5	8.78	239	1.93	0.92	2.73	***
4	201	1 (E->W)	Split	1997	1.5	8.65	235	1.91	0.94	2.76	***
5		3 (E->W)	Split	1997	1.5	8.86	235	1.92	0.93	2.75	***
6	204	1	Split	1992	1.5	9.08	234	1.75	0.82	3.01	****
7	303	4 (E->W)	Split	2002	1	5.99	240	1.41	0.97	2.49	*
8		6 (E->W)	Split	2002	1	6.09	238	1.41	0.97	2.49	*
9		1 (E->W)	Split	2002	1						
10	302	2 (N->S)	Split	2004	1.5	8.35	235	1.83	0.93	2.88	***
11		3 (N->S)	Split	2004	1.5	8.2	216	1.72	0.97	3.07	****
12		1 (N->S)	Split	2004	1.5	6.52	239	1.45	0.93	3.64	Less Refrigerant
13	301	4 (N->S)	Split	2004	1.5	7.75	220	1.65	0.96	3.20	Less Refrigerant
14		1 (N->S)	Split	2004	1.5	8.12	218	1.72	0.97	3.07	****
15	308	SE Corner	Split	1992	1.5	10.6	240	1.96	0.76	2.69	**
16		SE Corner	Split	1992	1.5	9.7	240	1.69	0.73	3.12	Less Refrigerant
17		E Middle	Split	1992	1.5	9.9	239	1.88	0.8	2.81	***
18		NE Corner	Split	1992	1.5	8.35	243	1.06	0.52	4.98	Less Refrigerant
19		WNN	Split	1992	1.5	12.08	235	2.26	0.79	2.33	*
20		WNS	Split	1992	1.5	9.05	238	1.78	0.83	2.96	Less Refrigerant
21	309	3 (E->W)	Split	2008	2	9.11	235	2.02	0.94	3.48	Less Refrigerant
22		4 (E->W)	Split	2008	2	9.35	236	2.08	0.94	3.38	Less Refrigerant
23	Library	2 (W: S->N)	Split	2004	1.5	10.8	242	2.05	0.78	2.57	*
24		3 (W: S->N)	Split	2004	1.5	7.9	243	1.81	0.94	2.91	****
25		1 (W: S->N)	Split	2004	1.5	5.37	226	1.03	0.85	5.12	Less Refrigerant
26		2 (S: W->E)	Split	2004	1.5	7.94	242	1.8	0.93	2.93	****
27		2 (S: W->E)	Split	2004	1.5	8.64	224	1.83	0.94	2.88	***
28	103		Split	2004	1.5						
29			Split	2004	1.5						
30	114	Computer room	Split	2003	1.5						
31			Split	2003	1.5						
32	303	New computer room	Split		1.5						
33			Split		1.5						
34			Window	1984	1.5	7	238	2.2	0.96	2.40	*

Hostel											
1	Dining Hall	4 W	Split	2008	2	10.9	234	1.97	0.79	3.57	Less Refrigerant
2		5 W	Split	2008	2	10.3	231	1.97	0.83	3.57	Less Refrigerant
3		6 W	Split	2008	2	10.3	231	2.03	0.81	3.46	Less Refrigerant
4	C-004		Window	2004	1.5	8.28	228	1.82	0.96	2.90	****
5	C-012		Window	2004	1.5	8.63	236	1.83	0.89	2.88	***
6	B-015		Window	2004	1.5	8.37	237	1.77	0.89	2.98	****
7	301		Split	2003	1	5.8	204	1.14	0.96	3.08	****
8	301		Split	2003	1	5.15	237	1.14	0.94	3.08	****

The analysis has been carried out assuming:

1) Air conditioners are delivering their rated TR of cooling
2) Field electrical measurement

As the measurements have been taken in winter season it can be safely assumed that the performance of the machines will not be improved in summer, however, the same can deteriorate further.

Therefore, **the machines with star rating of two and below can be replaced with new five star rated machines**. New air conditioners with deviated performance (marked as less refrigerant) can be given for immediate maintenance.

Savings due to replacement of under performing air conditioners:

Nos. of 1.5 TR machines	:	5
Avg. power consumption (existing), KW	:	2.114
Avg. power consumption (new), KW	:	1.72
Avg. Savings, KW	:	0.394
Savings per day(@12 Hrs/day), KWH	:	47.28
Annual savings (9 months), KWH	:	**5106.24**
Annual savings, Rs. @Rs.6.34/KWH	:	**32373.56**
Approximate Investment, Rs.	:	100000.00
Simple Pay Back, Yr.	:	3.1

Savings due to replacement of under performing air conditioners:

Nos. of 1 TR machines	:	2
Avg. power consumption (existing), KW	:	1.41
Avg. power consumption (new), KW	:	1.2
Avg. Savings, KW	:	0.21
Savings per day(@12 Hrs/day), KWH	:	5.04
Annual savings (9 months), KWH	:	**544.32**
Annual savings, Rs. @Rs.6.34/KWH	:	**3450.99**
Approximate Investment, Rs.	:	24000
Simple Pay Back, Yr.	:	7.0

PERFORMANCE TEST

One window AC at hostel (room no. B – 015) was checked for performance, the result is indicated below.

Performance of a window a/c at hostel:

Average Air velocity, m/s	3.29
Cross section, Sq. cm	416
Average Air flow, Cu. m/s	0.14
Average Air flow, Kg/Hr	566.04
Hot air I/L temperature, deg c	16.8
Cold air O/L temperature, deg c	6.4
Hot air I/L relative humidity, %	71
Cold air O/L relative humidity, %	84
Power drawn, KW	1.77
Hot air enthalpy, KJ/ Kg of Dry Air	38.8
Cold air enthalpy, KJ/ Kg of Dry Air	18.5
Ton of cooling	0.90
EER, (12 / KW/Ton) EER, (Wc / Wp)	7.49 1.8

It is clear from above that the AC is underperforming. However, to replace it we need further study in summer months.

As indicated in the table for installed air conditioners there are many instances of excess height of the ceiling, windows without sun filming, gaps in windows and ventilation windows etc. All of them are contributing to loss of cold i.e. TR generated by the air conditioners. The loss can be estimated as below. Also the resultant savings has been identified once the corrective measures i.e. **providing false ceiling, sun filming the windows and arresting the leakages** etc. has been taken.

Savings due to false ceiling, sun filming, leak arresting etc.:

Description

Room No	**309**	**308**	**303**	**302**	**301**
Approximate Area, Sq.ft	3375	4050	1575	1050	1600
False ceiling, Y/N	Y	Y	N	N	N
Sun film, Y/N	Y	Y	N	N	N
Sealing of window and door, G/B	G	G	G	G	G
Present TR	36	36	9	7.5	6
Required TR	32	36	9	7.5	6
Savings with sun film, TR	nil	nil	0.45	0.375	0.3
Savings with proper sealing, TR	nil	nil	nil	nil	nil
Savings due to false ceiling, TR	nil	nil	0.45	0.375	0.3
Total Savings, TR	0	0	0.9	0.75	0.6
Usage per month, Hr	120	120	120	120	120

Room No	**201**	**205**	**Hostel dining hall**	**Hostel room**	**Hostel dining hall (AR)**
Approximate Area, Sq.ft	1600	1575	1782	143	1056
False ceiling, Y/N	N	N	N	Y	Y
Sun film, Y/N	N	N	Y	N	N
Sealing of window and door, G/B	G	G	Poor	B	Poor
Present TR	6	9	16	1.5	6
Required TR	6	9	16	1	6
Savings with sun film, TR	0.3	0.45	0.4	0.05	0.3
Savings with proper sealing, TR	nil	nil	1.6	0.1	0.6
Savings due to false ceiling, TR	0.3	0.45	0.8	0.05	nil
Total Savings, TR	0.6	0.9	2.8	0.2	0.9
Usage per month, Hr	120	120	120	120	120
Savings Grand Total, TR					7.65
Annual Power Savings, (@1.0 KW/Ton),KWH					**8262**
Annual Savings, Rs					**52381.08**
Investment, Rs.					150000
Payback period, Yr.					2.86

The approximate thumb rule is that for every 1°C higher temperature in the evaporator, the specific power consumption will decrease by about 2 to 3%. So, **maintain air conditioned room temperature at 25°C instead of 22°C.** In air conditioned spaces, use of circulation fans can provide *apparent comfort* and help raise the room temperature settings about 26°C instead of 24°C.

Savings due to higher setting of air cinditioned space temperature:	
Total approximate TR	133
Present consumption, KW	159.6
Monthly usage, Hr	120
Fraction of TR utilized	0.75
Annual Power Savings, (@2%),KWH	**14364**
Annual Savings, Rs	**91067.76**
Investment, Rs.	Nil
Payback period, Yr.	Immediate

Room Air Conditioners

Air Conditioner is an appliance for controlling, especially lowering, the temperature and humidity of an enclosed space. It is designed to extract heat from an area via a refrigeration cycle. Its purpose is to provide comfort during either hot or cold weather. Air conditioner, once considered a luxury is now becoming a necessity. Air- Conditioning manufacturers have made them more affordable along with increasing their efficiency and improving components and technology. Air conditioning systems vary considerably in size and derive their energy from many different sources. Popularity of room air conditioners have increased dramatically with the advent of central air, a strategy that utilizes the ducting in a home for both heating and cooling.

The Efficiency of room air conditioners is rated only by EER (Energy Efficiency Ratio), which is cooling output divided by power consumption. The higher is the EER, the more efficient the air conditioner.

Tips for Saving Energy

- We can reduce air-conditioning energy use by as much as 40 percent by shading our home’s windows and walls. Plant trees and shrubs to keep the day’s hottest sun off your house.
- One will use 3 to 5 percent less energy for each degree air conditioner is set above 22^{0}c (71.5^{0}F), so set the thermostat of room air conditioner on 25^{0}C (77^{0}F) to provide the most comfort at the least cost.
- Using ceiling or room fans allows you to set the thermostat higher because the air movement will cool the room.
- A good air conditioner will cool and dehumidify a room in about 30 minutes, so use a time and leave the unit off for some time.
- Keep doors to air- conditioned rooms closed as often as possible.
- Clean the air- conditioner filter regularly.

MAINTENANCE TIPS FOR SPLIT / WINDOW AC

- Make sure your AC doesn't get overloaded; check the fuse or circuit breaker if it doesn't operate.
- Remember to replace or clean the filter and have your mechanic clean

the evaporator and condenser coils regularly, for the air conditioner to cool your home efficiently.

- Install a programmable thermostat, it will lead to 10-15% energy saving.
- Set your thermostat as high as possible comfortable.
- Set the fan speed on high except on very humid days, when humidity is high set the fan speed on low for more comfort.
- Install units in shade, it will lead to 10% saving in energy consumption.
- Use sun films on windows. That will cut heat entry by 70% of the building.
- If the AC makes noise it needs to be checked by the mechanic.
- Giving your air conditioning system a good electrostatic air filter is the best thing you can do for your air conditioner. A good air filter will extend the life of your air conditioner because the important parts, like the cooling coil, and other inner parts will stay cleaner, operate more efficiently and last longer.
- Avoid frequent opening of doors/windows. A door kept open can result in doubling the power consumption of your AC.
- Ensure direct sunlight (and heat) do not enter the air-conditioned space, particularly in the afternoons.
- Most people believe that a thermostat set to a lower temperature than desired, will force your air-conditioner to cool faster, not really, all it does, is make your air-conditioner operate for longer. Moreover, you will have an unnecessarily chilly room and wasted power. Every degree lower on the temperature setting results in an extra 3-4% of power consumed. Hence, once you've found yourself a comfortable temperature and set the thermostat at that level, avoid touching the

thermostat thereafter.

- Once an air-conditioning system has been designed and installed avoid any major change in the heat-load on the AC. This will add to wasted power.
- Always ensure that whenever you install new unit, make sure its EER (12/(kW/TR)) should be between 9.5 to10.5.
- No gap should be left during installing units for cool air escape.

5. STUDY OF MOTORS

Two numbers of 10 HP motors are employed for driving the water supply pumps. Both the pumps are v-belt driven.

MEASUREMENTS

Sl. No.	Description	Rated Power (KW)	Power Drawn (KW)	P.F.	Vr (Volt)	Vt (Volt)	Ir (Amp)	It (Amp)
1	Water Pump	7.5	7.9	0.86	401.00	403	13.60	12.8
2	Water Pump	7.5	6.37	0.82	400.00	401	11.2	113

ANALYSIS

CRITERIA

For Motor loading Analysis

- If % loading is > 100 : Overloaded
- If % loading is ≥ 50 and ≤ 100 : Satisfactory
- If % loading is < 50 : Under-loaded

Normally, under normal working conditions, motors should be loaded between 50 to 100% of their rated capacities.

For Power Factor Analysis

- If the operating Power Factor is > 0.7 : Satisfactory
- If the operating Power Factor is < 0.7 : Low

Operating power factor of 0.7 is satisfactory at the load centre, however, the overall plant power factor should be above 0.98.

Sl. No.	Description	Rated Power (KW)	Power Drawn (KW)	P.F.	% Loading	Loading Condition	Operating P.F.
1	Water Pump	7.5	7.9	0.86	98.59	OK	OK
2	Water Pump	7.5	6.37	0.82	79.50	OK	OK

6. STUDY OF DG SET

INSTALLED DG SET

There is one DG set catering the power requirement during grid failure.

DG Set details	
Nos.	1
Make, Engine	Kirloskar Cummins
Make, Generator	Kirloskar Electric Co.
KVA	100
Voltage	415
Amp	139.150
Frequency, Hz	50
Phase	3
Power Factor	0.8
Insulation Class	F
Ambient, ^{o}C	40

Observations

KWH generations and HSD consumptions are not noted in log book, there is no log book maintained.

Energy conservation in DG set

Generating efficiency of a DG set is measured by the nos. of units generated per litre of fuel consumed. As a rule, lower speed engines are more fuel efficient in larger sizes and less efficient in smaller sizes. While the engine speed is maintained constant within certain limits by means of governor of the engine, the load on the engine can vary from zero to full rated power and to a further 10% overload on the rated hp. The brake horse specific fuel consumption of an engine is characteristic of function of the bhp or load at any synchronous speed. It is seen that BSFC is at the minimum at approximately rated power increasing slightly at 10% overload and substantially at all lower loads. This situation arises due to the fact that the internal frictional horse power of the engine remains almost constant due to constant speed while the useful brake horse power taken from the engines decreases resulting in reduced mechanical efficiency of the engine and BSFC. It is recommended to load the sets at least 70% of the rated load, at all times. Action taken is to be based on the loading pattern. It may also be mentioned here that BSFC of air-cooled engines are lower than that of water-cooled engines, especially those water-cooled engines in which fans are driven by electric motors and not by the engine. In engine driven fan and water pump, there is a loss of 7 to 10% of engine bhp. Water-cooled engines having separate and independent cooling system that is cooling tower attached with fountain and heat exchangers have lower fuel consumption.

The way the unit was maintaining the logbook was quite adequate. It is very much essential for any unit to maintain proper logbook wherein all the data related to engine operation and performance should be recorded. The recorded data should also reflect the performance of various components like heat exchanger, etc. As discussed above, consumption will keep on varying with the change in load on the engine. It is therefore very important to take half-hourly or hourly reading of fuel consumption and energy produced, together which will give **specific fuel consumption (SFC)** in **KWH per Litre of fuel** consumed and a very good idea as to how to load the DG set judiciously and what is the load at a certain point of time. It is therefore recommended to maintain the SFCs. This will also indicate when the engine or its components need maintenance. This will help in scheduling the preventive maintenance of the DG set and thus reduce the down time and loss of production. The SFC will be reduced with the decrease in load and malfunction of any vital component of the engine. Although SFC varies with load, it is of utmost importance to conduct trial on all the sets to determine the actual SFC of each set. This will help in finding out the set or sets with low SFC. They have to be attended to immediately.

The following is the format recommended for any DG set logging:-

Date - Starting & Closing Time - kWh meter reading - AC Voltage - AC Amp - DC Voltage - DC Amp - Rpm - Frequency - kW - HSD Consumption in Litre (Physical measurement from the service tank and not by running hours) - SFC (KWH/Litre of HSD) - Lube Oil Pressure - Lube Oil Outlet Temperature - Total Running Hours - Total Lube Oil Consumption.

Engine room heats up during the DG set operation due to heat radiation from the hot exhaust pipes and due to the hot air from the radiator fan or from the exit of the air-cooled engines circulating inside the room. When the ambient temperature in the engine room goes up, fuel consumption increases due to decrease in the air fuel ratio due to lower density of available air. As the mixture becomes richer there is a decrease in the fuel efficiency. It has been seen that with the increase in the air intake temperature from 25°C to 42°C the air fuel ratio decreases by about 5% and this will result in higher BSFC in the range of 0.5 to 2% depending upon the engine design i.e. naturally aspirated or supercharged or inter-cooled. In other words, the engine output varies with the change in the intake temperature. It has been seen that for a rise of every 3°C in intake temperature beyond 32°C the engine output drops by about 1.2%. It is therefore essential to make arrangements for proper ventilation so that hot air is continuously removed by circulation of cool air. Using insulation lagging can reduce heat radiation from the exhaust pipe and manifold. The table given below gives the loss of heat from lagged and un-lagged pipes of different diameters at exhaust temperature of around 400°C and ambient temperature of around 30°C.

a) Diameter of exhaust pipe (mm)	150	200	300	400
b) Heat radiation in Kcal /hr. per meter of pipe length				
i) Base pipe	5800	7800	11600	15600
ii) Pipe with 50 mm thick lagging	235	350	520	630
iii) Pipe with 100 mm thick lagging	145	215	300	370

This will help to select the insulation thickness to reduce radiation heat. It is observed that all the exhaust pipes are un-insulated in the room, as a result when the DG sets are running the room temperature goes up.

Exhaust temperature of a DG set is an indication of the engine health and hence the fuel consumption. If the exhaust temperature is more than the recommended, the power generation is not proper and engine needs immediate attention before the situation worsens. Provision of measuring the cylinder temperature is very useful in identifying the damaged cylinder. So, it is recommended to incorporate the cylinder head temperature in the logbook to monitor the health of the DG set. Exhaust gas temperature should never be allowed to go beyond 450°C. Overloading and air starvation are the major reasons for increased exhaust gas temperature, poor efficiency of heat exchanger also has a bearing.

While designing the engine room, factors like ambient temperature, relative humidity, whether the batteries are positioned inside the DG set room or not and whether the engine is air-cooled or water-cooled, whether the engine is naturally aspirated or supercharged should be taken into account.

Exhaust system should be properly designed for proper fuel and engine efficiency so that the exhaust backpressure is within the permissible limits. If the exhaust backpressure higher than the permitted value the scavenging of the engine will be adversely affected and there will be less oxygen in the cylinder during the subsequent compression stroke. The mechanical efficiency will reduce due to higher exhaust pumping losses. This will increase fuel consumption. The following steps are to be taken to maintain the exhaust backpressure within permissible limits: -

i) Small diameter pipes and large number of bends increase the backpressure.

ii) Pipe diameter should be such that exhaust backpressure is about 30 to 40 mm Hg for uncharged engines and about 20 to 30 mm Hg for turbocharged engines.

iii) Gas velocity should be below 33 m /sec for optimum exhaust backpressure.

iv) Number of bends should be minimum, and they should be smooth, not sharp. Radius of the bends should be at least 4 times the pipe diameter.

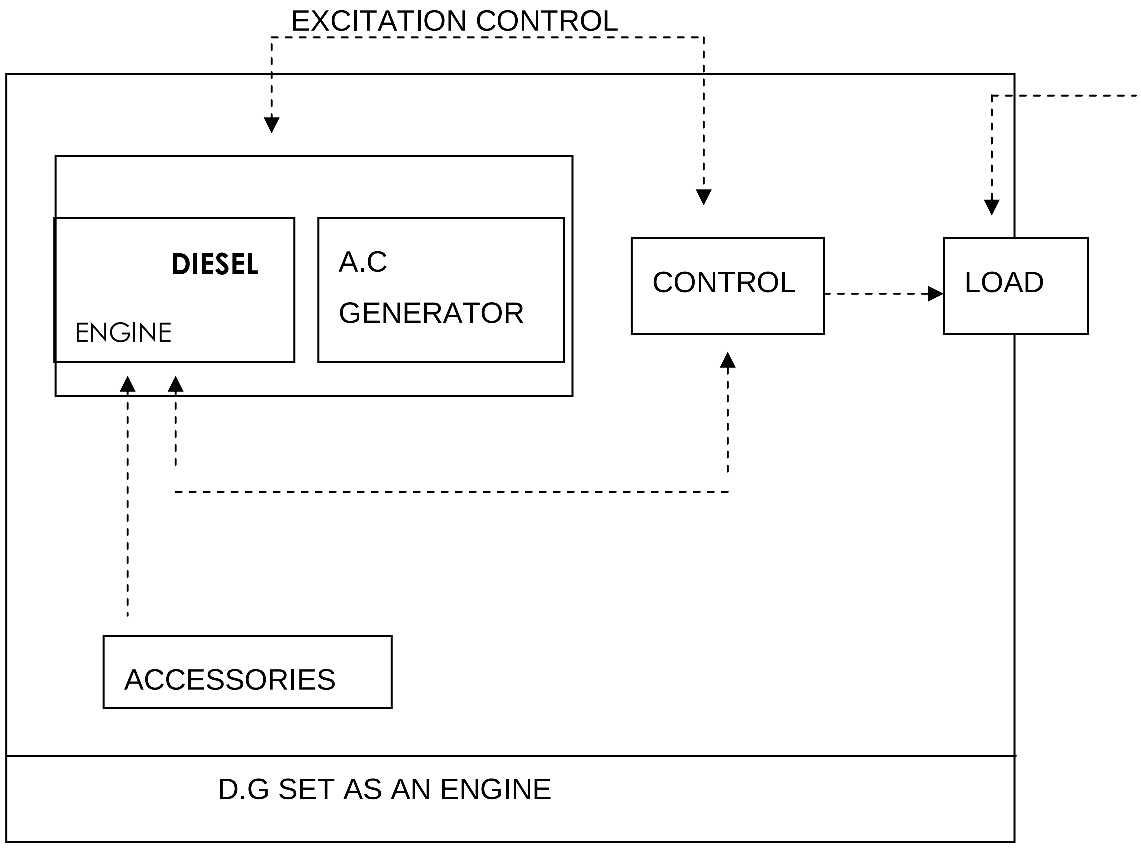
v) In case multiengine sets are connected to a single exhaust manifold the mean gas velocity should not exceed 15 m/sec.

Leakage even though they are of minor nature, should be avoided scrupulously as they are largely the major factor for higher fuel and lube consumption.

Monitor lubricant condition through regular sampling. Maintain proper cooling. Change oil on condition basis and not only on the rule of thumb as recommended by the Oil companies or engine manufacturers. In most of the cases it is found that the engine oil is discarded much before their life is over. This means wastage of oil and money. The parameters of oil change are sometimes ad hoc, bearing no relations to the actual state of oil in use. Many a time the extent of deterioration could be excessive resulting in damage to the equipment. Again, at times the deterioration may be mild and the oil may be in good condition and suitable for further use. Hence the condition-monitoring program is necessary.

3.12 Load Management:

A diesel generating set should be considered as a system since its successful functioning depends on the well-matched performance of its components namely:



1. The diesel engine and its accessories
2. The A.C. generators

3. The control system and switch
4. The foundation and power house civil works
5. The connected load with its own components like heating, motor drives lighting etc.

It is necessary to select the components with highest efficiency and operate them at their optimum efficiency levels to conserve energy in this system.

Energy conservation depends more on the management of the load connected to the D.G set than the performance of the D.G. set itself. Some of the aspects to be looked into are:

a) Load Balancing

There are a number of single-phase loads in the plant, which is fed through three-phase supply system. If the loads are not balanced the supply voltage will be heavily unbalanced though the D.G set can take up some degree of unbalanced loads. Such unbalanced supply for motors and other three phase loads will result in additional losses in the equipment and hence will make the system less efficient**. It may be noted that at no point of time the difference between maximum and minimum current in the R, Y and B phase should be more than 10%. It is necessary to distribute the loads judiciously or avoid single-phase loads in a three-phase system.**

b) Non-linear/ Fluctuating loads

Certain load causes serious output voltage variation and due to that the function of other voltage sensitive loads can be affected. For example, a thyrister converter driver or motor may malfunction if a flywheel rolling mill drive or a **compressor** is switched on. Hence it is necessary to provide a separate supply system for **such non-linear loads or at least isolate them through simple harmonic filters and transformers.**

c) Optimum loading

The efficiency curve of D.G set is almost flat above 60% load whereas below that load the fuel consumption increases drastically (Though the DG Set supplier mentions that at 25% load the f

7. CONCLUSIONS

ENERGY CONSUMPTION

Energy consumption present / expected is computed as:

PARAMETERS (As provided by the Installation Jan 07 to Nov 08)	
Annual Electricity Consumption (monthly average kWh)	364094.4
Annual Electricity Consumption (kWh) **Expected**	297876.4

SUMMARY OF ENERGY CONSERVATION OPPORTUNITIES

Electrical Savings

Recommendations	**Energy Savings**				**Estd. Investment**	**Simple Payback period**
	KWh	**Lac K.Cal**	**KL of oil equivalent**	**Rs Lacs**	**Rs Lacs**	**Months**
Reduction of Contract Demand and reduction in Maximum Demand Charges				5.0	-	Immediate
Installation of Automatic P.F. Controller				1.03	0.2	2 to 3
Reduction in Transformer loss due to Automatic P.F. Controller	1293.5			0.082	Nil	Immediate
Switching 250 KVA transformers beyond office hours	5825.4			0.37	-	Immediate

Electrical Savings						
Recommendations	**Energy Savings**				**Estd. Investment**	**Simple Payback period**
	KWh	**Lac K.Cal**	**KL of oil equivalent**	**Rs Lacs**	**Rs Lacs**	**Months**
Replacement of conventional tube lights (40w TFL) with energy efficient tube lights (28w T5)	20808			1.32	3.04	28
Replacement of conventional bulbs (60/40w GSL) with CFL lamps (18w)	10016			0.63	0.4	8
Replacement of 5 numbers 1.5 TR air conditioners	5106			0.32	1.0	37
Replacement of 2 numbers 1.0 TR air conditioners	544			0.03	0.24	84
Providing false ceiling, sun filming, leak arresting	8262			0.524	1.5	35
Higher setting (24^{o}C) of air conditioned space temperature	14364			0.91	Nil	Immediate
Total – (A)	**66218.9**			**10.2**	**6.38**	**8**