SOUTH BANK UNIVERSITY
FACULTY OF ENGINEERING, SCIENCE AND TECHNOLOGY

COURSE: MSc BUILDING SERVICES ENGINEERING

MAJOR PROJECT M

UNIT CODE: DEG-M-115

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ENERGY

CONSERVATION

FOR

Claridge's

ACKNOWLEDGEMENTS

A kind Sri Lankan that asked me to do my MSc in Building Services Engineering at South Bank University and suggested this energy conservation project for the Claridge's hotel. If he had not done so, then this project would not have come about. To you **Mr. Ranjith Rosa** ex. chief engineer for Claridge's, the greatest thanks from my deep heart.

Dr. Tony Day my course director, you taught me 'what is energy in building and how to manage it'. Thank you sir. At the same time I would like to thanks all the lectures.

Thank you **Dr. Stephen Dance** you guided me to get a valuable output from this project.

Medhanie Tesfaszion my Irrectarian friend who is an air conditioning engineer at Claridge's, you helped me in investigating the details of the building. Thank you

I gratefully acknowledge the encouragement and the support given by my brother and sisters **Janaka, Lalani and Kumudu**.

Finally I would like to thanks to my special friend **Rohan** who kept me smiling and happy, especially at times when I was struggling to find the motivation to complete this project.

CONTENT

1. ABSTRACT

No matter what is the nature or the size of our organization, we use energy. Sadly we waste energy, resulting in unnecessary energy cost and Carbon Dioxide emissions.

I hope this simple energy efficiency measurement will help to save money and CO2 emissions for Claridge's

2. SUMMARY

This report discusses the monitoring and targeting of energy consumption and calculation of energy level for Claridge's in order to asses the energy conservation programme. The object of this project is to develop the energy saving methods. Some possible energy saving proposals are described, considering both theoretical and practical situations. Especially for introducing CHP technology and CFL technology. For the CHP programme, the methods of selection and results described. In order to get on with energy conservation systems, there are two chapters describing the HVAC system and the DHW system. Waste water heat recovery systems are described to find out the most suitable system for Claridge's.

The report concludes with an account of work in progress to validate the measurement and analysis methods.

3. INTRODUCTION

3.1 BACKGROUND

I have been working as a building services engineer for the last two years at Claridge's hotel London. I joined Claridge's to do electrical based building services engineering, because I am qualified and experienced as an electrical (power) engineer. After I got this good job opportunity I felt I wanted to move forward in HVAC system and energy in the building field. So I decide at the same time to start doing MSc in Building services engineering at South Bank University. It is a good course to look forward for all building services engineers to see what they can do best for their buildings. It is now time for me present this document regarding 'how to energy conserve for Claridge's' with evaluation of the course.

3.2 PURPOSE

The main aim for doing this project is to serve the Claridge's building energy wise. Comparing to other hotels, comparing to new technology and trying to give a starting point for energy saving ideas in the building for Claridge's

3.3 METHOD

When I talking about 'Energy Conservation for Claridge's', my key point is Monitoring and Targeting of energy consumption for last two years. Then to calculate energy levels for Claridge's and compare with standard levels. Introducing the suitable Combined Heat and Power units for Claridge's and showing how much we can save energy and money. For this case I introduced CHP units under two categories. The main aim of the first option is replaced the standby generator and the second option is to optimise value by using CHP technology. After that talk about how much we can save energy annually by changing light bulbs in some areas and finally suitable waste water heat recovery system.

3.4 OUTLINE

This project is developed from energy meter readings for the last two years. My main concern of this project is monitoring and targeting of energy consumption & introducing a suitable combined heat and power plant (Chapter 2-8). Chapter 9 and 10 lighting systems and waste water heat recovery systems respectively are discussed.

4. HISTORY OF CLARIDGE'S

There has been a hotel on the site where Claridge's still conducts it's business since the year 1812. At that time it was a series of terraced houses trading under the name of Mivarts. In 1856 James Mivart retired selling the property to a Mr. William Claridge. William Claridge took over the hotel with his wife Marianne and they successfully grew the business. The portrait of Marianne Claridge still hangs in the Reading Room where she keeps a watchful eye over proceedings.

The hotel was called Claridge's Late Mivarts until 1860 when James Mivart died. It was at that point the hotel became known simply as Claridge's. The word hotel is never said helping to preserve the feel of a private house.

The Claridge's were for the most part successful, although new hotels were being built around town. No investment was made into this property however until eventually the business dropped off to such an extent it forced Claridges to agree to sell the hotel to the D'Oyly Carte family; owners of the Savoy Hotel. This they did in 1893 and Claridge's has been part of the Savoy group ever since. The terraced houses that formed the hotel were demolished and the hotel built.

The new Claridge's opened its doors on November 4th 1898.

In 1930 the new wing was added and the Front Hall altered to close in the courtyard (now the Foyer) and dispense with the Port Cochere (The horse and carriage entrance) and the hotel has remained largely unaltered since then.

The hotel has played a major part in the history of London both socially and politically. The hotel become home to exiled kings during the war, and even home to Winston Churchill after he lost the general election 1945. The majority of state banquets given in honour of her Majesty the Queen by visiting Heads of State have been held at this hotel. The hotel continues these traditions whilst welcoming an ever increasing and boarder selection of guests from around the world, as the world gets smaller.

1998 – The Centenary Year saw the hotel its in first condition since it was built. Having come through a £40 million restoration, the hotel is equipped to service the need of the modern traveller well into the 21st century, but at the same time respecting the traditions of the past where the reputation of the hotel was built. It is important to realise that reputation can only be maintained by realising that what was good yesterday, will only be acceptable tomorrow. With that ethos, complacency will never set in and were-examine ourselves daily to see how we can continually improve what we offer our guests.

5. MONITORING AND TARGETING OF BUILDING ENERGY CONSUMPTION

5.1 INTRODUCTION

Monitoring and Targeting is a disciplined approach to energy management system. Monitoring is the collection of data and Targeting is the analysis of data, leading to action. The important thing about M&T is the leading to action. Accountability is the key feature of M&T and two principle functions of the M & T are on going control of energy use and planned improvements in energy use.

Benefit from M&T

M&T can achieve an energy saving from 5% to 25% of annual energy for a little investment or even for no investment. These savings are a result from plant adjustment, operator training or improved operating practices etc.

Two key parameters for M&T system

1) Reporting period

   Weeks and months are commonly used reporting periods. But daily, shift and batch periods are also used. Reporting period is not the same as the monitoring period, for example monitoring can be done hourly and report weekly. Always reporting period is always larger than the monitoring period.

2) Number of meters

   There should be one or more meters in M&T to collect the data.

Why Computers for M&T?

Computer is an aid to M&T. Because of

- Easy storage and analysis data
- Fast reporting period
- Collect large number of data
- Accuracy
- Graphical outputs
- Easy of use

Computer System Requirements

- Personal computer
- Networks
- Hardware requirements
- PC operating system
- Software platform
- Computer security

5.2 BUILDING ENERGY MANAGEMENT SYSTEM – BEMS

This is the most powerful tool for building energy management. There are several ranges of BEMS, from individual plant room control to centralized system control. For Claridge's there is a BEMS known as 'SystemTech'.

'SystemTech' has a portion of primary roots of BEMS not fully completed. So it fails to do the main objectives of BEMS. They are,

- Monitoring system performance
- Optimization of system interrelationship with the building and its occupants
- Centralization of fault reporting

To deal with up to date energy consumptions and to achieve a good energy efficient level Claridge's need to upgrade this BEMS.

+5.3 MONITORING & ANALYSIS OF BUILDING ENERGY CONSUMPTION FOR CLARIDGE'S

Building using energy for variety of reasons. For past two years energy consumption for Claridge's (in kWh) can be shown as follows

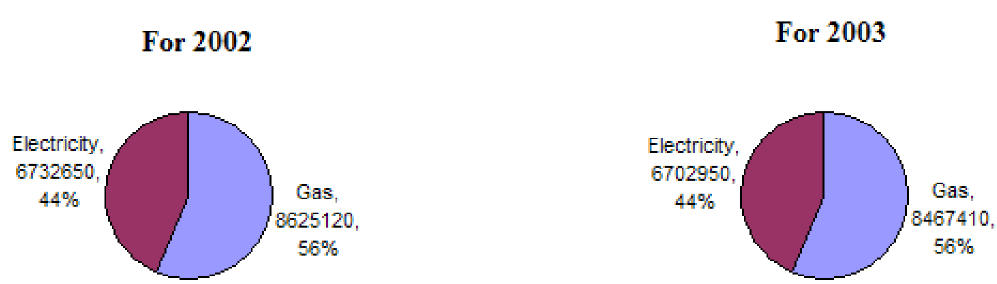


Figure 1 : Energy consumption for Claridge's for 2002 & 2003

Usage of electrical energy for 2002 & 2003 can represent by thumb graph as follows.

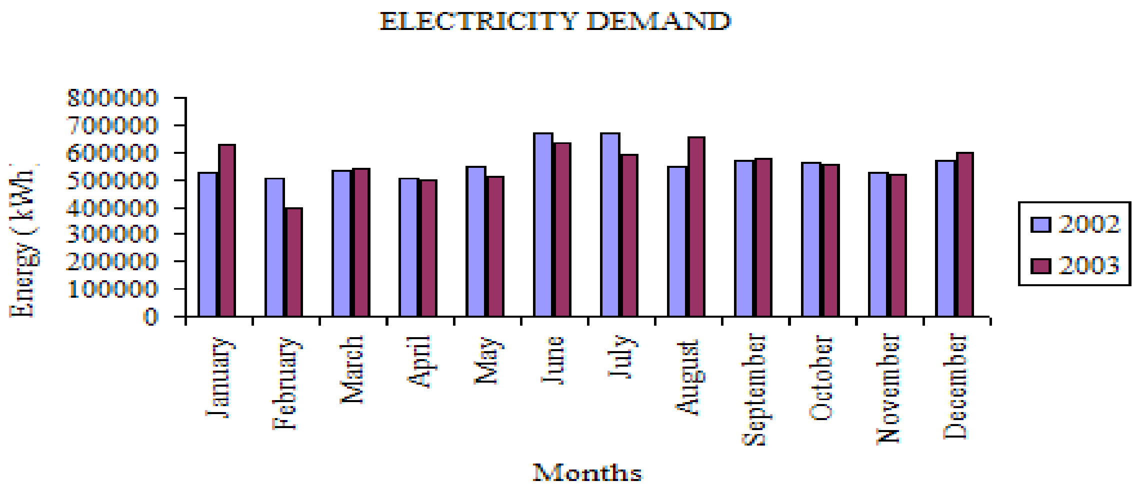


Figure 2 : Electricity demand for year 2002 & 2003

There is higher electrical energy usage for June, July and August months, because of air conditioning demand. Normally December & January experiences high electricity due to more social functions carrying on these months.

In Claridge's there are three main groups using gas

1) Space heating & domestic hot water (dhw)
2) Main production kitchen
3) Staff canteen kitchen

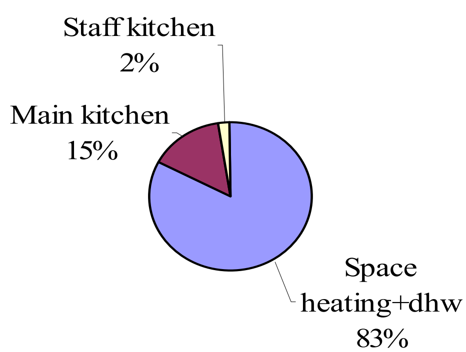


Figure 3 : Gas consumption for Claridge's

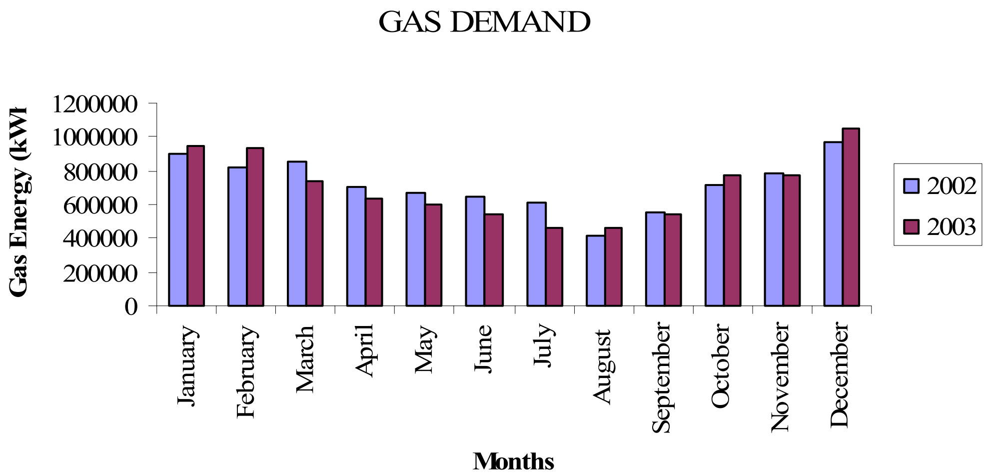


Figure 4 : Gas demand for year 2002 & 2003

There are lower gas demands for summer months and higher for winter. This is because the demand of space heating in the winter season. However January is colder than the December, but gas demand for December is higher than the January. A reason for this could be more functions (occupancy) carried out in December than in January in Claridge's

Space heating and domestic hot water demand for past two years as follows

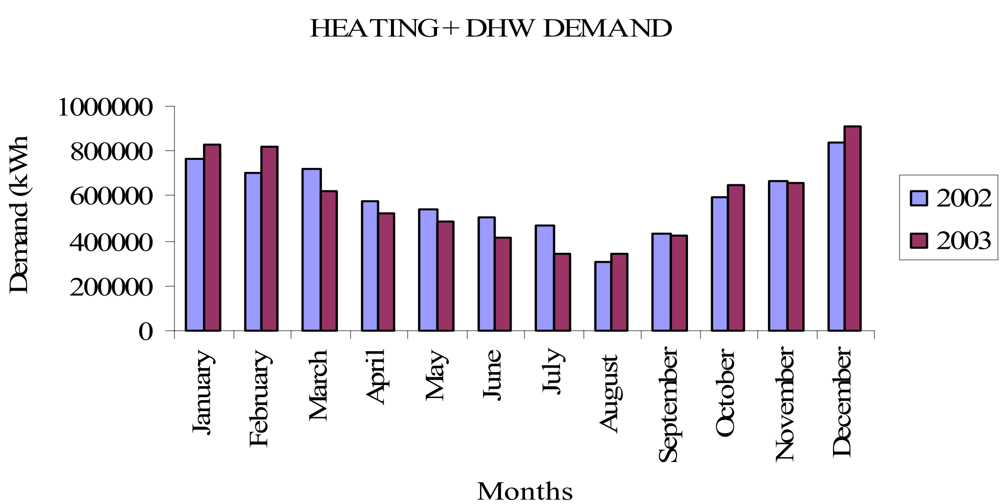


Figure 5 : Thermal demand for year 2002 & 2003

There is a strong variation with outdoor temperature for space heating and domestic hot water demand. For summer we not need space heating, only domestic hot water. We can see how this varies through last year by following graph.

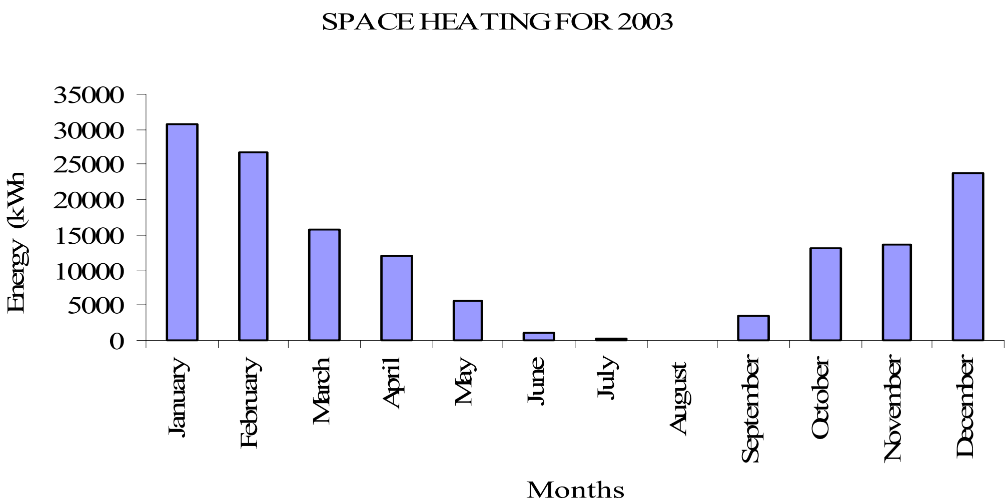


Figure 6 : Space heating demand for year 2003

5.4 ENERGY LEVEL

5.4.1 Electricity

Calculation for Claridge's

Annual electricity consumption for year 2002 = 6732650 kWh
Annual electricity consumption for year 2003 = 6702950 kWh

Floor area = 27657.81 m^2

Annual electricity energy consumption level for year 2002 = **243.43** kWh/m^2
Annual electricity energy consumption level for year 2003 = **242.35** kWh/m^2

Recommended level for a luxury hotel
(According to good practice guide 36)

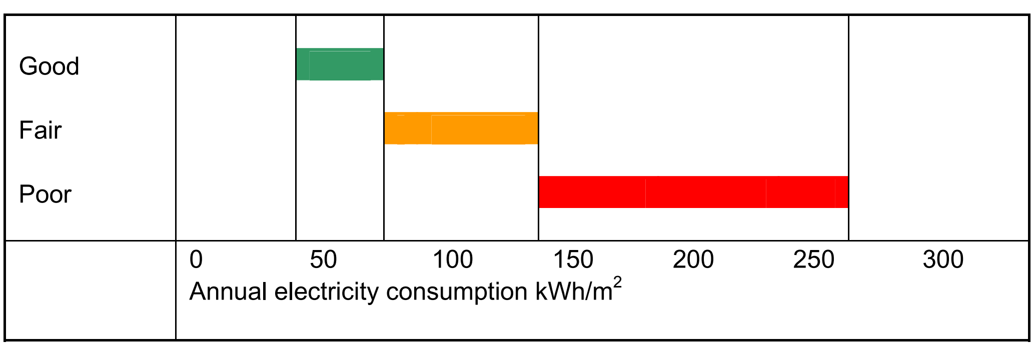


Table 1 : Recommended electrical energy level

Where are we according to GPG 36?

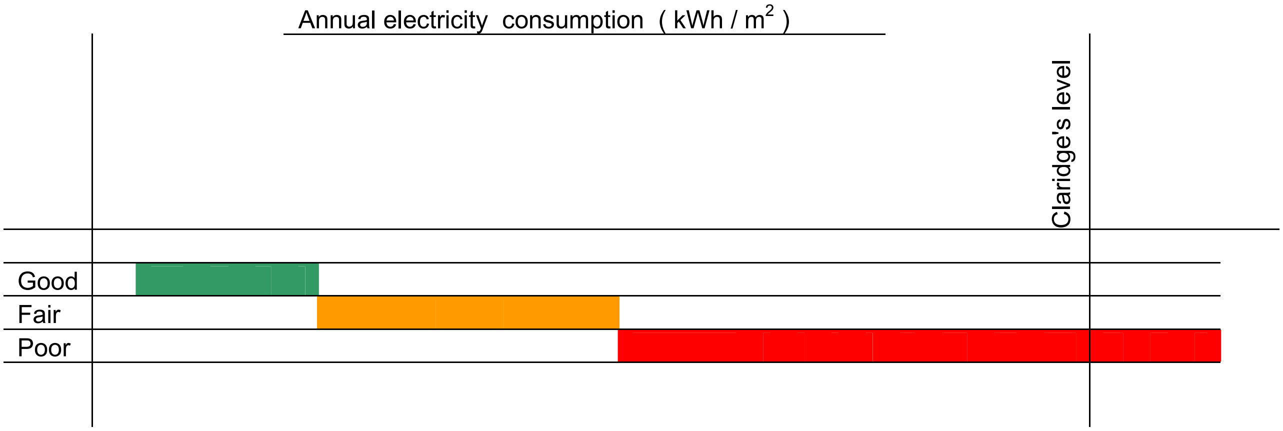


Figure 7 : Claridge’s electricity energy level

According to these results we are in a very high electrical energy consumption level. We have to improve this energy level.

5.4.2 Gas

Calculation for Claridge’s

Annual gas consumption for year 2002 = 8625120 kWh
Annual gas consumption for year 2003 = 8467410 kWh

Floor area = 27657.81 m^2

Annual gas energy consumption level for year 2002 = **311.85** kWh/m^2
Annual gas energy consumption level for year 2003 = **306.15** kWh/m^2

Recommended level for a luxury hotel
(According to good practice guide 36)

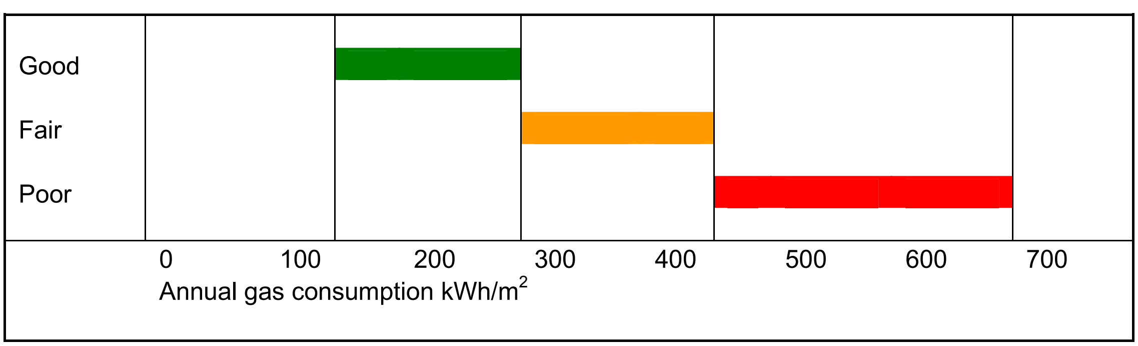


Table 2 : Recommended gas energy level

Where are we according to GPG 36?

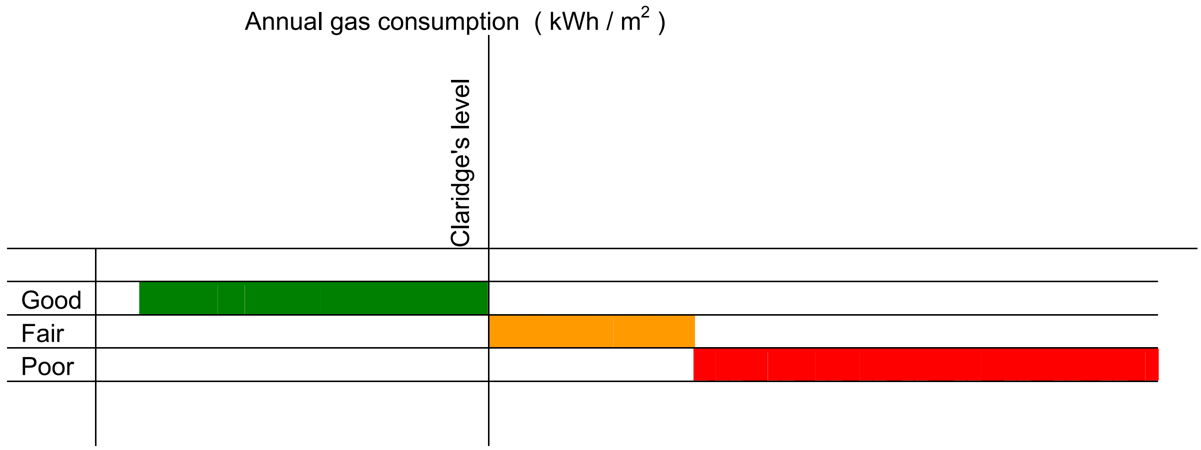


Figure 8 : Claridge's gas energy level

According to these results on figure 8, we are on the margin between fair and good gas energy consumption level. We are still not at a very good gas consumption level and we want to improve this gas consumption level.

5.5 CLARIDGE'S ENERGY SIGNATURE

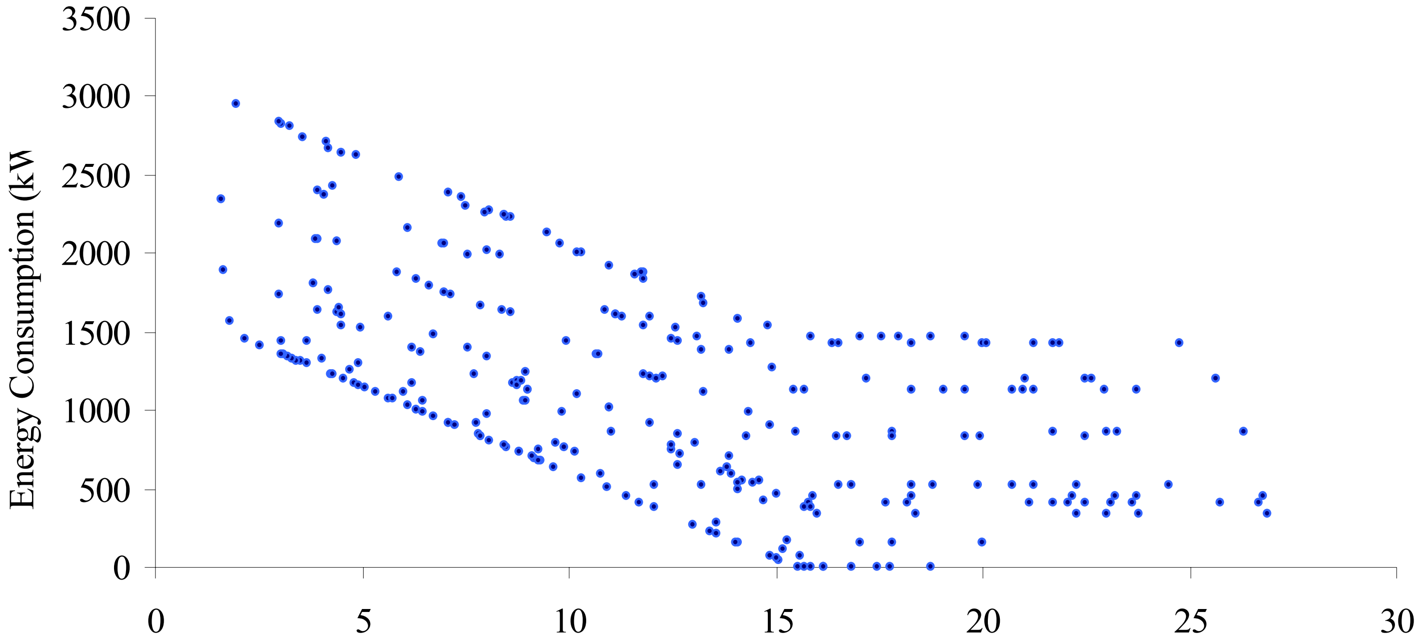


Figure 9 : Claridge's energy signature

5.5.1 To find the base temperature for Claridge's

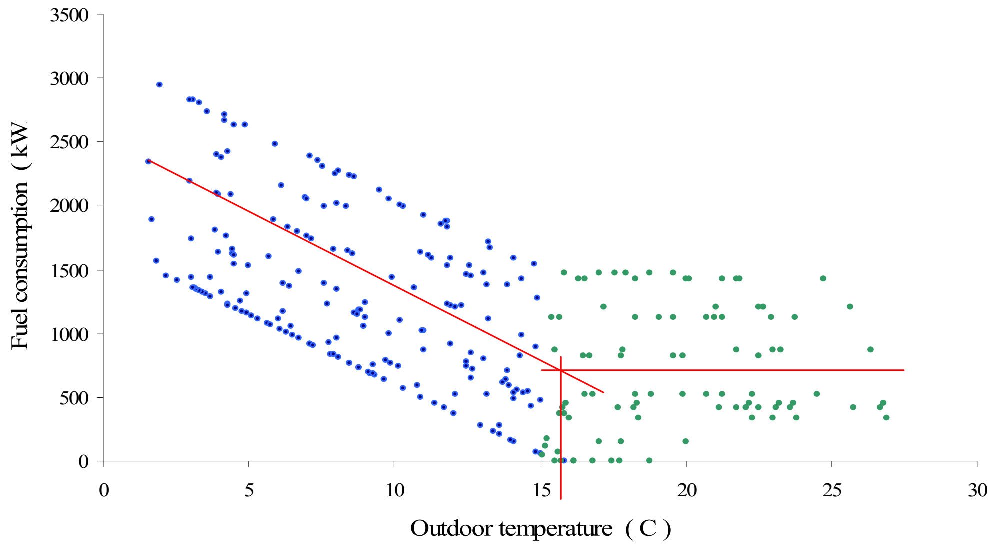


Figure 10 : Base temperature for Claridge's

According to the above graph base temperature for Claridge's is 15.5 C.

5.5.2 Building Performance Line for Claridge's

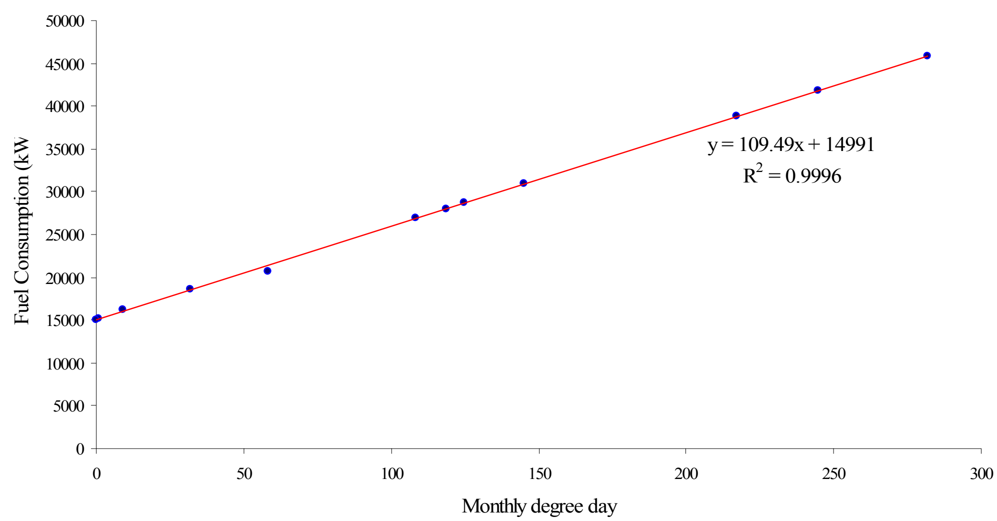


Figure 11 : Building performance line

The slope of this building performance line given for fuel consumption per a degree day and intercept denote fuel consumption which does not depend on the outdoor temperature. Basically this intercept denotes the energy for domestic hot water usage. In future if savings are made in this building the points would lie below this line and make the slope less steep and if fuel consumption increases the points would lie high above this line.

I would like to point out the value of correlation coefficient for this building performance line. i.e. r^2 is 0.9996. Which is very close to one meaning that this best fit line has a high accurate degree. So r is 0.9998. As this is extremely close to one, perfect correlation, there was a high degree of correlation between x and y.

5.6 Thermal & Electrical Load Profiles for year 2003

The following five pages showing thermal and electrical load profiles monthly and yearly for Claridge's. These two demands varying in particular patterns during a day but values are changing with months.

According to figure 12, 13 and 23 thermal demand is always higher than the electricity demand in December, January and February months. Within these three months January (figure 12) showing the highest thermal demand of 2800 kW. Further analysis of figure 12, in January the difference between heat and electricity demand varies from 700 kW to 2000 kW of power.

In March and April months within 1300 hrs to 1800 hrs thermal demand is less than the electricity demand and in May within 1100 hrs to 1800 hrs thermal demand is less than the electricity demand. This is showing by figure 14,15 and 16. Figure 14 shows the maximum thermal demand variation of 1900 kW of power in March.

From January to May electricity demand varies between 500 kW to 1000 kW of power. This is clearly showing by figure 12,13,14,15 & 16.

In June, July, August and September months electricity demand is more than the heating demand, because of summer cooling loads. The highest electricity demand of 1000 kW occurring in midday of June and July (figure 17 & 18). According to figure 17, 18, 19 & 20 , within 0800 hrs to 1130 hrs and 1730 hrs to 2130 hrs thermal demand is more than the electricity demand, because of domestic hot water requirements.

Further analysis of figure 21 & 22 , it is clear thermal demand is gradually increasing while electricity demand is a constant for October and November.

Figure 24 shows the variation of thermal demand for each month. Each month has the same pattern of variation with different values. Winter months have higher values and summer months have lower values for thermal demand curve. Figure 25 shows the variation of electricity demand for each month. Again these demand curves have same pattern.

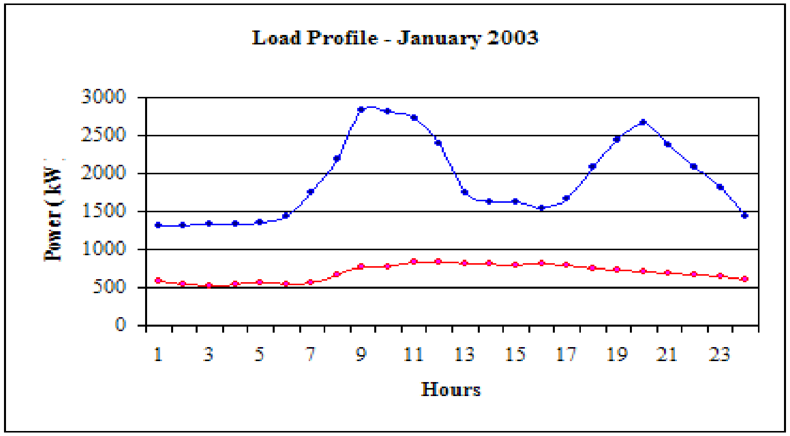


Figure 12

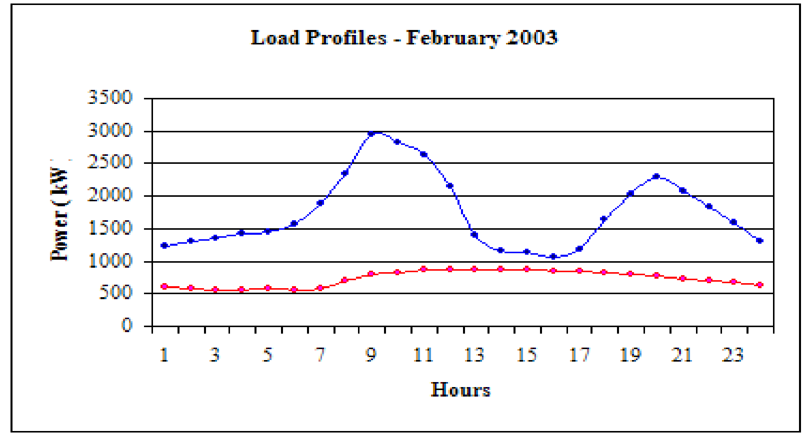


Figure13

denote by thermal demand

denote by electricity demand

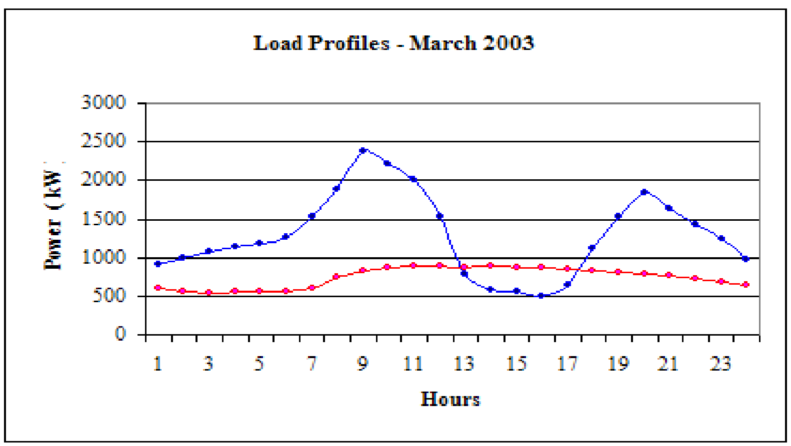


Figure 14

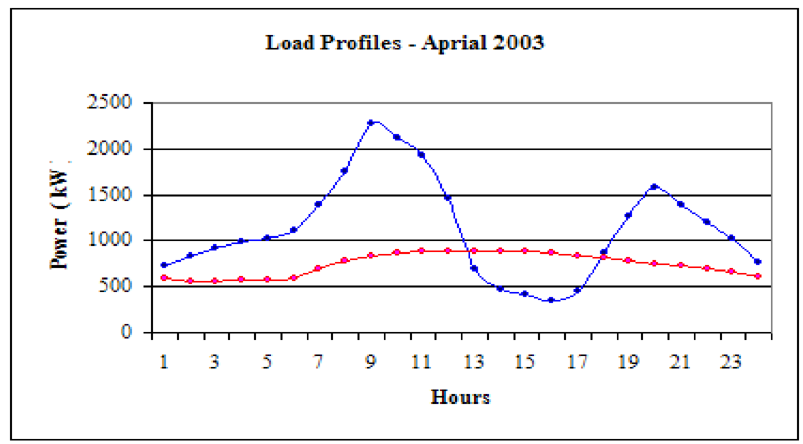


Figure15

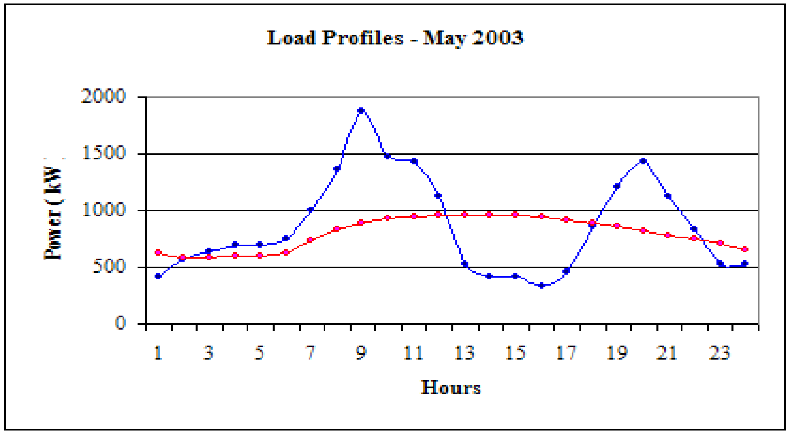


Figure 16

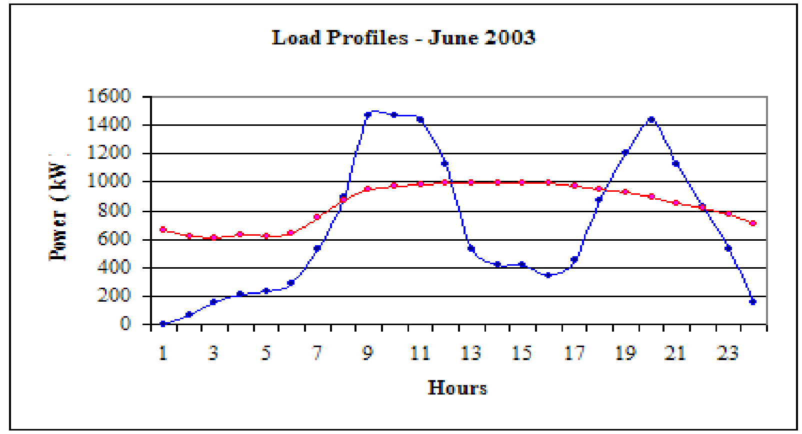


Figure17

denote by thermal demand

denote by electricity demand

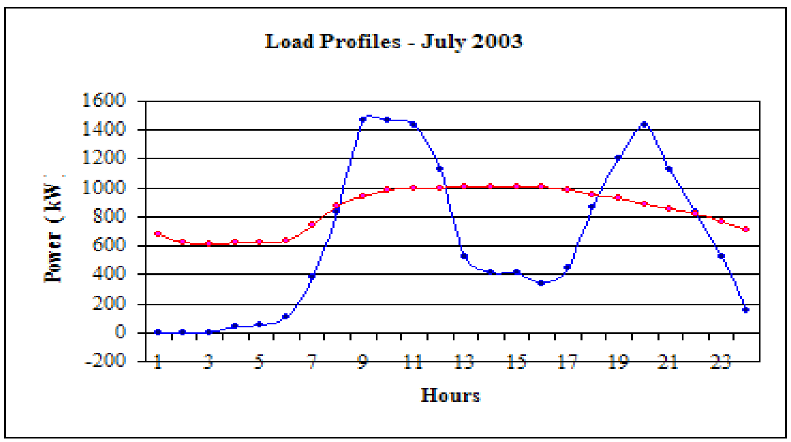


Figure 18

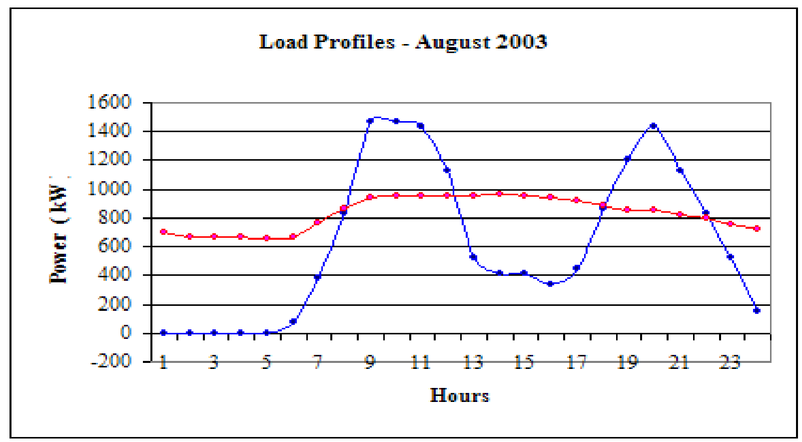
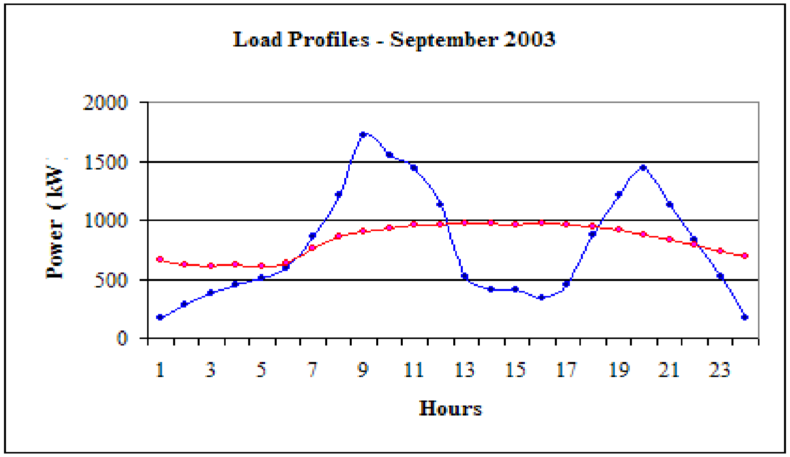


Figure19



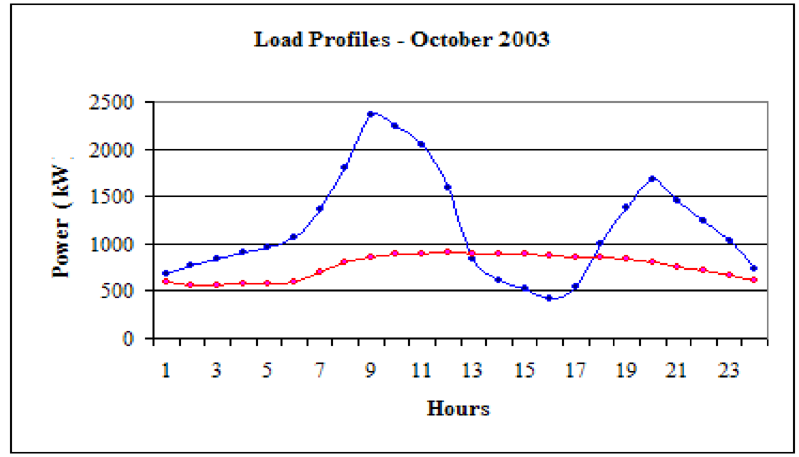
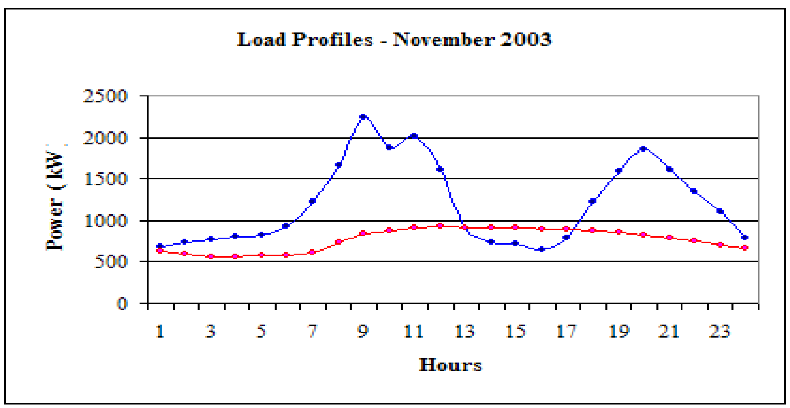


Figure 20

denote by thermal demand

denote by electricity demand

Figure21



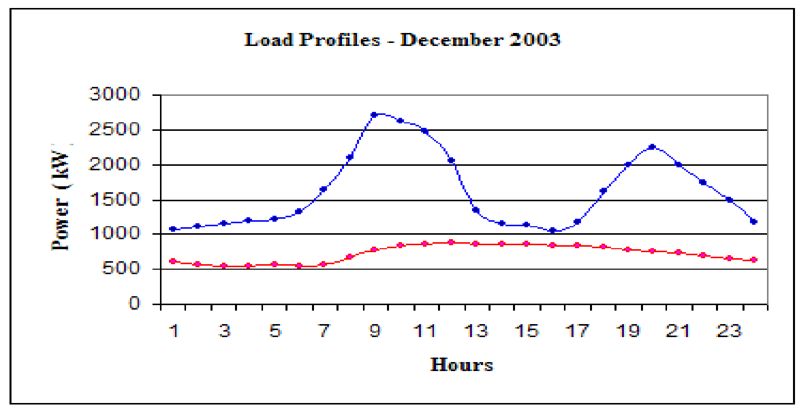


Figure 22

Figure23

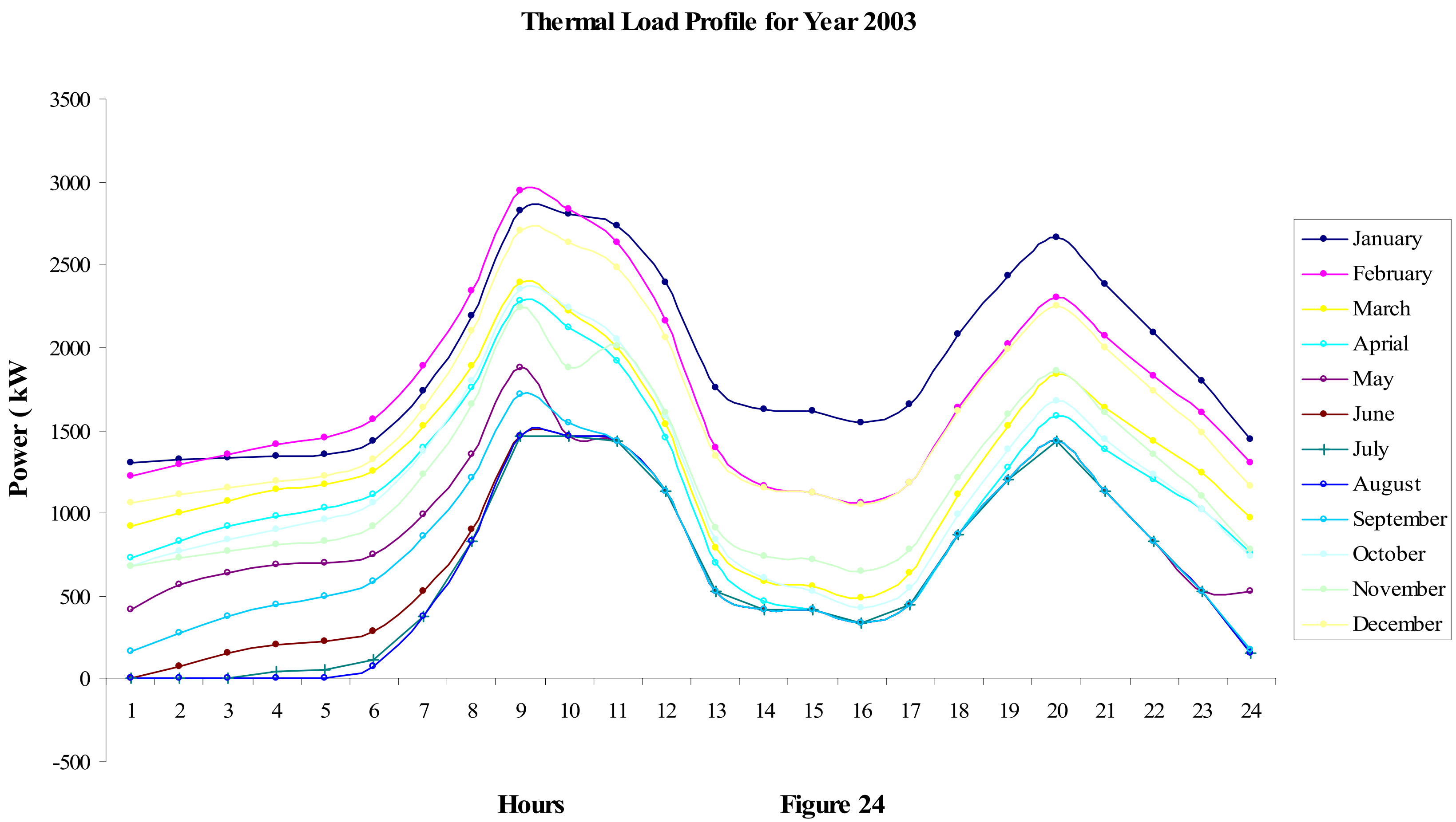

Thermal Load Profile for Year 2003
Power (kW
3500
3000
2500
2000
1500
1000
500
0
-500
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Hours
January
February
March
Aprial
May
June
July
August
September
October
November
December

Figure 24

Electrical Load Profile for Year 2003

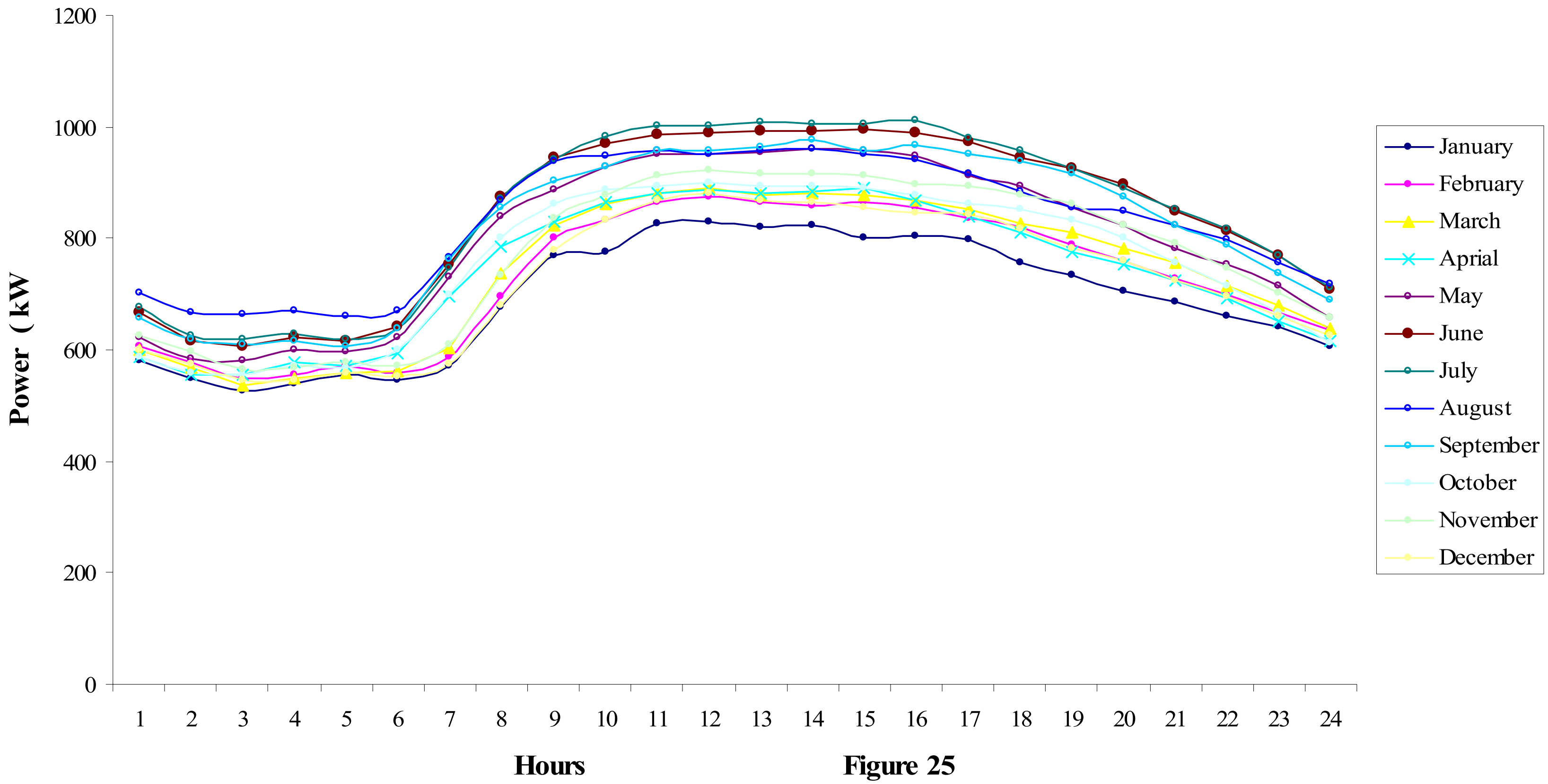


Figure 25

6. HEATING, VENTILATION & AIR-CONDITIONING SYSTEM - HVAC

6.1 INTRODUCTION

HVAC (Space Heating, Ventilation and Air Conditioning) System using more than 20% of the nation's total energy consumption and over 60% of the energy consumed in buildings. This consumes energy ten times more than the lighting. Basically there are two HVAC systems as package units and central HVAC system. Normally these package units contain a furnace, refrigeration compressor, condenser and fan coil unit designed to air-condition a specified zone. Central system may exceed 20 000 tons of refrigeration capacity and package units limited to 50 tons. Package units are best suited to low, sprawling buildings and small buildings whose total heating and cooling loads would not justify the heavier capital investment in a central HVAC system. Central HVAC system are most efficient in compact, multi-story buildings where the higher heating and cooling loads.

6.2 PACKAGED AIR CONDITIOING SYSTEM

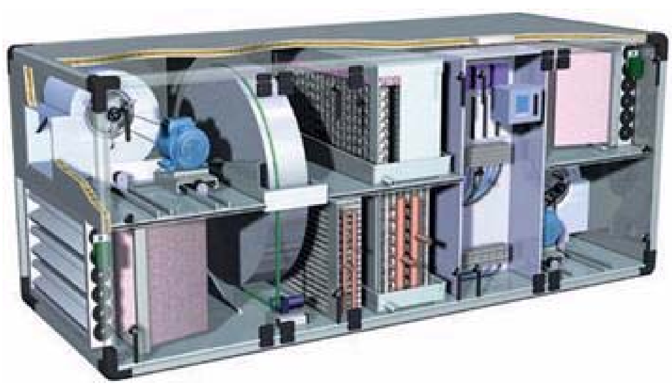


Figure 26 : Packaged air-conditioning unit

Energy consumption of a air conditioning system depend on number of building design aspects

- The form and fabric of the envelope, especially in relation to the solar gains to the space
- The efficiency of the cooling plant
- The method of cooling media distribution
- The design of distribution network
- The efficiency of the prime movers
- The control system

6.3 CENTRALISED AIR-CONDITIONING SYSTEM

This is the traditional air conditioning system. Theoretically, centralized air conditioning systems provides an atmosphere with controlled temperature, humidity, and purity at all times for any weather conditions. Main cooling and heating equipments are centralized. Widely applications for this system are in theaters, stores, restaurants, and other public buildings. Such systems, being complex, generally must be installed when the building is constructed. In recent years, these systems have increasingly been automated by computer technology for purposes of energy conservation. Centralized air conditioning system vary according to air distribution style.

6.3.1 Constant Air Volume system - CAV

If the building has even demand for cooling or heating, this building can be treated as a single zone. Therefore conditioned air will be delivered evenly through out the space. If a large zone such as an open plan space requires cooling through out the space then Single zone system or Constant volume system can be used. Since there is no diversity in supply air volume, significantly more air is circulated than required to meet the cooling load, even at design conditions. Constant volume systems use more fan power annually than VAV systems. Constant volume systems require some form of centralized air handling units. These can be indoor air handlers, vertical self-contained units, or rooftop units. For vertical self-contained & roof top AHU's use more cooling loads , because of decentralization of mechanical cooling. Most can use either air or water side economizers to take advantage of free cooling during mild weather.

Constant volume-variable temperature systems are typically used in small-to-medium projects of one or two stories. They are also used for air conditioning manufacturing plants. Common applications include:

- Retail
- Small office building
- Manufacturing

6.3.1.1 Advantages of CAV air conditioning system

- Easy to design & install
- Dedicated unit per zone offers good temperature control and redundancy
- Air or water side economizers can be added to the design to minimize mechanical cooling during cooler weather.
- The main air handling systems can accommodate the ventilation air, avoiding dedicated ventilation equipment
- Relatively easy to change system for tenant work
- No piping, electrical wiring and and filters are located inside the conditioned space

6.3.1.2 Disadvantages of CAV air conditioning system

- Supply air volume cannot be varied
- Rooftop and self-contained systems offer limited cooling diversity among different zones.
- Requires additional duct clearance which can reduce the usable floor space

6.3.2 Variable Air Volume system - VAV

Where the demand for cooling differs between spaces, control of individual temperatures is achieved by varying the amount of cooled air allowed to enter the room. This is achieved using a variable air volume system. The central air handling unit supplies air to satisfied the room design condition through a motorized damper. This damper working depends on room condition & varies the volume of air.

6.3.2.1 Advantages of VAV air conditioning system

- Making it more attractive as energy considerations and design flexibility
- It is suitable for partial operation of a building such as overtime or weekend usage of a partial area

6.3.2.2 Disadvantages of VAV air conditioning system

- Difficulties in maintaining ventilation rates
- Not very much suit where there are high latent heat gains

CAV and VAV both using in Claridge's.

Pros & Cons for centralized air conditioning system

Pros	Cons
Durability of system	High maintenance
Design feature	Distribution loss
Low noise level	Need more space
	Difficult to accommodate within the structure in existing system
Central filtration	
Free cooling is possible	

Table 3

Claridge's using Centralized air-conditioning system because of durability of the system and more consideration of design features of the hotel. There are four fan coil pipe system using in guest rooms. Chilled water for cooling coil provide by chillers on the roof of the building and hot water for heating coil provide by boilers in the basement.

6.4 COMPONENTS OF THE AIR CONDITIONING SYSTEM

6.4.1 Air Handling Unit - AHU

The heart of the centralized air conditioning system is Air Handling Unit.

The most basic AHU, contains a fan, a cooling coil, heating coil and an air filter enclosed in a box-structure. When air is passed through the cooling coils, water usually condenses out at the surfaces of the coils. Collection pans are installed below the cooling coils to collect any condensed water. This water is removed through drains pipes. Many enclosures are sound insulated and are installed on vibration damping pads. Many others have damper vanes for controlling the airflow. The most common AHU's have their fans and motors enclosed inside the box. Other specialized AHU's have motors outside the box. There are some with steam coils too.

Figure 27 : Air handling unit

In Claridge's , there are twenty one nos. of AHU's to provide quality air environment.

6.4.2 Mixing Box

Mixing box is a part of the air handling unit, which recirculated and fresh air mixed before entering an air-handling unit. The return fans pulls air from occupied building space through the return air ducts. Some of this air is exhausted outside through the exhaust air damper, while a small amount of it continues through the air handling unit to mix with air drawn in from outdoors. This mixture of outside air and return air, before additional heating and cooling, is called mixed air.

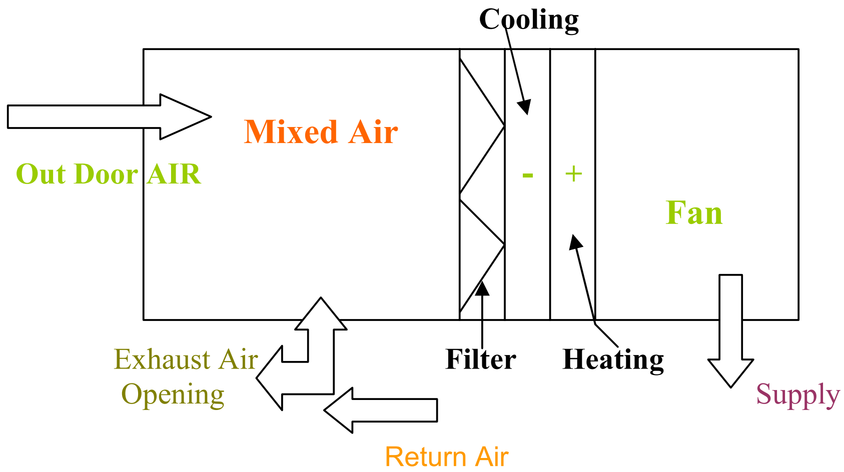


Figure 28 : Block diagram for mix air in AHU

In the typical mixing box, outside air and return air pass through steel damper blades before entering the mixing chamber. Once in the chamber, the two air streams are expected to blend and then continue through the rest of the air handling system at a consistent temperature. Mixing box should provide sufficient mixing so that low temperature outside air should mix with relatively warm return air. In the typical mixing box, control of mixing rate control by manual or motorized damper. Control of mixing box gives us opportunity to save energy. Claridge's always using motorized valves for control of mixing air.

6.4.3 Air Filter

Outer air may contend smokes, fumes, mists, fibers, dry granular particles and, sometimes, living organisms, such as plant pollens, mold spores and bacteria. This matter freely flows into the human system with each breath taken. If not controlled, these contaminants can be unpleasant at best and life threatening at worst.

Filters can effectively remove these offenders from the air. They are normally part of the air conditioning system and typically are located in the air-handling unit.

<u>Filter Types</u>

Mechanical filters - Involves passing the air stream through a filter media
Pad filters
Panel filters
Anti-microbial filters
Bag filters
High efficiency particulate air filters (HEPA)

Electrostatic filters - Remove dust from air by electrostatic attraction
Electrostatic filter have a mechanical pre filter to remove large parts of the dust. Replacement plates is high cost.

In Claridge's, panel and bag filters are using for air filtration. Because of easy to replace and cheaper.

Panel filters can be easily slid into position in a metal holding frame in the AHU. This is the filter we are mostly using in Claridge's AHU's.

Figure 29 : Panel filter

6.4.4 Heating Coil

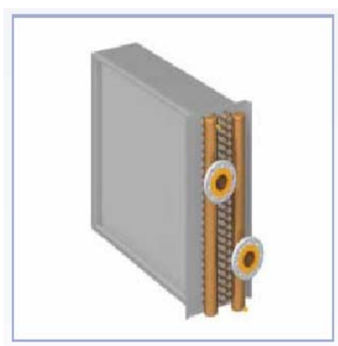


Figure 30 : Heating coil

We can use heating coil to heat the incoming airstreams. Heater coil can be a simple electrical heater or consist of different copper pipes, which conveying heated water between flow and return pipes. When hot water flows through these pipes heat transfer between the hot coil to air flows. Copper fins increase the coil surface to help heat transfer.

Temperature sensor on heated or extract duct gives a signal to control unit and it set the position of the valve of supplying hot water to the heater coil.

6.4.5 Cooling Coil

Cooling coil can be either a direct expansion cooling coil or it may be a water coil similar to the heating coil described above. Difference from the heating coil is , here we used a antifreeze (normally glycol) circulates through it and this mixer cooling by chiller

6.4.6 Diffusers

This is the last important part of the air conditioning system, which helps to effective input of conditioned air into the space. Diffusers should work under the noise level it means air should enter the space quietly. Diffuser can supply comfortable environment, if it is suitable one. Before testing the air conditioning system, we need to wait for the system to stabilize itself, after that diffuser must not cause uncomfortable physical and thermal sensation. After all, diffuser should help to effective air distribution.

Types of diffusers:

- Adjustable air grille
- Swirl diffuser
- Staircase diffuser
- Square ceiling diffuser

In Claridge's we are using all the above mentioned types of diffusers in different places.

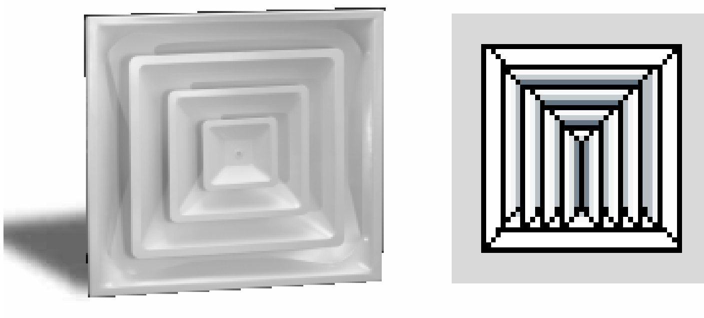


Figure 31 : Square ceiling diffuser

Positioning of supply diffusers are very important, even well designed air conditioning system can be useless due to incorrect placing of diffusers.

6.4.7 Extract Grilles

Extract grille make return air path of the air conditioning system. At extract grille air has lower velocity than the incoming air & location of grilles has less critical than the diffusers. But their positioning can be used to improve the effectiveness of ventilation system. The grille should not placed near to diffusers, this make short circuit the system and not having the opportunity for mix the existing room air.

6.4.8 Damper

We can use damper to control the amount of outdoor air that enters the system, the amount of air exhausted from the system, and the amount of return air from the room that is circulated through the system.

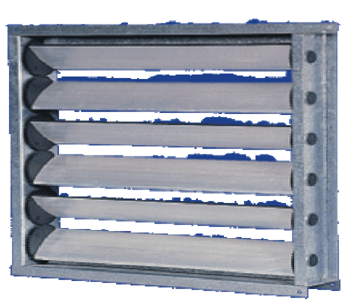


Figure 32 : Damper

They are constructed from an array of blades which rotate about their central axis like a lured window system. The rotation is driven by motorized actuators in response to signals. Basically there are two types of dampers as butterfly dampers and multi blade dampers.

6.4.9 Fan

Fan creates air movement by using an electric motor. We can use fan to deliver warm or cold air to the main hall during a year. Fan performance depends on the size, air delivery efficiency, pressure, speed and power input at a given air density. The size of fan can change energy consumption and system efficiency.

Type of fans

Figure 33 : Centrifugal fan

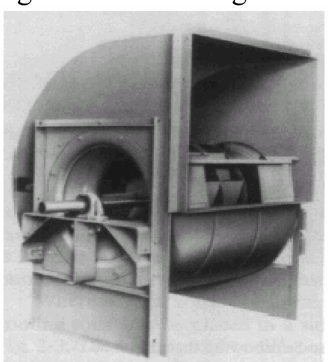


Figure 34 : Axial fan

[Ref : http://www.arche.psu.edu/courses/ae310/post-ch4.pdf]

In Claridge's using both types of fans for AHU's. But widely using centrifugal fans.

6.5 CONTROL SYSTEM

Control System must design to supply and maintain a comfortable building interior environment with simple , inexpensive as possible and efficient way. Control system is essential part for centralized air conditioning system.

Basic control hardware are

- Pneumatic systems
- Electronic control systems
- Direct digital control systems

<u>Sensing devices</u>

Placing of sensing devices more important for a better control system.

Temperature
Humidity
Pressure
Flow
Enthalpy

<u>Control devices</u>

Electric motor - By controlling voltage, control the power

Solenoid valves- By varying the coil voltage, varying the position of the spindle

Valves - An equal percentage valve would be most suitable for this a/c System. Because it has a closer relation ship between valve lift and heat output.

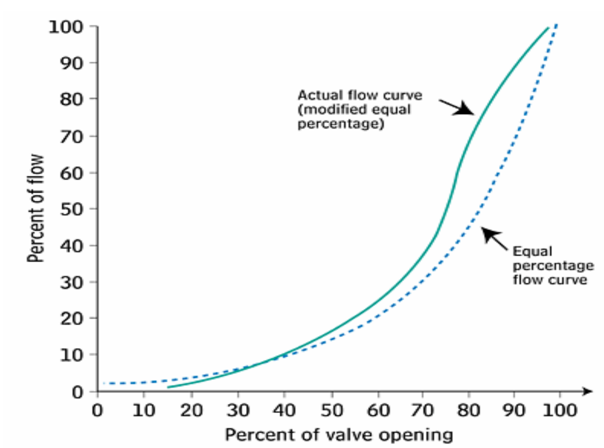


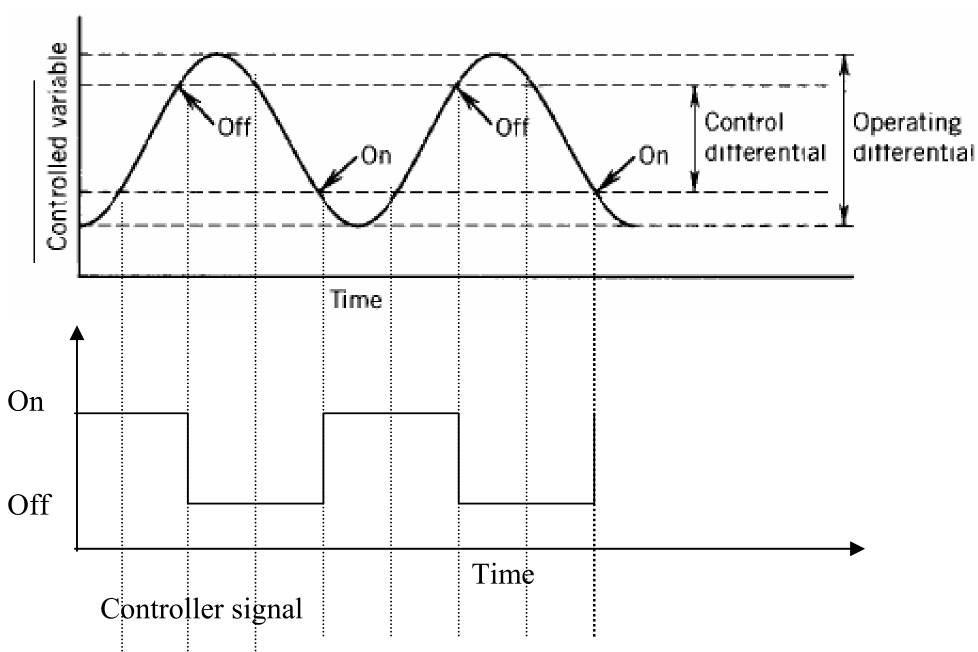
Figure 35 : Characteristic of equal percentage valve

Dampers - There are two forms of control damper, parallel and opposed Blade types

6.5.1 Controller modes of operation

Two position control

A typical application for two position control system is on/off switching. As a example simple switching thermostat provides two signals, opening contact below the set point & closing contact above the set point.

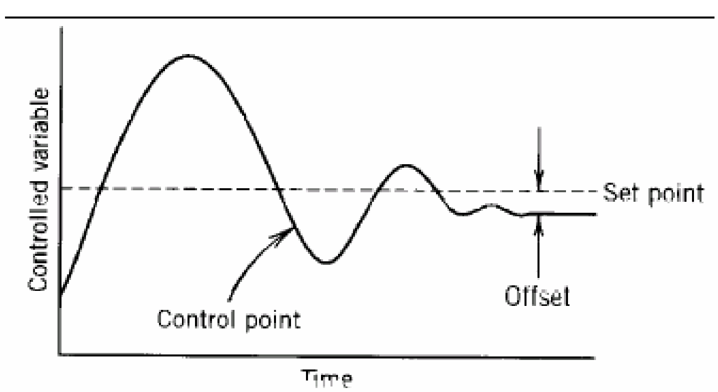


[Ref : http://www.arche.psu.edu/courses/ae310/post-ch4.pdf]

Figure 36 : Two position control system

Proportional Control

For this form of control output signal from the controller is proportional to the input signal from the sensor



[Ref : http://www.arche.psu.edu/courses/ae310/post-ch4.pdf]

Figure 37 : Proportional control system

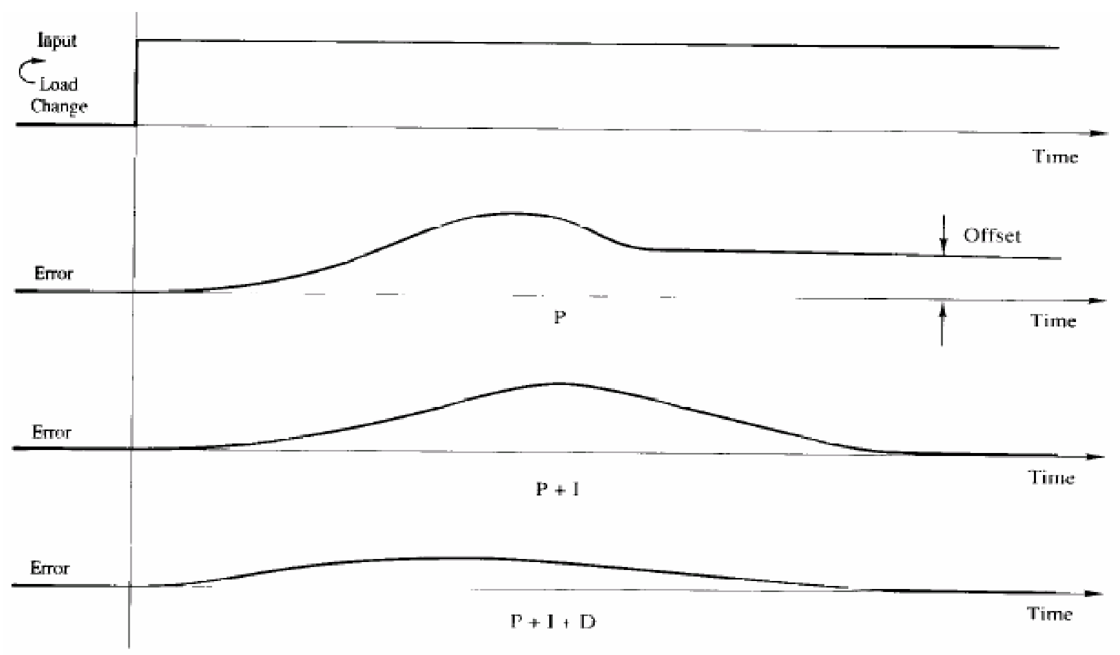
Integral Control
This is an important addition control to proportional mode. With integral action there is continuous movement whilst deviation from the set point.

Derivative Control
This is a further development of integral action. Controller output is a function of the rate change of variable. Normally this form of control (like integral control) , combination with others

Proportional plus Integral Control
This system designed to eliminate the offset.

Proportional plus Integral plus Derivative (PID) Control
This type of mode more used where there are sudden or significant variable changes. So this system can do great control of air conditioning system.

Comparison of P, PI and PID controller response to input step change



[Ref : http://www.arche.psu.edu/courses/ae310/post-ch4.pdf]

Figure 38 : Comparison of P,PI & PID controllers

Claridge's using PID control system for controlling of AHU's

7. HOT WATER SYSTEM FOR CLARIDGE'S

7.1 LOW PRESSURE HOT WATER HEATING SYSTEM

LPHW for space heating and DHWS primary heating is generated by six gas-fired hot water boiler units. Hot water generated by the boilers is circulated through a reverse return boiler primary circuit from which separate flow and return connections are taken to

- A general LPHW heating circuit
- A bedroom LPHW heating circuit
- The primary sides of four DHWS heat exchangers

Both the general and bedroom heating circuits are connected into the primary circuit. Both circuits are served by standby pumps with 3-way flow and return mixing valves to allow flow temperature to be varied. The general heating circuit provides circulation to air conditioning and ventilation plant heating coils. The bedroom heating circuit provides circulation to bedroom heat emitters.

Primary circulation through the DHWS heat exchangers is maintained by individual pre-piped primary circulating pumps provided as an integral part of each heat exchanger unit.

The complete system has been designed as a closed, pressurised installation with an automatic pressurisation unit, operating to maintain a pressurised cold fill and absorb system thermal expansion.
A facility for chemically dosing the system with water treatment chemicals is provided by a side-stream dosing pot connected across the primary circuit flow and return.

7.2 DOMESTIC HOT WATER SERVICES

Hot water to meet the hotel's domestic requirement is provided by a central domestic hot water service (DHWS), an installation designed to use LPHW as a primary heating medium and centred on four water to water heat exchangers and buffer storage vessels.

Each plate heat exchanger incorporates a pre-piped primary circulating pump, a motorised control valve, control and high limit thermostats and a pre wired control panel housing monitoring indicator lamps, temperature controller and local selector switch.

The primary sides of the units use LPHW from the boiler primary LPHW circuit as a heat transfer medium and are connected in parallel to the boiler primary circuit through individual valve flow and return connections. The secondary sides of the units are connected in parallel by valve flow and return connections to DHWS secondary distribution circuit flow and return header within the boiler house. Two cylindrical buffer vessels are connected in parallel across the flow side of the DHWS secondary header to even out fluctuations in hot water demand.

8. COMBINED HEAT & POWER CHP

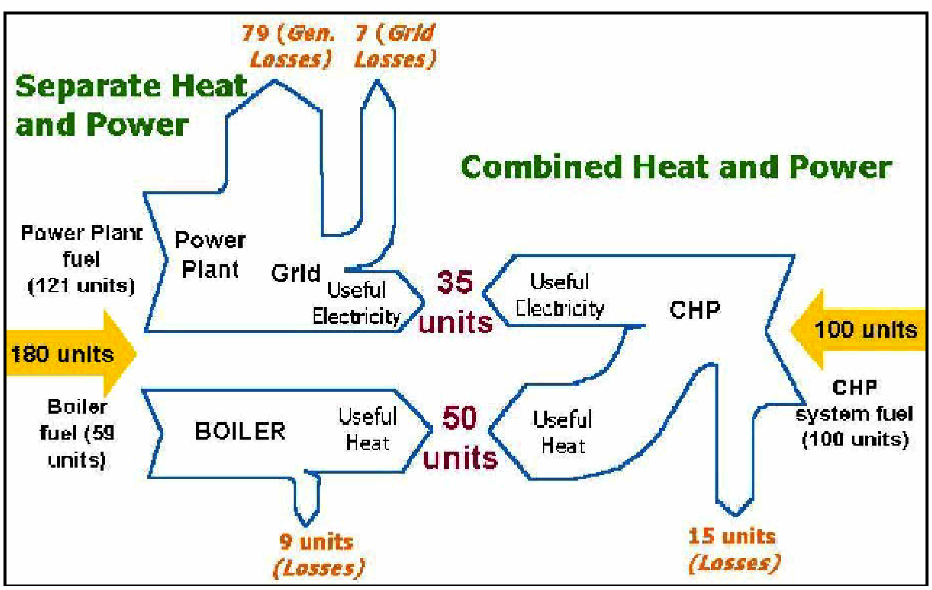
8.1 INTRODUCTION

What if a technology could cut energy costs by 40 percent, reduce pollution and greenhouse gas emissions by 50 percent, increase energy efficiency by 20 percent, and pay for itself in less than five years? Such a technology exists — we call it Combined Heat and Power or "CHP"

CHP is profitable, and good for the nation as well as for the environment.

Electrical power is generated by some form of heat engine in the UK. This heat engine should be steam, gas or combustion. However electrical output of these engines is small compared to supply energy. The remainder is rejected to the environment as waste heat.
In Combined Heat & Power plants this waste heat is converted into useful heat. This is the main difference between the conventional power plant & the CHP plant. This is not a new technology but gained renewed interest following the advent of 1983 energy act.
CHP offers significant energy savings compared with the supply of electricity & heat from conventional power stations and onsite boilers. A comparison of used & wasted heat units between conventional & CHP plants can be expressed by the famous Sankey diagram shown below.

Figure 2. Energy Flows in a Typical CHP System



Source: Kaarsberg and Elliott (1998)

Figure 39 : The way of energy flows in a typical CHP system

This wasted & used heat can be presented as a percentage on pie charts as below.

Figure 40 : Heat energy consumption between convention & CHP

Great advantages for the building by introducing a CHP

- Improvements of energy levels
- Improvements of secure of standby electrical supply
- Minimize the carbon emissions to the environment

CHP unit has three fundamental items

1) A prime mover
   This is the heart of the CHP plant & drives the electricity generator.
2) An electrical generator / alternator
3) Equipment for heat recovery

To cover-up above three main criteria CHP covering range of technologies.
According to prime mover selection we can categorise five main plants.

1) Gas turbine
2) Reciprocating engine
3) Steam turbine
4) Micro turbine
5) Fuel cells

According to heat recovery system there are three main types

1) Steam
2) Hot water
3) Direct exhaust

To provide a quality CHP unit, it needs to have
Automatic running controls &
A safety & monitoring control system

8.2 DIFFERENT TYPES OF CHP PLANTS

8.2.1 Reciprocating Engine

Reciprocating engines are the most efficient & widely used prime movers in a CHP system. The two most common types of Reciprocating engine is the spark ignited engines & compression ignited engines. These engines can supply power from a few kW's to several MW's. The output of the compression ignition engine is up to 15 MW & for the spark ignition engine is up to 2 MW. The cooling system for compression ignition engine is more complex than the spark ignition engine.

Reciprocating engines produce out of balance & more noise. Therefore these engines need supports and foundations specially designed for absorb the vibration noise. Noise is better than gas engines but this low frequency noise is disturbing to the human ear. That is why these machines may need extensive acoustic shielding especially for in house installation. According to the nature of these engines they have more moving parts and so these machines need running as well as shutdown maintenance.

8.2.2 Steam Turbines

Steam turbines are one of the most versatile & oldest prime mover technologies. Steam turbines require a source of high pressure steam. That is produced in a boiler or heat recovery steam generator.

8.2.3 Gas Turbines

The gas turbine has been more widely used as a prime mover for large scale CHP in recent years. The usable heat power ratio ranges from 1.5:1 to 3:1 depending on the type of gas turbine. This gas turbine requires more air than fuel combustion and so exhaust gases contain more oxygen. This oxygen can burn more fuel & it brings up the heat power ratio to as high as 10:1. This may cause valuable flexibility of heat loads & suit higher temperature applications. Traditionally gas turbines served two applications as aero & industrial.

Gas turbines are available for a wider range of output, 500 kWe to 20 MWe. For applications less than 1 MWe, gas turbines unlikely to be used because of low efficiency & the high cost of output kWe. Gas turbo generators are extremely noisy & need very good acoustic enclosure. Again this enclosure raises a fire risk.
This is economic for CHP in sizes from 5MW to several MW's.

8.2.3 Micro Turbines

Micro turbines are exactly as their name implies very small combustion turbines sized from 30 kW to 250 kW. They run at very high speed (70 000 to 100 000 rpm). These engines therefore need complex power electronic gear to rectify & invert this high frequency power output.

8.2.4 Fuel Cells

Fuel cells are a class of technologies that convert a chemical fuel directly into electricity. The chemical input to the cell is in the form of Hydrogen & Oxygen, these fuel cells are emerging technology. They are inherently clean & efficient, but cost is much higher.

See section 8.5 for a comparison of above technologies.

8.3 NEW CHP TECHNOLOGIES ARE EVEN BETTER

This next generation of turbines, fuel cells, and reciprocating engines is the result of intensive, collaborative research, development, and demonstration by government and industry. Advanced materials and computer-aided design techniques have increased equipment efficiency and reliability dramatically, while reducing costs and emissions of pollutants. Now the range of CHP system configurations includes:

- <u>Boiler Systems with Steam Turbines</u>

  In the traditional cogeneration configuration, a boiler generates steam from burning fuel or utilizing waste heat from an industrial process, such as a furnace. Some or all of the steam turns a steam turbine that generates electricity. The steam then satisfies thermal requirements like space heating or industrial processes. This CHP configuration still dominates industrial electricity cogeneration.

- <u>Combustion Turbine or Reciprocating Engine with Heat Recovery</u>

  In this configuration, a combustion turbine or engine generates electricity or mechanical energy. The heat in the exhaust and in the cooling water and oil generates steam in a boiler. Such systems will capture a greater share of the CHP market in the future. Reciprocating engines are the dominant technology for smaller systems with an average installed size of less than one MW.

- <u>Combined Cycle Systems</u>

  In a combined cycle system, a steam turbine is used as part of a combustion turbine system in order to increase the electricity produced. The electricity fraction of usable energy in these systems frequently exceeds the thermal output. While these systems account for only a small number of industrial CHP systems, they are significant in terms of capacity and are the dominant configuration for new merchant power plants. These independently-owned power generation facilities produce both electrical and thermal energies that are sold to third parties.

- Fuel Cell with Heat Recovery

  Fuel cells are an emerging technology that converts chemical energy directly into electricity, producing very little pollution. Heat is a byproduct of the reaction, and can be recovered in much the same way as with turbines and reciprocating engines. This technology will gain an increasing market share in coming years as new types of fuel cells enter the marketplace.

8.4 SIZE OF CHP PLANTS

The measuring unit for size of the CHP plant is power of electrical output. i.e. denoted by kWe or MWe.

1) Micro CHP plants
   Electrical output up to 5 kWe

2) Mini CHP plants
   Electrical output from 5 kWe to 500 kWe

3) Small scale CHP plants
   Electrical output from 500 kWe to 5MWe

4) Medium scale CHP plants
   Electrical output from 5MWe to 50MWe

5) Large scale CHP plants
   Electrical output more than 50MWe

8.5 SUMMERY OF CHP TECHNOLOGIES

CHP System	Advantages	Disadvantages	Efficiency	Installed Cost $ / kWh	O & M Cost $ / kWh	Available Sizes
Gas Turbine	High reliability Low emissions High grade heat available No cooling required	Required high pressure gas or in-house gas compressor Poor efficiency at low loading o/p falls as ambient temperature rises	21 - 40	600 - 900	0.003 - 0.008	500 kW to 40 MW
Micro Turbine	Small no. of moving parts Compact size and light weight Low emissions No cooling required	High costs Relatively low mechanical efficiency Limited to lower temperature cogeneration application	20 - 28	600 - 1000	0.003 - 0.01	30 kW to 250 kW
Spark Ignition reciprocating engine Compression Ignition reciprocating engine	High power efficiency with part load operation flexibility Fast start up Relatively low investment cost Can be used in island mode and have good load following capability Can be overhauled on site with normal operators Operate on low pressure gas	High maintenance cost Limited to lower temperature cogeneration applications Relatively high air emissions Must be cooled even if recovered heat is not used High levels of low frequency noise	28 - 45	500 - 1400	0.007 - 0.02	< 5 MW High speed (1200 rpm) ≤ 4 MW
Steam Turbine	High overall efficiency Any type of fuel may be used Ability to meet more than one site heat grade requirement Long working life & high reliability Power to heat ratio can be varied	Slow start up Low power to heat ratio	13 - 25	400 - 1000	0.003 - 0.006	50 kW to 250 MW
Fuel Cells	Low emissions & low noise High efficiency over load range Modular design	High costs Low durability & power density Fuels requiring processing unless pure hydrogen is used	36 - 60	1900 - 3500	0.005 -0.01	200 kW to 250 kW

Table 4

8.6 UK GOVERNMENT'S EYE ON CHP

Number and capacity of CHP schemes installed in buildings by sector in 2001 in UK

Sector	Number of Sites	Electrical Capacity (MWe)	Heat Capacity (MWth)
Leisure	437	41.92	73.08
Hotel	308	37.98	64.95
Health	228	110.81	316.74
Residential Group Heating	55	46.57	75.65
Offices	28	18.37	22.61
Education	23	10.26	26.12
Universities	33	29.57	88.04
Government Estate	17	11.92	19.23
Retail	8	5.97	4.86
Other (incl. agriculture, airports, domestic bldg)	7	15.10	23.37
TOTAL	1,144	328.48	714.65

[Ref : Digest of UK Energy Statistics 2002]

Table 5 : Installed CHP scheme in the UK in 2001

According to above table hotel sector got the 2nd place for CHP installation in UK & below graph shows the target of UK government for the CHP installation by 2010.

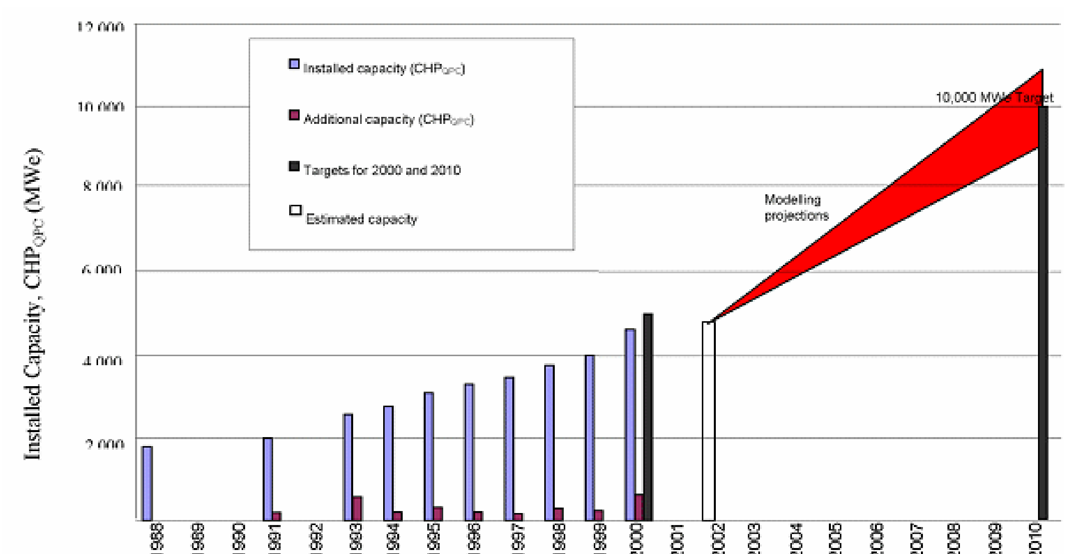


Figure 41 : UK government target on CHP

8.6.1 Why is CHP important for the government?

Reaching the Government's target of 10,000 MWe of CHP would realize further carbon savings of six million tones (6 MtC) each year. This saving is more than 25% of the current shortfall required to achieve the UK's domestic target of a 20% reduction in CO_2 emissions by 2010. This would also stimulate some £3 billion of largely private investment in the UK economy.

- It is the most predictable and cost effective way of cutting UK CO_2 emissions
- It tackles the social exclusion caused by fuel poverty
- It offers customers, particularly in industry, a competitive choice
- It can, in the right market framework, deliver long term, sustainable price Reductions
- It creates training and employment opportunities both directly and indirectly

8.6.2 Government Measures

In the Strategy for Combined Heat Power in the UK to 2010, the Government identified a range of measures that they have introduced which support CHP. These include:

- exemptions from the Climate Change Levy
- Climate Change Agreements
- the Emission Trading Scheme
- eligibility for Enhanced Capital Allowances (ECAs)
- Business Rates exemption for CHP power generation plant and machinery
- changes to the licensing regime
- the £50m Community Energy Programm to encourage CHP in Community Heating schemes
- the establishment of the Carbon Trust to promote CHP as an effective low carbon technology

8.6.3 Climate Change Levy - CCL

CCL is a tax for the environment and on energy use in industry, commerce, agriculture and the public sector. The levy paid via energy bills by all UK businesses and public sector organisations. The full rates of the levy is 0.43p/kWh for electricity, 0.15p/kWh for gas, 1.17p/kg for coal and 0.96p/kg for LPG. The levy is recycled principally by a 0.3% reduction in employer's National insurance contributions

There are some exemptions to the levy

- Certain 'new' forms of renewable energy
- 'Good quality' combined heat and power plants
- Energy products that act as both fuel and feedstock within the same process
- Electricity used in some electrolytic processes

Energy intensive consumers who sign up to energy saving targets agreed between the government and relevant trade associations are eligible for an 80% discount.

£ 50 million per annum allocated to an ‘energy efficiency fund’ from 2001. It is proposed that this provides advice and help for businesses, particularly small and medium enterprises for the development of low carbon technologies and for renewable energy

Intention of CCL

The Climate Change Levy is intended to help the UK to reduce carbon dioxide emissions and is part of the Climate Change Programme being developed by the government. This will ensure that the UK will be on track to meet its international greenhouse gas target of a 12.5% reduction in emissions on 1990 levels averaged over 2008-2012.

8.7 WHY CHP FOR CLARIDGE’S

It is the right time to introduce a CHP for Claridge’s. As we need

1) A standby electricity generator plant
2) To review of electricity supply
3) To improve the energy efficiency

I’m going to introduce a CHP technology for Claridgde’s under two selection points.

1) Replacing the standby generator
2) To achieve the optimum values of CHP technology

8.7.1 Introducing CHP to replace the standby generator

Here my main concern is to obtain the standby electricity supply by new CHP unit with more reliability. The highest electrical demand for the Claridge’s is my selection point of size of the CHP unit.
According to electrical load profiles, maximum electrical demand is 1000 kW (1MW) for July 2003. (demand always goes up)
I am therefore selecting a CHP unit given 1MW electrical output. i.e. large scale CHP plant. However, I want to run this machine with part loads to achieve the maximum profits.

To decide whether my site is suitable for large scale CHP, there are three main questions to answer.

1) Is the heat demand greater than 500 kW?
2) Is the electricity demand greater than 500 kW ?
3) Is energy required for at least 5000 hours a year ?

If the answers for all these questions is ‘yes’, this site would then be suitable for a large scale CHP plant.

Answers for Claridge's are

1) Yes, heat demand is greater than 500 kW
2) Yes, electricity demand is greater than 500 kW
3) Yes, we need energy for 24 hour a day whole through the year. i.e. more than 5000 hours a year.

Therefore, Claridge's is suitable for the installation of a large scale CHP plant

8.7.1.1 Selection of the Most Suitable CHP technology for Claridge's

Micro Turbine CHP cannot fulfil my energy requirement of 1MWe as these are designed from 50 kWe to 250 kWe.

Fuel Cells are inherently clean & efficient however installation cost is as high as $1900 / kWh for 200 kWe CHP unit due to this technology being still so new, for this reason this is does not suit Claridge's well.

Steam turbines have high overall efficiency but have low start up & this need separate boiler for supply steam. Normally we are using steam turbine CHP for very big scale sites, usually supplied in more than one building. This is up to 250 MW and is also not suitable.

Selection between Gas turbine & reciprocating turbine.

Gas turbine CHP is available from 500 kWe to 40 MWe and need no cooling, plus has high reliability. However, in practice it is rare to find the gas turbine CHP units for less than 1MWe of electrical output. This shows low efficiency and high cost for output of kWe for CHP's with less than 1MWe. For Claridge's maximum electrical output requirement is 1 MWe & I am going to run with part loads for some months during the year for gaining optimum value. In this case gas turbine is not helpful for my gains. Gas turbines are also much noisier and require quality acoustic enclosure which is a fire risk.

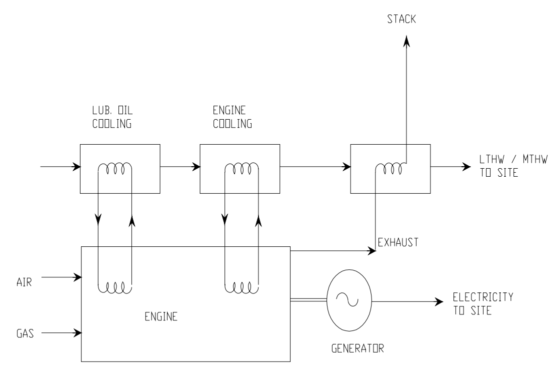
For Claridge's I am planning to install new CHP plant in the existing generator room, as the space is available and it is adjacent to the boiler room & pump room. It is therefore easy to install new ducts, minimise the cost and can use the installed power cables from stand by generator to electrical substation on roof top. This room is in the basement and underneath the ground floor reception area and Ball-room area, which cause concerns about the noise. Due to these reasons gas turbine technology is not suitable for Claridge's.

Reciprocating engine is the highest efficiency for CHP unit, except fuel cells. The reciprocating engine has a wide range of unit sizes. These engines produce out of balance forces, so they need good support and foundations specially designed to absorb vibration & noise making the noise less than that of the gas turbines. Again however, this unit still requires a good quality acoustic shield, because this is a five star hotel & there is no way to move out any noise to guest area (upper- floor).
These engines have low instalment cost, but higher maintenance cost than the gas turbines. These have good flexibility for load operations.

Compression ignition is up to 15 MWe & the cooling system is more complex than the spark ignition which is up to 2MWe.These spark ignition reciprocating engines are more suitable for smaller and simpler CHP installation.

After considering the technical values & site practical vales my final selection is **CHP technology for Claridge's is Spark ignition reciprocating engine.**

8.7.1.2 Block & Sankey diagram for Spark Ignition reciprocating CHP plant



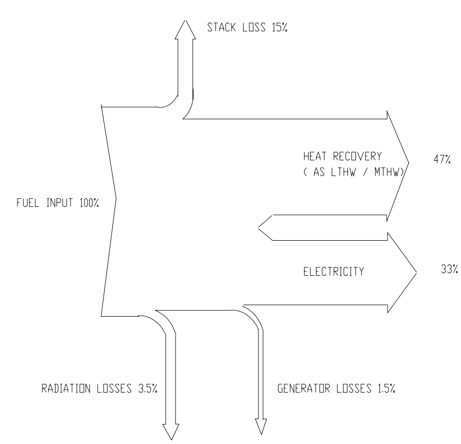


Figure 42 : Spark ignition reciprocating engine

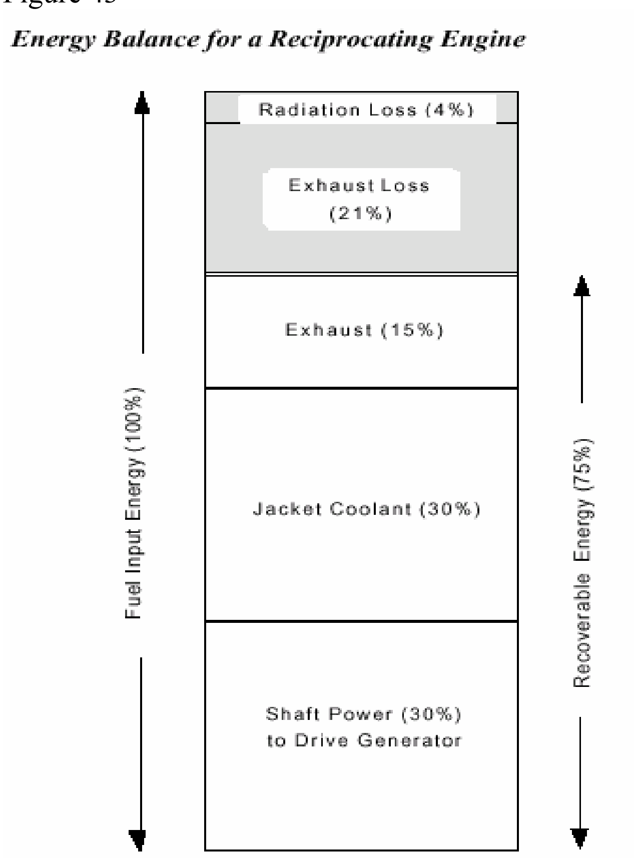
8.7.1.3 Applications

Reciprocating engines are typically used in CHP applications where there is a substantial hot water or low pressure steam demand. When cooling is required, the thermal output of a reciprocating engine can be used in a single-effect absorption chiller. Reciprocating engines are available in a broad size range of approximately 50kW to 5,000kW suitable for a wide variety of commercial, institutional and small industrial facilities. Reciprocating engines are frequently used in load following applications where engine power output is regulated based on the electric demand of the facility. Thermal output varies accordingly. Thermal balance is achieved through supplemental heat sources such as boilers.

8.7.1.4 Technology Advancements

Advances in electronics, controls and remote monitoring capability should increase the reliability and availability of engines. Maintenance intervals are being extended through development of longer life spark plugs, improved air and fuel filters, synthetic lubricating oil and larger engine oil sumps. Reciprocating engines have been commercially available for decades. A global network of manufacturers, dealers and distributors is well established.

Figure 43



[Ref : http://www.eere.energy.gov/de/pdfs/combo_docs/eiaind.pdf]

8.7.1.5 Heat Recovery System

CHP plant required the conversion of CHP heat into form of heat required by the site but most favourable cases require no conversion. As an example, according to theory engine cooling water could be used direct for space heating; however because of scaling and corrosion of cooling circuits we use heat exchangers.
For Claridges CHP plant going to be integrated with centralised boiler plant through shell and tube heat exchanger.

8.7.1.6 Proposing 'Absorption Chiller'

I would like to install an absorption refrigeration plant for cooling in main three functioning rooms. The Telecommunication switch room, computer room & TV head end room which are very close to each other. At the moment we have a problem for the correct cooling for these rooms and so the investment for an absorption chiller would be worthwhile. These three rooms are in Mezzanine floor which is six meters above the basement and ten meters away by horizontal from the existing generator room. So there is no need for very long ducts and there are ducts present between these three rooms from roof to basement.

8.7.1.7 Control & Monitoring

The basic system and their subsystems are integrated into the operation of CHP plant. Control system is the key for gaining the greatest efficiency for a CHP plant. To get high optimisation we need to install fully computerised control system using programmable logic controllers, having the ability to fine tune itself.

Traditionally there are two main control systems as heat led and power led for CHP plants. Heat led CHP plant gives priority to meet heat demand and power led is conversely, but this categorisation is less valid when considering optimising.

It is essential to install all required instruments and data collectors to get the accurate monitoring of the performance. Monitoring data is needed to

- Detect faults, malfunctions, underperformance etc.
- Enable fine tuning and enhance optimisation
- Facilitate to modifications according to site requirements
- Audit the return on investment

8.7.1.8 SINGLE LINE DIAGRAME FOR CONNECTING ELECTRICAL OUTPUT OF CHP TO MAIN DISTRIBUTION SYSTEM FOR CLARIDGE'S

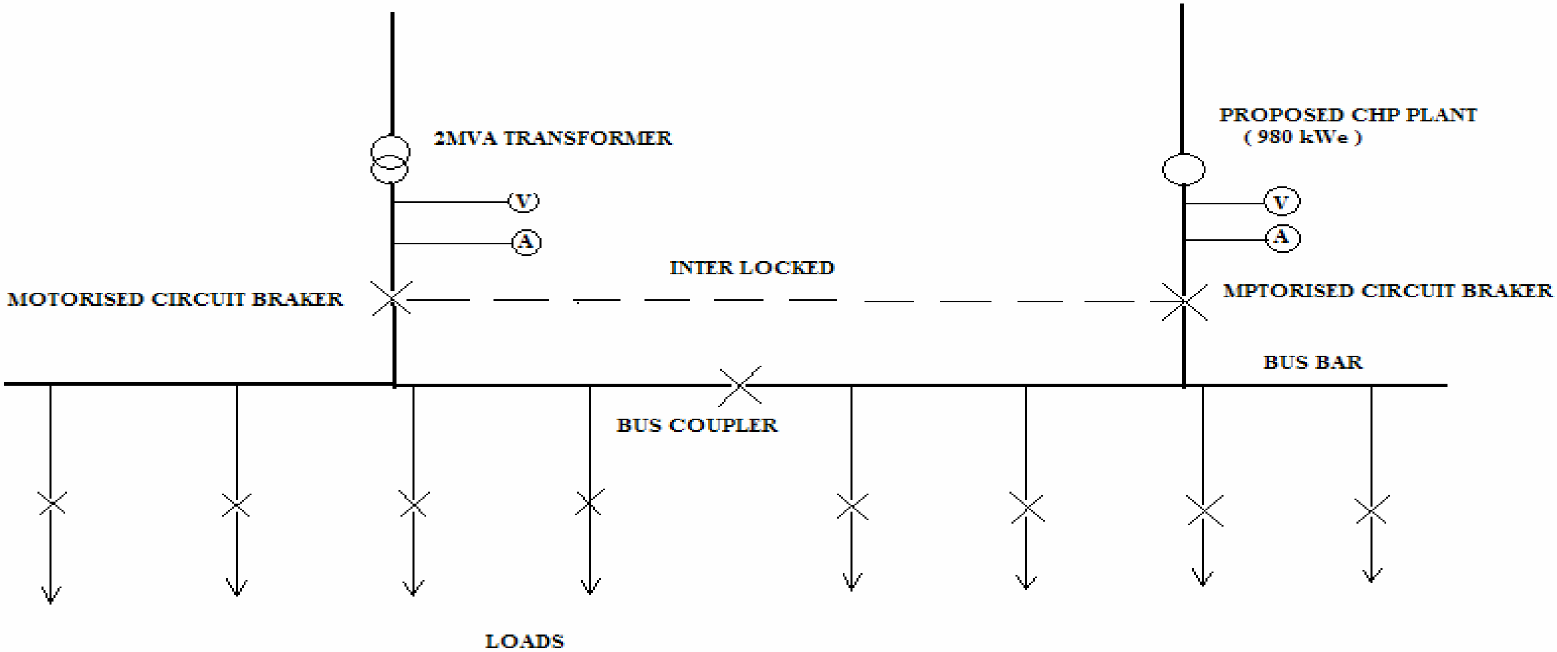


Figure 44

Details of selected CHP plant given by Appendix I

8.7.1.9 Savings due to partial and full load runs of the 1MWe CHP plant

	Savings (£)		
Months	**Full Load**	**50%**	**75%**
January	4468	1220	2822
February	3959	1102	2549
March	3483	1426	2353
April	3074	950	2048
May	3012	940	2041
June	2673	812	1747
July	2689	839	1782
August	2689	839	1782
September	2874	910	1964
October	3407	1123	2317
November	3633	1180	2507
December	4376	1220	2822
Yearly	40337	12560	26734

Table 6 : Savings due to 980 kWe CHP plant

8.7.2. Financial Analysis

There are competitive demands on company finances for investment. All major decisions concerning proposals for schemes relating to capital expenditure to revenue return should be subject to some form of economic appraisal.
I am going to express the investment appraisal by three methods for this combined heat and power energy saving project.

1) Accounting Rate of Return
2) Net Present Value (NPV)
3) Internal Rate of Return (IRR)

8.7.2.1 Accounting Rate of Return - ARR

This can be defined as follows

ARR = (average net annual savings / Book value of capital) x 100

This is a simple method of indicating the level of return from an investment, known as Return of Investment (ROI). Using ARR analysis we can get an idea which size of CHP is more suitable. In other words this is a first filtration point. But still we can’t go for final selection of CHP, because in ARR an analysis assumed annual net saving is a constant. In practice however, we don’t have fixed annual savings. It varies due to inflation.

ARR does not

- Take account of the timing of cash flows (discounting costs)
- Include all costs
- Consider about risk of investment

Valuation of IRR (Internal Rate of Return) is a better solution to overcome the above weak points of ARR.

8.7.2.2 Net Present Value NPV

In this method all costs and returns are discounted by a consistent pre-selected discounting percentage and the total pluses compared with the total minuses over the period being studied. For this CHP project I assumed 1.1% of discount rate. A minus NPV means investment is not worthwhile and a plus NPV means it is a worthwhile investment.

8.7.2.3 Internal Rate of Return IRR

IRR is the discount rate for which the NPV is zero over the expected life of the project.
For this CHP project, I assumed this life of the project is ten years. This can be easily determined by the graphically as below.

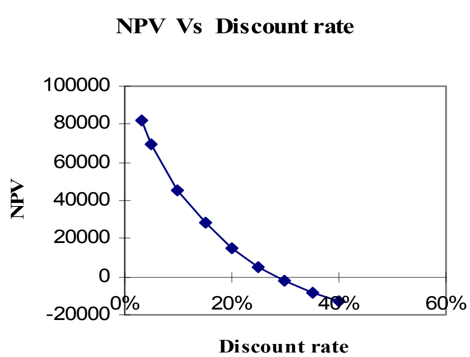


Figure 45 : NPV analysis

Of course when comparing project schemes, the project with the higher IRR should generally be selected. Most organizations are not going to support the projects which has lower IRR value.
For this CHP project I'm analysing the IRR values according to two types of depreciation methods.

1) Single Line Depreciation - SLD
   SLD returns a fixed sum for each year. Let an asset cost equal A, a salvage value S and number of years n then annual depreciation Dt is given by following equation.
   $Dt = (A – S) / n$

2) Double Declining Depreciation - DDB
   DDB calculates depreciation in a given year from the previous year's residual value, and does not start with an initial estimate of salvage. That can be given by
   Dt = 2/n (A – D1 – D2 - …….- Dt-1)

   For this case depreciation in a given year can be subtracted from the net savings, and this subsequent value is using for tax payable calculation. After tax has been deducted the depreciation is added back into the savings.

For NPV and IRR analysis, I assumed £500 /annum of extra maintenance cost, 0.45% of tax and 1.0 of RPI for the SLD & 1.02 of RPI for the DDB.

8.7.3 Financial Analysis for Option 1

Replacing the 750 kVA existing generator by 980 kWe CHP plant

8.7.3.1 ARR analysis

I calculated these values for full and partial loads of the selected CHP plant

Condition	Load (kW)	ARR (%)
100 % of full load	980	7.35
75% of full load	735	6.50
50% of full load	490	4.58

Table 7 : ARR analysis for option 1

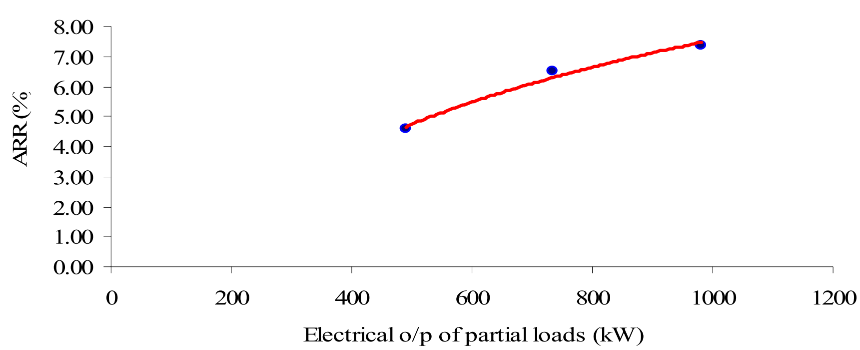


Figure 46 : ARR Vs Electrical o/p

8.7.3.2 NPV analysis

Electrical Output	kWe	980	735	490
NPV	According to SLD	-368,811	-283149	-199649
	According to DDB	-34992	-44563	-58066

Table 8 : NPV analysis for option 1

8.7.3.3 IRR analysis

According to SLD

Electrical o/p of CHP (kW)	980	735	490
IRR (%)	-12.42	-13.78	-17.53

Table 9 : IRR analysis according to SLD for option 1

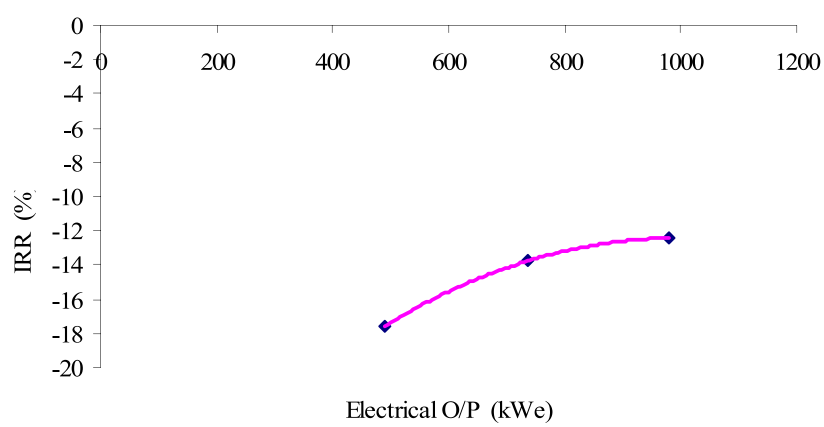


Figure 47 : IRR Vs Electrical o/p of CHP

According to DDB

Electrical o/p of CHP (kW)	980	735	490
IRR (%)	9.07	6.81	1.3

Table 10 : IRR analysis according to DDB for option1

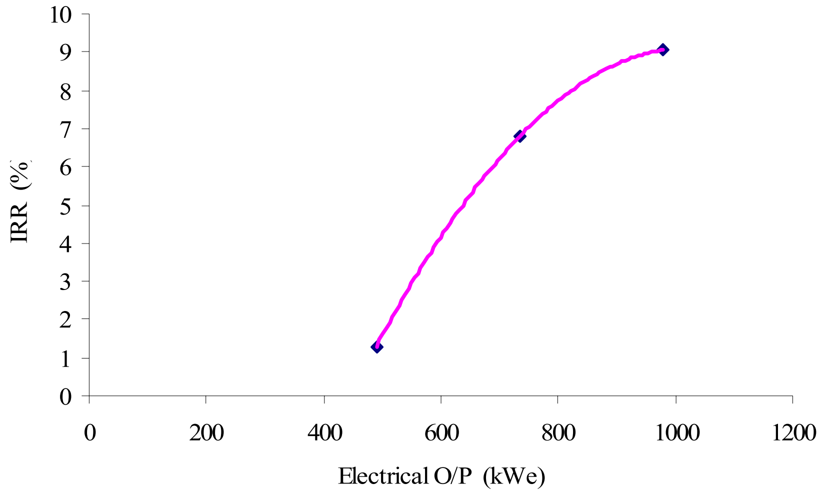


Figure 48 : IRR Vs Electrical o/p of CHP

It is very clear the highest ARR and IRR for DDB has full load operation of the CHP plant. Each month it is saving money but in some hours in some months it is not worth to run the CHP. This time periods are,

1800 hrs to 0600 hrs during whole year.

In summer months, i.e. in June, July and August this period extends by one hour, up to 0700 hrs.

In May, June, July, August and September this CHP plant not worth to run in between 1200 hrs to 1700 hrs.

For March, April and October it is from 1300 hrs to 1700 hrs.

8.7.4 Option2 - To achieve the optimum values by introducing CHP technology for Claridge's

Here my main aim is to improve the energy efficiency of the Claridge's. I am going to select the size of CHP unit considering load profiles. According to load profiles behaviour through the year, I selected three CHP plants operating by reciprocating engine technology. The electrical output of the three units are 500 kWe, 770 kWe & 800 kWe. I am considering these plants as 1st filtration point to find out the most suitable CHP plant for Claridge's.

8.7.4.1 <u>Technical details of these CHP units are as follows.</u>

		Size of the CHP unit (as a electrical output)		
		500 kWe	770 kWe	800 kWe
Fuel Input	kW	1500	2365	2580
Heat Output	kW	580	900	877
Installation cost	£	146630	231000	438400
Operating & Maintenance cost	£/kWh	0.0073	0.0075	0.006

All these CHP plants running by natural gas

Table 11 : Technical details of CHP units for option 2 – 1st filtration

8.7.4.2 <u>The result of financial appraisal for the above CHP plants can be shown as below</u>

ARR analysis Electrical output of CHP	kWe	500	770	800
Capital cost for complete unit	£	146630	231000	438400
Annual net saving	£	16826	20698	20187
Accounting Rate of Return (ARR)	%	11.48	8.96	4.60

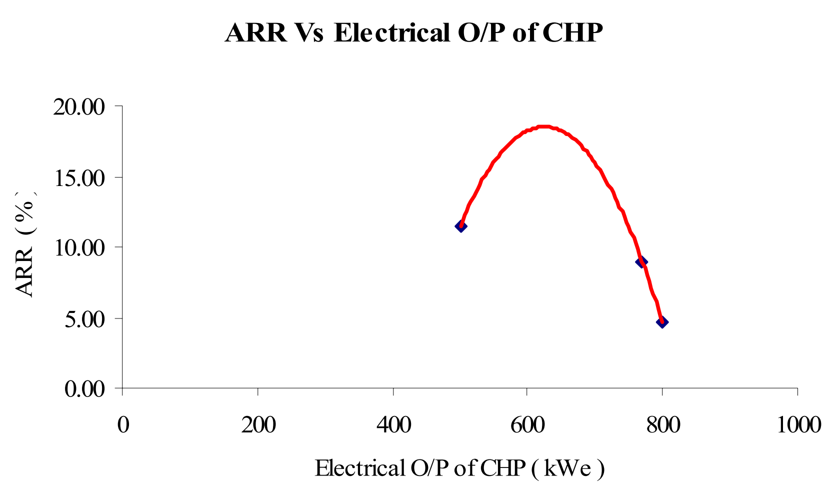


Figure 49 : ARR Vs Electrical o/p for option 2 – 1st filtration

NPV analysis

Electrical Output	kWe	500	770	800
NPV	According to SLD	-52538	-125417	1645
	According to DDB	22338	2801	-91337

Table 15 : NPV analysis for option 2 CHP units – 1st filtration

IRR analysis

According to SLD

Electrical o/p of CHP (kW)	500	770	800
IRR (%)	-1.94	-8.27	-18.11

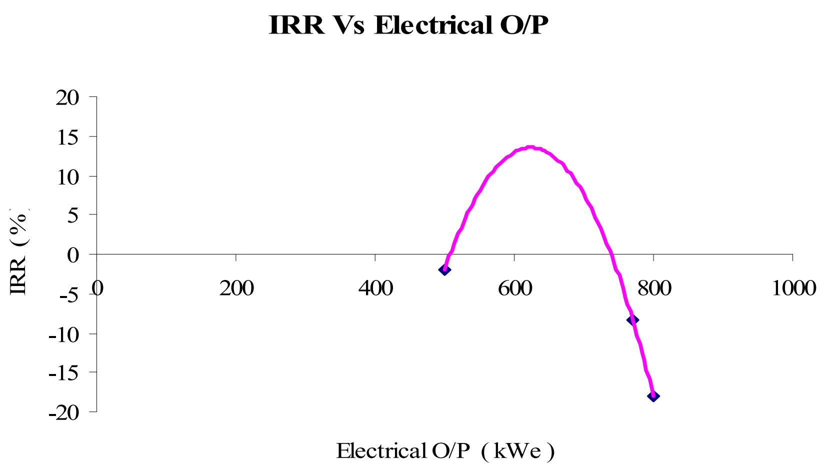


Figure 50 : IRR Vs Electrical o/p according to SLD for option 2 – 1st filtration

According to DDB

Electrical o/p of CHP (kW)	500	770	800
IRR (%)	19.49	12.79	1.51

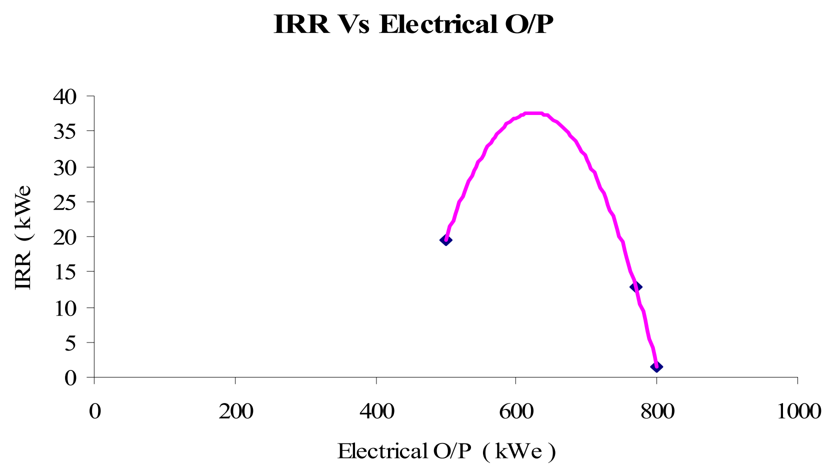


Figure 51 : IRR Vs Electrical o/p according to DDB for option 2 – 1st filtration

8.7.4.3 Overview

According to the above ARR, NPV and IRR analysis (Figure 50, Table 15, Figure 51 and Figure 52) it is clearly showing that the maximum ARR and IRR values occur in between 600 kWe and 650 kWe values. So now I'm considering other three more CHP plants with electrical output of 633 kWe, 625 kWe and 601 kWe. These three units complete with spark ignition reciprocating engine and are fuelled by natural gas. I am considering above selected CHP plants are my 2nd filtration point to find out the most suitable CHP plant for Claridge's.

8.7.4.4 Details of new CHP plants are

Electrical output of the CHP unit	kWe	633	625	601
Capital cost of the CHP unit	£	188190	185690	178190
Annual net saving	£	30253	31513	30316
Account Rate of Return (ARR)	%	16.08	16.97	17.01
Internal Rate of Return (IRR) according to SLD	%	2.46	3.61	3.83
Internal Rate of Return (IRR) according to DDB	%	27.3	28.81	28.89
Net Present Value (NPV) according to SLD	£	-46407	-39134	-36169
Net Present Value (NPV) according to DDB	£	60793	66358	63950

Table 16 : Details of new CHP plants for option 2 – 2nd filtration

8.7.4.4.1 Graphical analysis of ARR and IRR for the above three CHP plants are shown below.

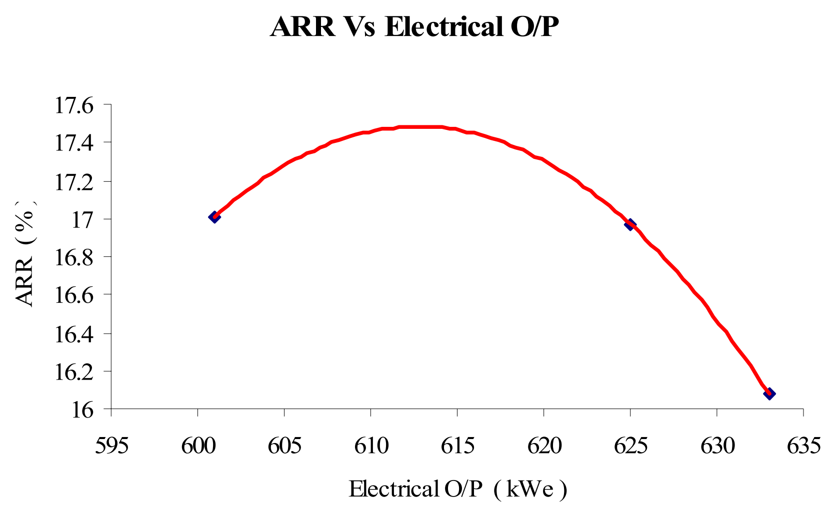


Figure 52 : ARR Vs Electrical o/p for option 2 – 2nd filtration

According to SLD

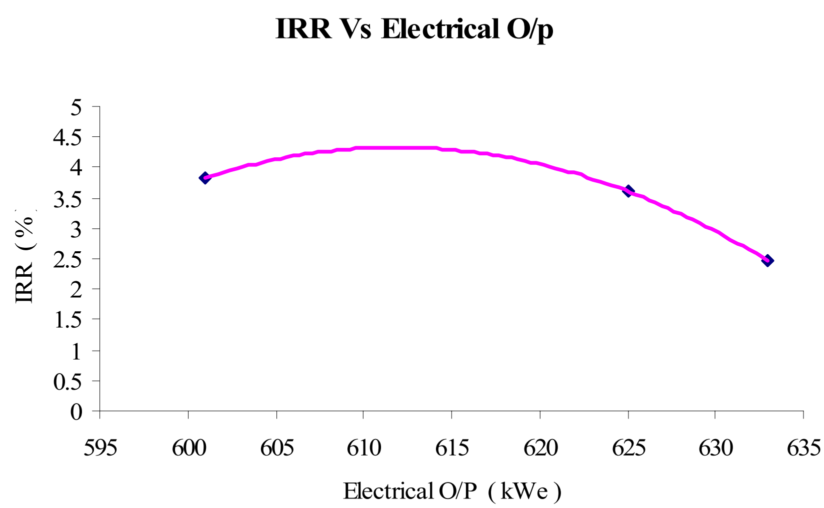


Figure 53 : IRR Vs Electrical o/p according to SLD for option 2 – 2nd filtration

According to DDB

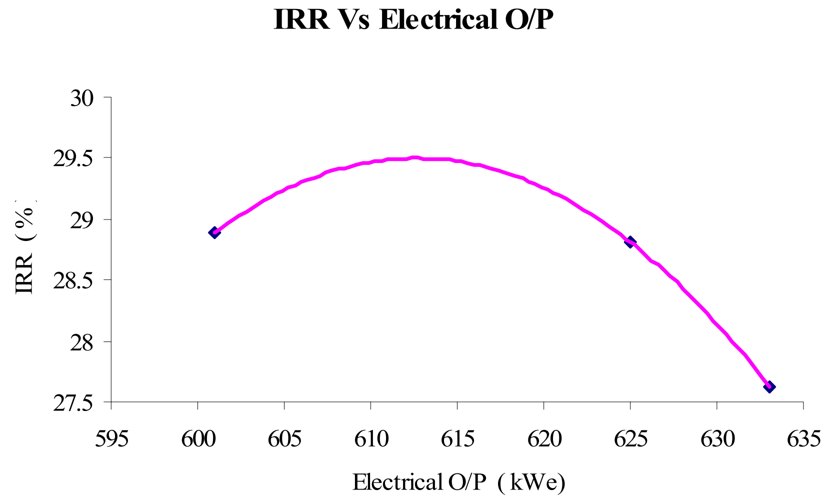


Figure 54 : IRR Vs Electrical o/p according to DDB for option 2 – 2nd filtration

Further analysis of figure 53, 54 & 55 , to achieve the maximum values of Combined Heat and Power technology, I proposed 601 kWe CHP plant is the most suitable unit for Claridge's.

Details of this CHP plant is
Make : GE jenbachar
Type : J312 GS – N.L
NOx < 250 mg / Nm^3
RPM : 1500 at 50 Hz

9. LIGHTING SYSTEM

9.1 INTRODUCTION

Lighting systems are often the second greatest use of electric power after heating and cooling system. By reducing lighting loads, we can save a significant amount on the energy bill.

Ways we can save energy on lighting

- Replacing existing lamps with more efficient ones
- Decreasing the wattages
- Improving controllers
- Changing fixtures
- Repositioning lights

Lighting energy management has three basic tasks

- Identify the light quantity and quality needed to perform the visual tasks
- Increase the light source efficiency
- Optimize lighting controls

Many energy saving technologies are available today, such as lamps, ballasts and lighting controllers etc. The best control strategy for the space depends on the occupancy pattern, type of work and availability of daylight. Timing controllers can automatically turn lights on or off at specified times. Greater energy can be saved by using photocell controls. These controls turn lights on or off according to the daylight and preset level. The payback for these controllers is usually three to six years.

Most of the energy consumed by lighting systems is converted to light, heat and noise, which dissipates into the building. If the amount of energy consumed by the lighting system is reduced, the amount of heat produced is also reduced. Therefore it will reduce the air conditioning load especially in summer months. On the other hand if a lighting system can produce less heat with same lighting output that will reduce the air conditioning load as well as the amount of energy consumption by the lighting system. That means producing the same lighting output for less energy consumption. This is known as the energy efficient lighting system.

The goal of lighting management is to achieve the right quantity and quality of lighting in any given facility. Each lighted space has its own unique lighting requirements. These recommendations are published by the CIBSE Lighting guide LG1.

9.2 EFFICACY OF LIGHTING

Efficacy describes on output/input ratio. The higher output for a given input gives higher efficacy. Efficacy is the amount of lumens per watt from a source.
Energy efficient lighting savings describes according to the following simple equation.

Energy (kWh) = Power (kW) x Time (h)

This equation tells us that energy efficient light can save energy by

- reducing the power demand of the lighting system or
- reducing the system's hours of use or by both

Both methods are using today's energy efficient lighting technologies.

Efficient and Effective lighting means

- Ensuring that the correct lighting standards are provided both in terms of quantity and quality
- Selecting the correct type of lighting system
- Using the most suitable lighting equipments
- Controlling the hours of use
- Maintaining the system in efficient working order

9.3 LIGHTING SOURCES

9.3.1 Fluorescent Lamps

Fluorescent lamps use less energy, last longer, give more light, less heat output, and less expensive to run. This is a big improvement of incandescent bulbs. The fluorescent lamp is an electronic device. It functions through conduction in a gas. It consist of a drop of mercury and a small amount of argon gas with electrodes sealed into each end. Both electrodes will function as cathodes (emits electrons into the enclosure). This will enable the lamp to conduct in either direction and therefore allow alternating current. The performance of fluorescent lamps has dramatically improved last few years. They have same length and connections as the old ones. But new ones has 25mm diameter and filled with Krypton and Argon (T8) instead of 38mm diameter old ones with only Argon (T12). Result of this new lamp is using 9% less energy than old lamp. Another technological advance made at the same time was to change the coating of these lamps. This coating help to emit 7% more light as well. These are 70% more efficient than earlier, that's why lighting industry recommends to use T8 (25mm diameter) rather than the T12 (38mm diameter) when ever possible. Because of their economic advantage.

Claridge's using various types of bulbs. Most of them are incandescent bulbs. In basement, back of housing area, offices and common corridors of guest area lighting by T8 fluorescent bulbs. Because of fluorescent has a good color rendering property and high efficacy.

9.3.2 Compact Fluorescent Lamps - CFL

Compact fluorescent lamps are still new to Claridge's. One of my main aim of this project is introducing this valuable CFL to Claridge's. Chapter 9.4.1.2 and chapter 9.4.1.3 describe how much we can save money by introducing CFL for some specified areas in the hotel. At the moment Claridge's not using any CFL bulbs. Following I am describing advantages of CFL with comparing other bulbs.

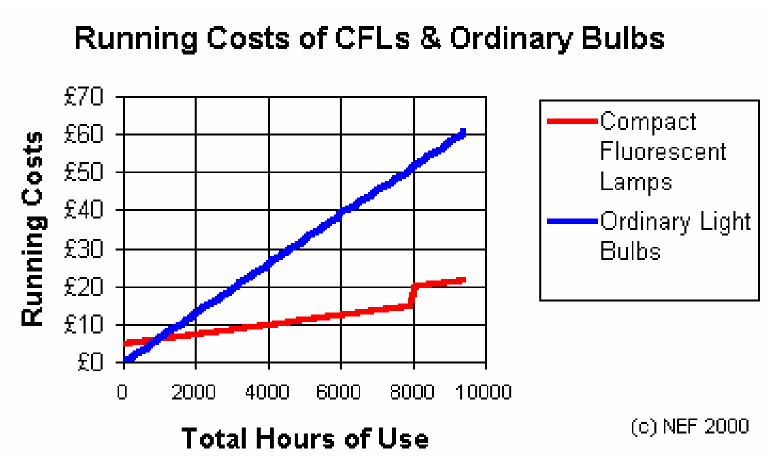
Technology of compact fluorescent lamps are still developing. This is especially designed for replace the tungsten lamp. Compact Fluorescents are very efficient, economical light sources. A Compact Fluorescent (CF) uses only about a quarter as much electric power as an incandescent lamp with the same light output. A 22 Watt CF has about the same light output as a 100 Watt incandescent; an 18 Watt CF is equivalent to a 75 Watt incandescent. Compact Fluorescents outlast incandescent 10 to 1. The average incandescent bulb is rated to last about 1000 hours, (about 6 months at 5 hours/day). CF's are rated for about 10,000 hours, (about 5.5 years at 5 hours/day). This may cause to low maintenance cost. Compact Fluorescents have great color rendition and won't flicker or hum. CF's use rare earth phosphors for excellent color and warmth. Using an CF instead of a incandescent lamp will keep out the air a carbon dioxide (the global warming gas), sulfur oxides (which cause acid rain), and smaller amounts of other gases and heavy metals.

9.3.2.1 Comparison of lumens and watts of incandescent and compact fluorescent as below.

A-shaped Incandescent Bulb (Watts)	Equivalent CFL Bulbs (Watts)	Typical Lumens (Measure of Light Output)
40	15	> 450
60	20	> 800
75	25	> 1,100
100	30	> 1,600
150	50	> 2,600

Table 17 : Comparison of light output between incandescent and CFL bulbs

9.3.2.2 Comparison of Cost between 100W tungsten and 21W CFL



[Ref : http://www.natenergy.org.uk/cfl_save.htm]
Figure54 : Comparison of cost between 100W tungsten and 21W CFL

Blue line represent the running cost of an ordinary 100W bulb and red line represent the running cost for 21W CFL. Life time for ordinary bulb is 1000 hours and capital cost is 50p to buy. Life time for CFL is 8000 hours, but capital cost is £5 to buy.
But we can observe from the graph CFL saves £35 for its life time than ordinary one.

9.3.3 Control gear for Fluorescent lamps

All fluorescent lamps need control gear. Two main types as

- Conventional electromagnetic ballasts (old design) and
- Electronic high frequency ballasts (new design)

New electronic starters for fluorescent lamps have the performance and reliability of high quality starter less circuits, but save energy, improve lamp life permit control gear to optimized. Completely electronic low loss gear is available today. These new ballasts operating at high frequency range (20 – 35 kHz) and therefore their efficiency is improved and irritating flicker disappears.
CFL also need a ballast. Normally CFL is integrated with ballast, that is the reason for been a heavier than the tungsten bulb.

9.3.4 Incandescent Lights

This is the most famous bulb for Claridge's with different shapes, different bulb holders and different colors. This bulbs keep up the maintenance cost for Claridge's

Incandescent bulbs are the most familiar source of light. The incandescent lamps deriving light from a heated wire filament. Tungsten is the material for filament and Argon and Krypton using as filling gas.
This light has simple construction, no need especial equipments and light distribution can controlled by easily. This bulb has a good colour rendering property through wide variety of wattages (5W to 2000W)

Main disadvantage of this bulb is less efficiency, use more energy than the other types of lamps to produce the same amount of light. (more than 90% of consumed energy emits as heat). At high temperatures, Tungsten gradually evaporates. This has a short lamp life compare to other types.

9.3.5 High Pressure Sodium Lamps

High Pressure Sodium lamps (SON) widespread in sports hall, exterior and floodlighting. These lamps have the longest life and the highest efficacy. But the color quality is very poor, for indoor use not acceptable. A few years ago a revolutionary new form of high pressure sodium lamp was introduced. It's called as De-luxe high pressure sodium (SON-DL) and this has excellent color rendering. The color rendering is better than the standard white fluorescent tubes. They are well suited for up-lighting.
In Claridge's we are using SON-DL in foyer up lighting and 'Olympus' suite (health and fitness department) up lighting

9.3.6 Low voltage tungsten halogen lamps

This is an incandescent lamp filling with halogen gas to reduce the rate of filament evaporation. These lights are more efficient and more controllable. These lamps are available 50W and 35W for 12V. Use energy more efficiently than incandescent and have a long life. Main disadvantage of this lamp is high heat output increases air conditioning costs & fragile filaments which are sensitive to shock

We are using lot of this low voltage halogen bulbs in guest rooms as a ceiling spot light.

9.3.7 Quantity of light emitting by different type of bulbs

Following page Table 18 and Figure 57 showing comparison of different types of bulbs in energy wise.

Type	lm/W	%
light-emitting diode	0.04-20 [6]	0.005%-2.9%
40W tungsten incandescent	12.6 [7]	1.9%
60W tungsten incandescent	14.5 [7]	2.1%
100W tungsten incandescent	17.5 [7]	2.6%
glass halogen	16	2.3%
quartz halogen	24	3.5%
tungsten-halogen	18-25 [6]	2.6%-3.6%
13W twin-tube fluorescent	56.3 [1]	8.2%
compact fluorescent	45-60 [4]	15%-32% [3]
xenon arc lamp	30-150 [5]	4.4%-22%
mercury-xenon arc lamp	50-55 [5]	7.3%-8%
high-temperature incandescent	35 [2]	5.14%
ideal blackbody radiator	95 [2]	14% [7]
ideal white light source	242.5 [2]	36%
monochromatic 556nm source	680 [7]	100%

Table 16 : Quantity of light emitting by different types of bulbs

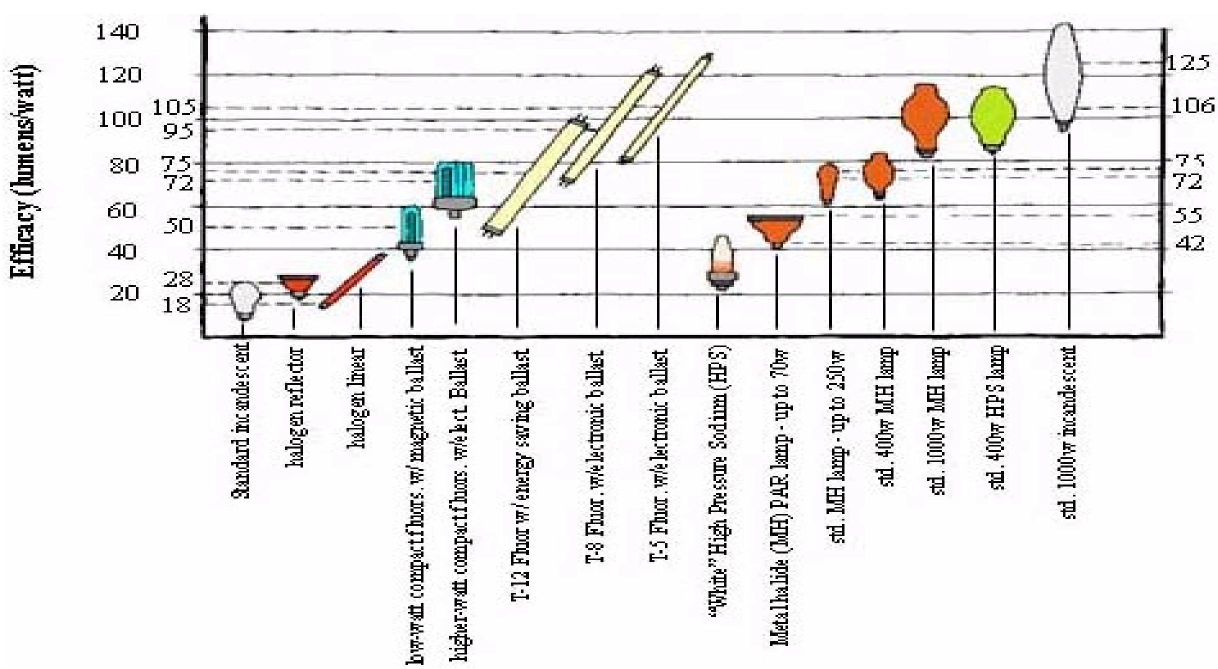


Figure 56 : Comparison of efficiency between different types of bulbs

9.4 ENERGY EFFICIENT LIGHTING FOR CLARIDGE'S

Lighting plays a major role in Claridge's to keep up a traditional glamorous looking and warm welcome. There is no doubt Claridge's is a heavy lighting user. Therefore it is important to consider energy efficient lamps as it does not damage Claridge's glamour.

9.4.1 By Changing bulbs

Front of house is the most widely used lights which are kept on for attraction and to give the customer's a relaxed feeling.

9.4.1.1 By changing size of the bulb
Proposal 1 : Chandelier at main entrance hall

One of my main concerns is changing bulbs in the front entrance chandelier which carries 25 numbers of 40W incandescent bulbs. This lights up twenty four hours a day the whole year through. That means this take 25 x 40W x 24 x 365 h of energy per year. That means 8760 kWh of energy consumption annually. But when I am proposing to change these bulbs I am taking extra care to select a right bulb without doing any damage to the lighting level. This chandelier is a decoration to the front hall and is not meant for practical use, standing lamps and wall lamps are use to light up this area. Further I am referring to the lighting manuals for the hotel, this is designed for 25W incandescent bulbs, this is now carrying 40W's bulbs, this may be a result of less care when changing bulbs. But it's a big energy consumption.

Energy consumption annually for 25W bulb	= 25 x 25W x 24 x 365 h = 5475 kWh
Annual energy saving	**= 8760 kWh – 5475 kWh = 3285 kWh**
Annual money saving	**= £73**

9.4.1.2 By replacing different types of bulbs
Proposal 2 : Main stair case and Corridor Lighting

In Claridge's there are two main guest stair cases, landing areas and some guest corridors using 40W incandescent bulbs. All of these are wall mounted types and mounting height is below 2.7m. Disadvantages of Tungsten light bulbs are that they are the least efficient bulb in the market, relatively short life and heat output may cause to the damaging of fabric shades. Alternative light bulbs for tungsten bulb are Compact fluorescent lamps (CFL), linear fluorescent lamps and tungsten halogen lamps. Here I propose to replace with CFL, because of easy to replacement, long life, good colour rendering and high efficacy.
So my second proposal is replacing these bulbs to suitable compact fluorescent bulbs.

Ordinary 40W opal white candle bulb

Cost for each bulb is £0.45. This bulb has 90mm of length and 35mm of diameter.

Proposed 8W CFL is

Cost for this bulb is £7.16 each. This bulb has 119mm of length and 40mm of diameter.
This ultra long life energy saver gives similar brightness to normal 40W light bulb. This CFL has extra warm white, 2700K color temperature and 15000 hrs rated life time. Very low heat output. Ideal for small lamps and delicate lamp shades.
Of course this CFL is a little bit bigger than the tungsten one, but for this light fitting the CFL is best suited. Because it is complete with a tall lamp shade.

No. of bulbs carrying by front hall staircase = 25
No. of bulbs carrying by ladies staircase = 21
No. of bulbs caring by grand staircase landing area for every floors = 61
No. of bulbs carrying by 6th floor corridor to conference rooms = 12
Total number of incandescent bulbs = 119
Annual energy consumption by incandescent bulbs is 119 x 40W x 24 x 365 h.
That is 41698 kWh
But energy consumption for proposed 8W CFL is 8340 kWh
Annual net energy saving going to be 33 358 kWh

9.4.1.3 Proposal 3 : Changing bulbs in some of the guest rooms

My third proposal for saving energy on lighting is replacing 40 W tungsten bulbs by 8 W CFL bulbs in some of guest rooms.
Those are (01&02) , (07&08) , (11&12) , (19&20) , (21&22) and (29&30) series on each floor.
This is a wall mounted common light fitting carrying two 40W tungsten bulbs. Normally these light fittings placed in sitting room. These light fittings mainly do the decorating for the room. There are standing and table lamps to light up the room as well. For the whole hotel has 256 numbers of these wall mounting type light fixtures.
Power saving due to this replacement is 8.192 kW. i.e. [(40-8) W x 256]
Normally these suites have high annual occupancy rates. If this annual occupancy level is 80% and within these occupied period each light fitting lights up for six hours per day.
Annual energy saving = 8.192 kW x 6 h x 365 x 80% = 14 352 kWh
For proposal 2 and 3 need to spend considerable amount of capital cost for buying CFL's. That is going to be £ 2685.
Total saving due to this replacement is £4022
So net saving by this replacement for lamp life time is £1337.

9.4.2 Lighting control by Sensors

I am glad to tell you Claridge's already placed sensors for controlling lighting wherever possible. Especially in the basement area, two staff ladies cloak rooms lighting control is now by occupancy sensors. In the banqueting kitchen which is using only for functioning times, lighting control by occupancy sensor as well. This controls 864 W of power. Exterior lighting is controlled by a timing controller on Brook street side lights and by day light sensor on Davis street side lights.

9.4.3 Back of House Lighting

Most suitable lighting for back of house area is linear T8 (witch is having 28 mm diameter) fluorescent lamp. These lamps are highly efficient as discussed earlier.
Standard 58W, 1500mm long fluorescent tube producing about seven times more light than a 60W tungsten lamp. The other main thing is the back of house area needs good light not like the front of house. As this is the back of scene area and staff need light to carry out their job safely. This bulb has good colour rendering quality. This is a main advantage for the food processing area, because of producing more light by this bulb, it reduces the quantity of lamps needed. In Claridge's every where in the back of house area we are using T8 linear fluorescent bulbs.

9.5 LIGHTING CONTROLLERS

Lighting controllers are saving lot of money on lighting energy consumption bill and extending lamp life. Chapter 9.5.1 describes the different types of lighting controllers. Claridge's using automatic lighting controllers in back of house area and exterior lighting. All guest's area having manual controllers as switches and dimmers, but not automatic controllers as sensors. Next two paragraphs describe pros and cons of lighting controllers.

9.5.1 Types of Lighting controllers

Following devices using to control the light.

- Switches
  Earlier days we used to control the light by switches
- Dimmers
  More using with incandescent lamps, simply by stepping the voltage up or down via an electromagnetic coil
- Microchips
  More sophisticated, automated & programmable control system
- Setting the scenes
  One room can be use for different functions. So we have to set the light according to the scene. This can be done by microprocessor control systems
- Sensors
  Occupancy sensors / Noise sensors / Photocells

Automatic lighting controllers dividing into three main groups. Such as Time controllers, Occupancy sensors and Photocell controllers.

The Advantages of using lighting control devices are

- Can save energy by tailoring lighting to occupancy and use
- Dimming of incandescent lamps can extend the lamp life
- Can extend range of functions in specific rooms
- Eliminate problem of haphazard manual switching
- Allow imperceptible transition between day time & night time conditions
- Enable precise control of changing effects over time

The disadvantages of using lighting control devices include :

- Relatively expensive to buy and install
- Circuit wiring can be complex & costly
- Extended period needed for installation, programming & snagging
- Limited range of lamp types when using dimmers
- System can be inflexible
- Detailed planning required

10. WASTE HEAT RECOVERY

I am going to introduce the heat of light recovery system, exhaust heat recovery system and waste water heat recovery system. My main aim of this chapter is proposing the most suitable waste water heat recovery system for Claridge's.

10.1 INTRODUCTION

Vast quantities of heat energy exhausted from buildings and it is practical to recover this waste heat. Most productive waste heat reclamation techniques are,

- Recovery of lighting heat loads
- Exhaust heat loads
- Heat recovery cycle
- Total energy plants

10.2 HEAT OF LIGHT RECOVERY

Excessive lighting wastes energy as heat and then additional energy required to dissipate this heat, which build up cooling load. This wasted heat of light energy can be partially prevent by two basic techniques.

1) Circulating cooling water through lighting fixture reflectors
2) Exhausting room air through air cooled fixtures

10.3 EXHAUST HEAT RECOVERY

Exhausting interior heat can be reclaimed through four different heat exchangers.

- Rotary wheel exchangers
- Water-cooled, coil exchangers
- Heat-pipe banks
- Air-to-air exchangers

A rotary wheel heat exchanger can recover heat up to 80%. This wheel made by heat conducting materials such as Aluminium or Stainless steel. It's operation can be express by following block diagram.

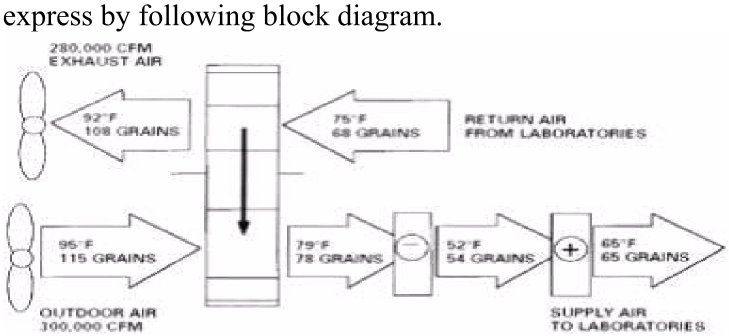


Figure 57 : Rotary wheel heat exchanger

In Claridge's I propose to install a rotary wheel heat exchanger in laundry exhaust and supply ducts at lighting well and recover waste heat.

A water cooled, coil exchanger offers a advance technique to the rotary wheel exchanger. Because to place the rotary wheel exchanger, exhaust and supply air ducts should be adjacent. But water cooled coil exchanger, can transfer heat widely separated exhaust and supply ducts by finned coils. Efficiency for this coil exchanger is about 50% to 55%.

Heat pipe banks just like rotary wheel exchanger, require adjacent exhaust and supply ducts. A heat pipe bank contains about hundred small cylindrical tubes carrying charge refrigerant moves back and forth. Under optimum conditions, heat pipe bank can recover nearly 70% of the exhaust heat energy.

Air-to-air heat exchanger works passing two ducts through a common intersecting duct segment. Heat is transferred by conduction through the walls of the cellular passages. Efficiency range is about 50% to 60% and its depending on air velocity. High air velocity cause to low efficiency.

10.4 WASTE WATER HEAT RECOVERY SYSTEM

10.4.1 Introduction

In many processing Systems, as much as 40% to 60% of the hot water heating capability is being discharged down the sewer. By installing a Waste Water Heat Recovery System, we can recover that lost thermal energy by using the heat from the waste water of one processing operation to preheat the incoming fresh water to be used in other operations. In a building hot water using by showers, tubs, dishwashers and cloth washers. Waste water of all these cleaning applications carrying significant amount of it's initial energy. This energy can be recovered and reused.

Types of Wastewater heat Exchanger

- Plate heat exchanger
- Shell & Tube heat exchanger
- Spiral heat exchanger
- Gravity film heat exchanger

10.4.2 Plate Heat Exchanger

Plate heat exchangers consist of series of thin corrugated plates suspended from a carrying bar and clamped between a fixed and a movable heat plate. Each heat transfer plate is fitted with an electrometric gasket, partly to seal and partly to distribute process fluids. Connections in the fixed or movable heat plate permit entry of process fluids into heat plate pack.

Figure 58 : Plate heat exchanger

Advantages of Plate heat exchanger

- Design produces high thermal efficiency, allowing maximum heat recovery
- Compact design requires a fraction of the space taken up by convention heat exchanger
- Unit may be expanded
- Access to heat transfer surface for maintenance is simple
- Design exhibits low fouling tendency
- Unit is economical to operate

10.4.3 Shell & Tube heat exchanger

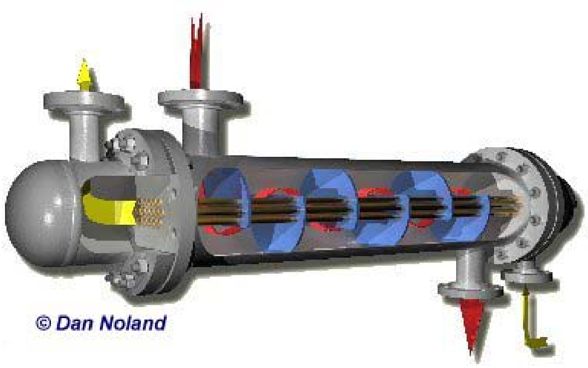


Figure 59 : Shell & Tube heat exchanger

Designed for greater thermal efficiency. Hot water flows through the heat exchanger tubes in one direction while the incoming fresh water flows through the shell in the opposite direction.
But it is unique baffle design that provides more heat transfer per square foot. The baffle window design, coupled with closer baffle spacing, creates a circulation flow of fresh water over and around the heat exchanger tubes, generating greater thermal efficiency
Even greater thermal efficiency is assured through precise control of the baffle and shell tolerance, thus reducing the loss found in other heat exchangers due to leakage of fresh water between the baffle and shell.

10.4.4 Spiral Heat Exchanger

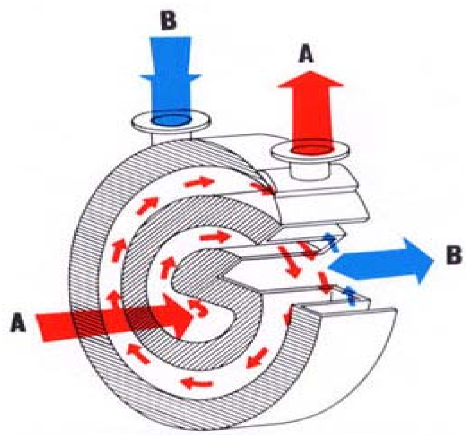


Figure 60 : Spiral heat exchanger

This type of heat exchanger is used for cooling and heating the liquid inside a reactor. In it, the temperature is held within the range to assure the best activity for bacteria. The liquid containing fibers is sent to one channel (A side) of the heat exchanger from a reactor, and is cooled by cooling water which flows the other channel (B side). The other hand, heating is possible by using warm water instead of coolant. This Spiral heat exchanger for wastewater use is indispensable to run smoothly because the liquid containing fibers without entanglement and/or blocking of them. Because the heat exchanger has one-way pass channel without stud.

Advantages of Spiral heat exchanger

- Passage spacing can be as large as 1 ¼” allowing sewage sludge to be handle
- Each fluid flows thro’ single uniform passage, eliminating, misdistribution and localized low velocity areas
- Fluid flow is fully counter current for optimal thermal efficiency
- Covers may be removed exposing the heat transfer surface for inspection and or cleaning
- Compact design requires less space than a conventional heat exchanger
- Spiral passage promotes turbulence and induces a scrubbing action which lowers the fouling tendency

10.4.5 Gravity Film Heat Exchanger - GFX

The GFX is a simple heat exchanger design for heat recovery. This straightforward design is a vertical, counter flow heat exchanger that extracts heat out of drain water (usually warm) and applies it to preheat the cold water entering the building. The design consists of a 3- or 4-inch central copper pipe (that carries the warm wastewater) with 1/2-in. copper coils wound around the central pipe. Heat is transferred from the wastewater passing through the large, central pipe to cold water simultaneously moving upward through the coils on the outside of the pipe. The coils are flattened a little where they touch the pipe to increase the contact area and improve heat transfer. The key to this patented device was the inventor's observation that wastewater clings in a film-like fashion to the inside wall of the pipe as it undergoes gravity flow in the open drain, and this warm, falling film transfers heat through the pipe wall to the incoming cold water that passes through the copper coil wound around the pipe.

Advantages for using GFX

- Rugged, no moving parts
- All copper construction
- Compact; replaces about five feet of vertical drain line; can be installed where drains are piped, including inside stud walls
- Sweat connections at each end of the coil where line pressure exists; rubber connectors to attach each end of the copper pipe to the drain
- Available with multiple parallel coils outside the central pipe to reduce pressure drop.

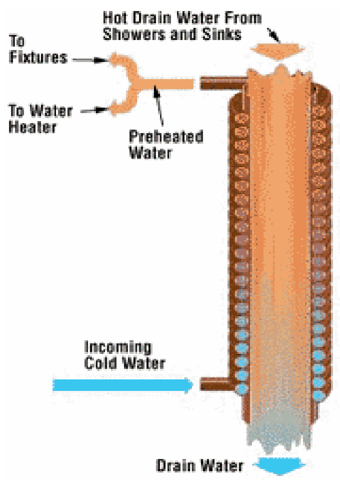


Figure 61 : Gravity film heat exchanger

10.4.6 Most suitable wastewater heat exchanger for the hotel industry is…

- Spiral heat exchanger is more suitable for chemical industry, because it gives extra benefit for cleaning of waste water. This is not good practice in hotel industry due to limit passage space cause for block sewage sludge.
- GFX is more economical, simple and compact as well. This type of heat exchanger more useful for houses waste water system. Again this is not very good for hotel industry, because not enough powerful for a industry as hotel and incoming cold water rise up to high pressure due to small diameter of tubular films.
- Shell & Tube type heat exchanger very good application for industry and we can directly placed at any place of waste water pipe. So this heat exchanger needs very little extra space.

- **Plate heat exchanger is the best for waste water heat recovery for the hotel industry.** Because of high thermal efficiency, unit may be expanded, access to heat transfer plates for maintenance and economical.

11. CONCLUSION

The main outputs of this project, I conclude to three main paragraphs as monitoring and targeting of energy, combined heat and power and waste water heat recovery.

11.1 MONITORING & TARGETING OF ENERGY CONSUMPTION

Claridge's consumes energy from electricity and gas. According to the results of past two years monitoring (figure 1) 44% of energy consuming by electricity and 56% of energy consuming by gas.

11.1.1 Electrical Energy Consumption and Lighting

The minimum electricity consumption occurring in February and reasons for this are February complete with twenty eight days, end of winter season and normally February complete with limited functions. Comparing of winter and summer seasons electricity consumptions, summer months consumes more electricity, because summer cooling need more electricity than winter heating.

According to electrical load profiles (figure 25) electrical power consumption varies from 500 kW range. The maximum point is 1011 kW in July month and minimum point is 525 kW in January month. For each month electrical energy consumption varies with same pattern.

Claridge's electrical energy level is in poor range according to Good Practice Guide 36. I observed few reasons for this result.

1) Still most of the lights carrying incandescent bulbs. I proposed to change this incandescent bulbs to CFL in common areas and few more rooms. This proposal reduces the energy level to 239 kWh/m^2.
2) Every room has at least six numbers of incandescent 40W bulbs. My suggestion is if we can replace these by 7W CFL our energy level reduces to 238 kWh/m^2, I am sure if we can replace this incandescent to CFL in rooms we can reduce energy level more. Because some of the rooms have more than fifteen numbers of incandescent bulbs.
3) Front hall entrance and ball room entrance canopy lights are on twenty four hours a day through out the year. These lights consuming 25229 KWh per year. If we can control these lights by timer we can reduce energy level to 237.6 kWh/m^2.
4) In Foyer, Ballroom and other function rooms on the ground floor carrying much more incandescent and fluorescent bulbs. These incandescent bulbs control by dimmers. So we can't go for the proposed of CFL. So we go for dimmable type CFL, investment is much higher than savings
5) Guest corridor areas in each floor lights up by 4X18 W fluorescent fittings. These lights consuming higher proportion of lighting. That is 118575 kWh per year.

Above I described the impacts by lighting to electrical energy level.

11.1.2 Gas Energy Consumption

Claridge's using gas energy mainly for space heating, DHW system and cooking appliances. Cooking appliances use only 17% of gas energy and rest of 83% of gas energy used from fro space heating and DHW system.

Winter months using more gas for space heating than other months. Figure 6 shows the space heating energy consumption graph for 2003, January using more energy than other months, because of January is the coldest month. Summer months do not consume gas energy for space heating, but consumes electrical energy for cooling. (Comparing figures 2 & 6)

Gas energy level for Claridge's are 312 kWh/m^2 and 306 kWh/m^2 for year 2002 and 2003 respectively. According to GPG 36 (Table 2) 300 kWh/m^2 is the margin for good and fair categories. So the gas energy level for Claridge's is in the beginning of fair region. Considering Claridge's high occupancy pattern I think this value is a appropriate.

Gas energy consumption is always varying with outdoor temperature. I represented this variation for year 2003 by figure 9, Claridge's energy signature.

This energy signature is a powerful graphical tool for finding out the base temperature. If we know the base temperature for a building, it is easy to calculate the heating energy consumptions. For Claridge's this value is 15.5 C. This is shown by figure 10.

Thermal load profiles (figure 24) has a wide varying range as 3000kW. Because of no heat demand for August and high heat demand as 3000kW for January. Each month having same pattern of heat demand.

11.2 COMBINED HEAT AND POWER

I described two selection methods for introducing CHP technology to Claridge's.

11.2.1 CHP plant as a stand by generator

Here I have to select the CHP with 1MWe, as the maximum electrical demand for Claridge's is 1000 kWe. Considering the market availability for this size and suitable technology for Claridge's I found a 980 kWe spark ignited reciprocating engine CHP unit. Details of this CHP plant is given on appendix I. This reciprocating engine has the capability of partial load running.

Capital cost for this CHP plant is £548 000 and annual net savings are £ 40337, £12500 and £26734 for full load, half load and 75% of full load running respectively. (Table 6)

The highest ROI (Rate of Investment) given by full load running condition is 7.35%. This plant given minus net present value is at the end of year ten £ 34992 and the IRR (Internal Rate of Return) is -12.42% 0f value.

According to NPV & IRR analysis this plant directly shows a grey shadow of the CHP technology, but the main purpose of this CHP plant is act as a stand by generator.

11.2.2 CHP plant as gaining maximum values

Here my selection point is referring to the thermal and electrical load profiles. I first selected three CHP plants with 500 kWe, 770 kWe and 800 kWe outputs, details of these units are given on table 13.

1st Filtration

According to financial results the 500 kWe CHP plant gives the highest ARR value of 11.8% (figure 49). NPV analysis shows this same plant has the highest net present value of £22 338 at the end of year ten. According to Double Depreciation Balance based IRR value analysis (figure 51) , 19.45% of IRR value given by same plant. Within these three plants the maximum values gained by 500 kWe CHP unit.

2nd Filtration

More consideration about ARR and IRR analysis graphs (shown by figure 49, figure 50 and figure 51), shows the maximum values obtained around 600 kWe to 650 kWe CHP plants for Claridge's load profiles.

I select three CHP plants having 601 kWe, 625 kWe and 633 kWe outputs with spark ignited reciprocating natural gas fuelled engine. Details of these plants and financial results of ARR, NPV and IRR shown by table 14.

Within these CHP plants, 601 kWe CHP plant shows attractive financial results which are 17.01% of ARR, £ 63950 of NPV and 28.89% of IRR for DDB.

Further analysis of ARR and IRR graphs (figure 52, figure 53 and figure 54), I observed the most valuable CHP plant obtained by 612 kWe of electrical output. This plant with 612 kWe will give 17.5% of ARR value and 29.5% of IRR for DDB.

Considering the most suitable technology for Claridge's, practical issues and market availability, I proposed this 601 kWe CHP plant for Claridge's and the details of this are given on page 55.

11.3 WASTE HEAT RECOVERY

Under chapter 10, I described the recovery of lighting heat loads, the recovery of exhaust heat loads and the recovery of waste water heat loads.

I proposed for Claridge's a rotary wheel heat exchanger as an exhaust heat recovery for laundry exhaust and supply ducts as these laundry machines are running continuously from 0800 hrs to 2200 hrs a day, throughout the year. Now this exhausts heat waste continuously to the environment. Considering a practical situation, we can easily place the rotary wheel heat exchanger for this supply and exhaust ducts.

I described the pros and cons of different types of waste water heat recovery systems. They are plate heat exchanger, Shell & tube heat exchanger, Spiral heat exchanger and Gravity film heat exchanger. From those proposed, plate heat exchangers are the most suitable waste water heat recovery system for Claridge's, when considering practical and theoretical issues.

12. REFERENCE

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APPENDIX I - DETAILS OF 980 KWE CHP PLANT

ENI 1000 Lean Burn

Continuous Duty Generation

DTE Energy

DTE Energy Technologies

Production Specifications

Model Number: ENI-1000A-PNLOS
ENI-1000A-JNLOS
ENI-1000A-FNLOS

Net Electrical Output @ 0.8 power factor		kW	980
Net Electrical Efficiency		%	36%
Pkg Efficiency w/ Thermal (Net)		%	81%
Heat Rate (Net, LHV)		Btu/kWh (kJ/kWh)	9,400 / (9,918)
Engine/Generator Type			Continuous Duty Synchronous
BHP (shaft)	@ ISO	hp (kW)	1408 (1050)
RPM		rpm	1800
Output voltage			480/277 Volts, 3 Phase, 60 Hz
Emissions @ ISO	NO_x	g/bhp-hr	1.20
	CO	g/bhp-hr	2.30
	NMHC	g/bhp-hr	0.40
	THC	g/bhp-hr	5.00
Noise Level		74 dBA @ 7 meters	(option: 65 dBA @ 7 meters)
Operating Capability		Blackstart capable in either isolated or grid parallel operation	
Power Quality	THD		Meets IEEE 519
	Load Unbalance	%	10% negative sequence (maximum)
	Overload	%	no overload capability at continuous power
	Voltage Regulation/Adjustment	%	+/- 0.5%
Fuel Supply[2]	Types		Natural Gas
	Fuel (LHV/HHV) +/-5%	MMBtu/hr (GJ/hr)	9.188 (9.694) / 10.10 (10.65)
		ft^3/hr (m^3/hr)	10,096 (286)
	Minimum Supply Pressure	psig (bar)	2.0 (0.14) - 5.0 (0.34)
	Fuel Standard (LHV/HHV)	Btu/ft^3 (kJ/m^3)	910 (33,906) / 1,000 (37,259)
Enclosure	Height	ft (m)	9.5 (2.9)
	Length	ft (m)	40 (12.2)
	Width	ft (m)	8 (2.4)
	Weight	lbs (kg)	52,100 (23,633)
	Shipping Weight	lbs (kg)	55,000 (24,948)
		Standard ISO Hi-Cube shipping enclosure (full sound attenuation)	
Warranty		Earlier of 18 months from delivery or 1 year (8,000 hrs) from initial start up	

Notes: These specifications represent the design data as of the publication date listed in the lower righthand corner and may change without notice. Please contact your sales representative for the most current specifications.

1. **All data based on ISO standard conditions of 29.54"Hg barometric pressure, 77F ambient & induction air temperature, 30% relative humidity.**
2. **Fuel Standard: dry natural gas, 910 Btu/ft3 lower heating value (LHV).**

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ENI 1000 Lean Burn

Continuous Duty Generation

DTE Energy

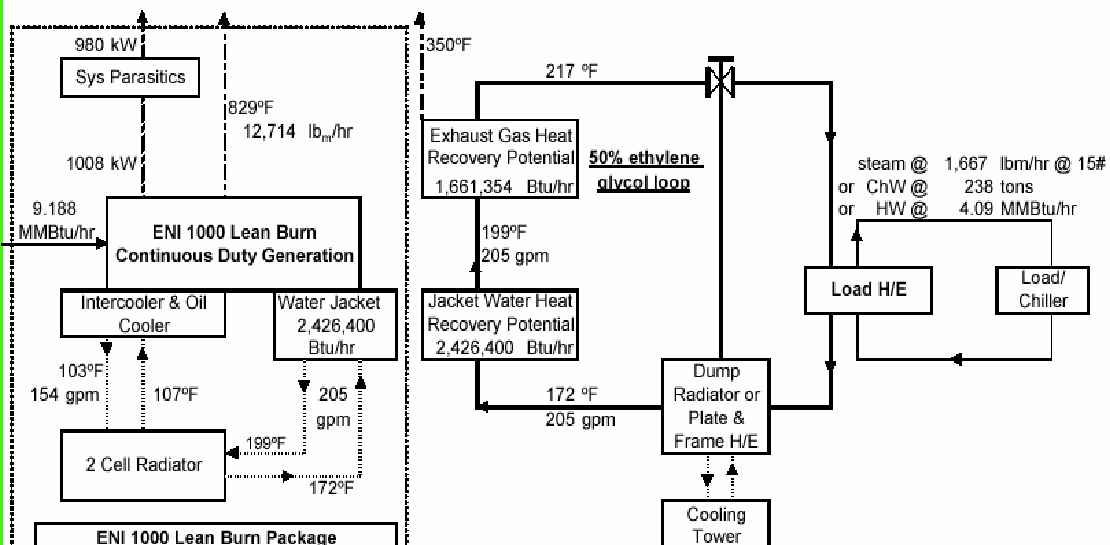
DTE Energy Technologies

CHP - Production Specifications

Model Number: ENI-1000A-FNLOS

	Exhaust Flow	lb/hr (kg/hr)	12,714 (5,767)
	Exhaust Temperature	ºF (ºC)	829 (443)
	Jacket Water Flow	gpm (L/min)	205 (777)
	Jacket Water Temperature (Out)	ºF (ºC)	199 (93)
	Jacket Water Temperature (In)	ºF (ºC)	172 (78)
	Auxiliary Water Flow	gpm (L/min)	154 (583)
	Auxiliary Water Inlet Temperature	ºF (ºC)	107 (42)
	Auxiliary Circuit Heat Rejection	MMBtu/hr (kWth)	0.287 (84)
	Heat Gain from Water Jacket	MMBtu/hr (kWth)	2.426 (711)
	Heat Gain from Exhaust Gas	MMBtu/hr (kWth)	1.661 (487)
Total Heat Recovery Potential		**MMBtu/hr (kWth)**	**4.088 (1,198)**
Heat Recovery Potential:			
Hot Water	Flow Rate	gpm (L/min)	240 (908)
	Temp IN	ºF (ºC)	166 (74)
	Temp OUT	ºF (ºC)	200 (93)
Chilled Water	Temp IN	ºF (ºC)	54 (12)
	Temp OUT	ºF (ºC)	44 (7)
Cooling Tons @	COP = 0.7	tons (kW)	238 (178)
Steam Output (15 psi) dry saturated		lb/hr (kg/hr)	1,667 (756)

Heat Recovery Potential @ 100% load



Typical Jacket Water and Exhaust Gas Heat Recovery Schematic

DTE Energy Technologies
37849 Interchange Dr.
Farmington Hills, MI 48335
877-DTECH-11
248-668-9530
www.dtetech.com

Apr-03

APPENDIX II - LIST OF FIGURES

APPENDIX III - LIST OF TABLES

APPENDIX IV - LIST OF ABBREVIATIONS

CHP	Combined Heat and Power
M&T	Monitoring and targeting
BEMS	Building Energy Management System
DHW	Domestic Hot Water
GPG	Good Practice Guide
HVAC	Heating, Ventilation and Air-Conditioning
CAV	Constant Air Volume
VAV	Variable Air Volume
AHU	Air Handling Unit
HEPA	High Efficiency Particulate Air
LPHW	Low Pressure Hot Water
CCL	Climate Change Levy
ECA	Enhanced Capital Allowances
ARR	Accounting Rate of Return
ROI	Rate of Investment
NPV	Net Present Value
IRR	Internal rates of return
SLD	Single Line depreciation
DDB	Double Depreciation Balance
CIBSE	Chartered Institute of Building Services Engineering
LG	Lighting Guide
CFL	Compact Fluorescent Light
SON	High Pressure Sodium Lamps
SON-DL	De-luxe High Pressure Sodium Lamps
GFX	Gravity Film Heat Exchanger
NR	Noise Rating
T	Temperature (ºC)
t	Time (s)

APPENDIX V - FLOOR DRAWINGS

BUILDING FEATURES

This building has ten floors.

- Basement using by servicing area, mainly back of house area including kitchens, laundry, staff canteen, staff cloakrooms and offices

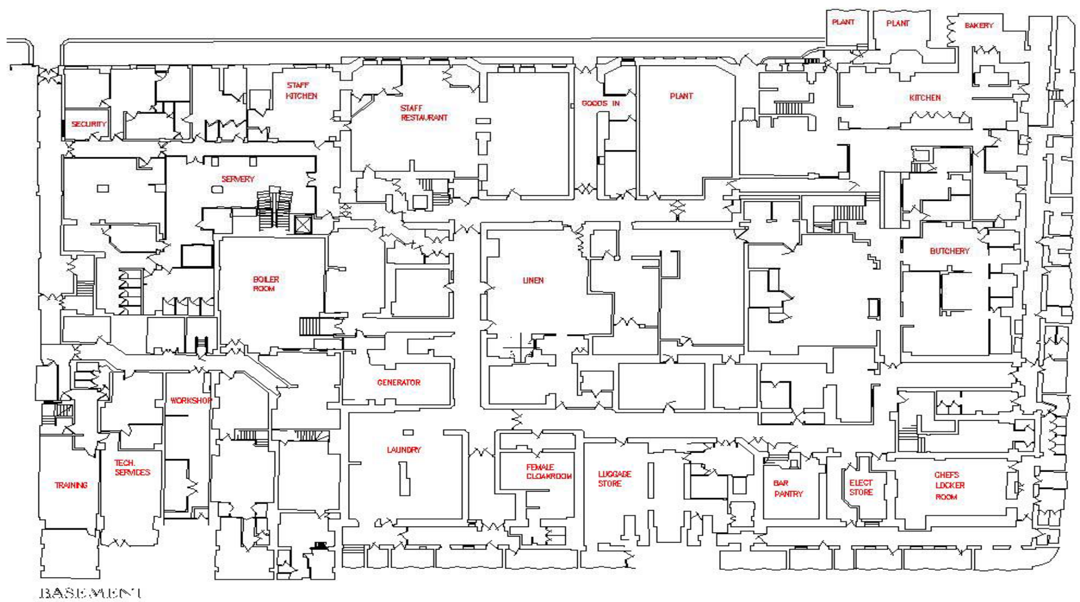
- Ground floor including five banqueting rooms, two bars, foyer area and famous Gordon Ramsey restaurant

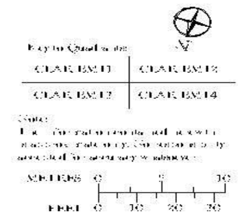
- Mezzanine floor using by eight guest rooms and few office rooms

- First floor to fifth floor are very similar arrangement of guest rooms and each floor has 47 numbers of guest rooms.

- Half of the sixth floor occupied by guest rooms and other half occupied by four conference rooms and health and fitness suite.

- Seventh floor occupied by six guest rooms and two famous Brook and Davis pent houses.





Hotel:

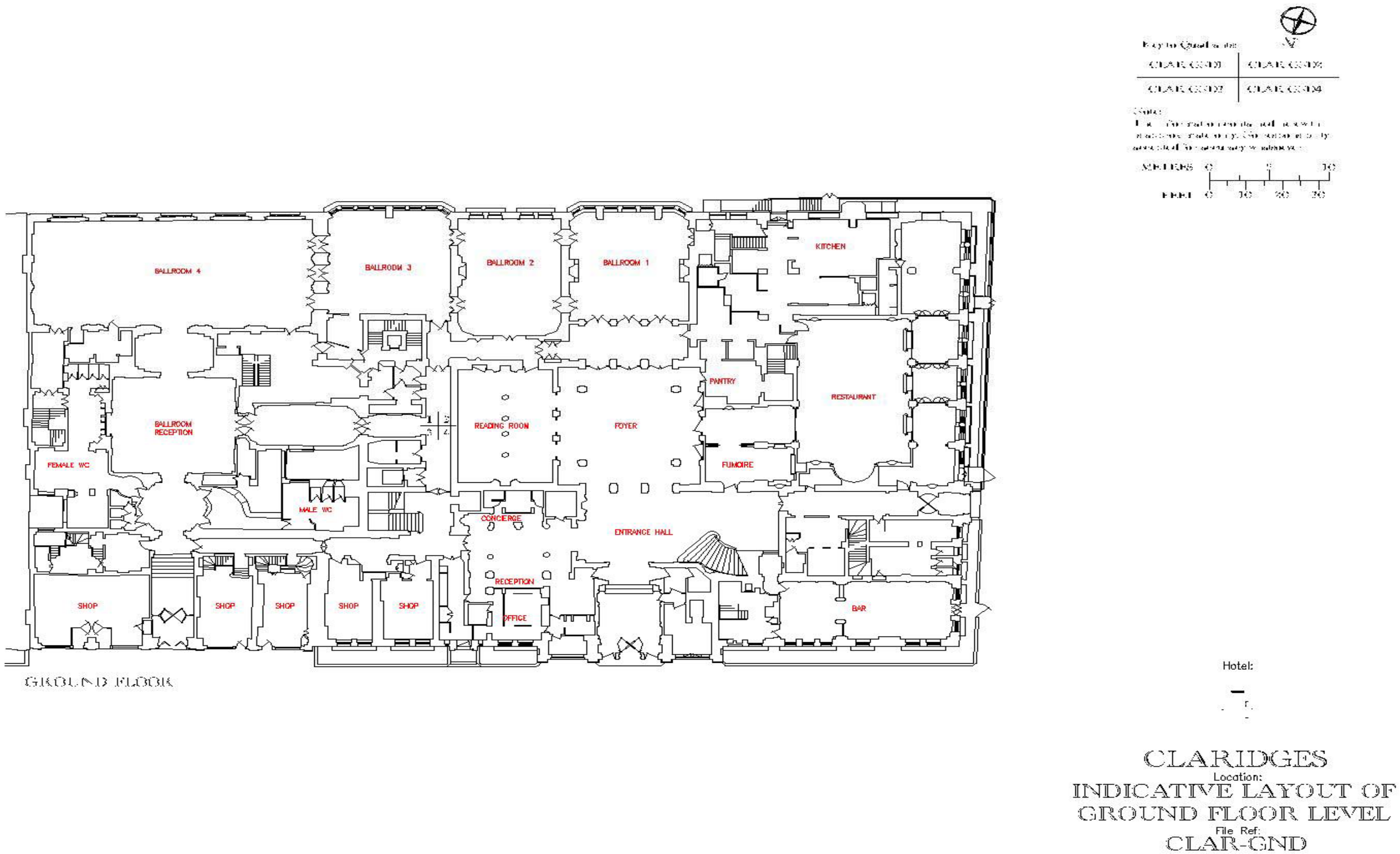
CLARIDGES

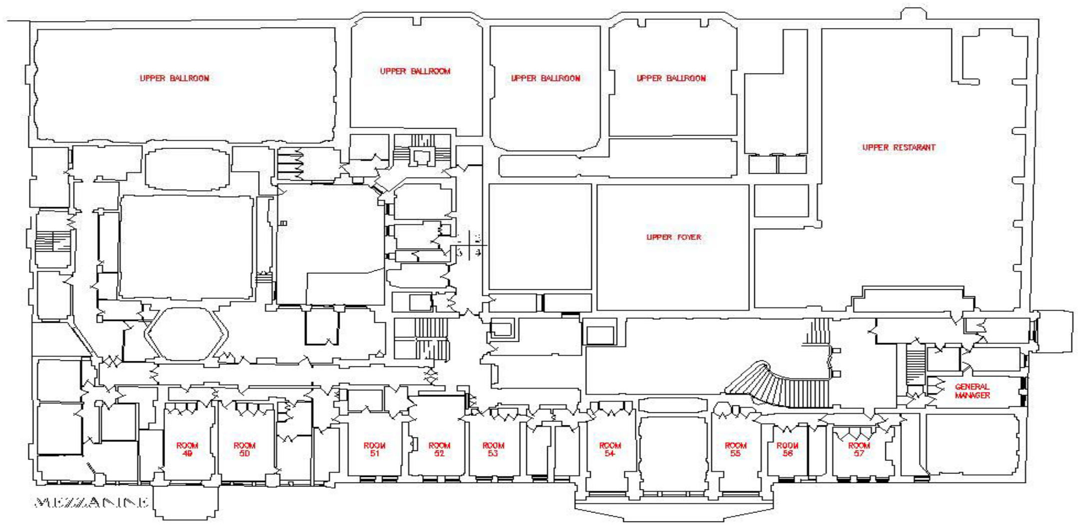
Location:

INDICATIVE LAYOUT OF BASEMENT LEVEL

File Ref:

CLAR-BMT


BALLROOM 4
BALLROOM 3
BALLROOM 2
BALLROOM 1
KITCHEN
BALLROOM RECEPTION
READING ROOM
FOYER
PANTRY
RESTAURANT
FEMALE WC
MALE WC
FUMOIRE
CONCIERGE
ENTRANCE HALL
RECEPTION
OFFICE
SHOP
SHOP
SHOP
SHOP
SHOP
BAR
GROUND FLOOR
Hotel:
CLARIDGES
Location:
INDICATIVE LAYOUT OF
GROUND FLOOR LEVEL
File Ref:
CLAR-GND



Hotel:

CLARIDGES

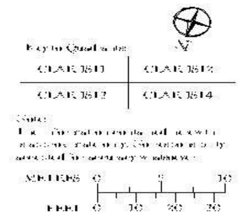
Location:

INDICATIVE LAYOUT OF MEZZANINE LEVEL

File Ref:

CLAR-MEZ

1st FLOOR



Hotel:

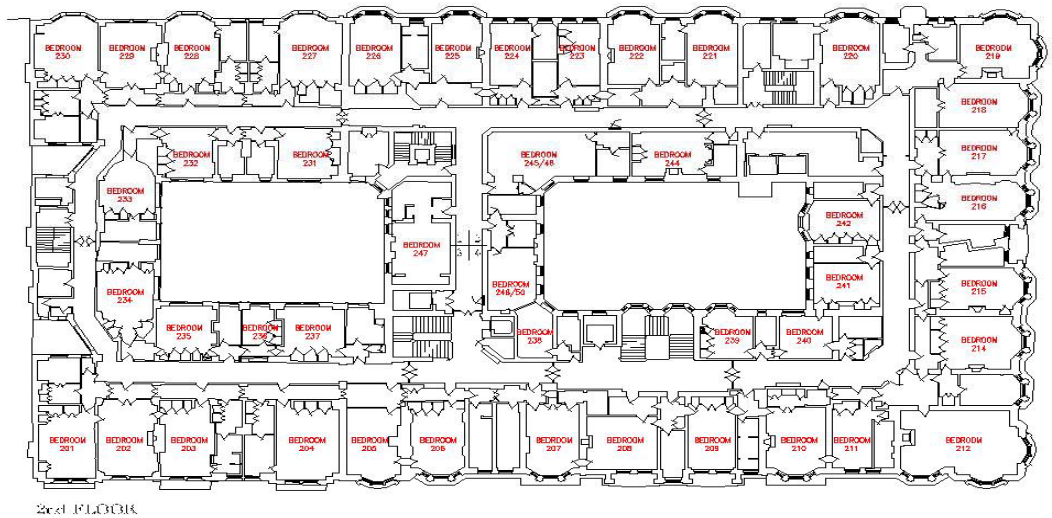
CLARIDGES

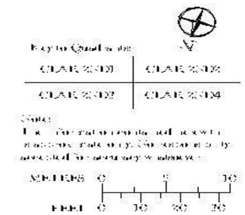
Location:

INDICATIVE LAYOUT OF FIRST FLOOR LEVEL

File Ref:

CLAR-1ST





Hotel:

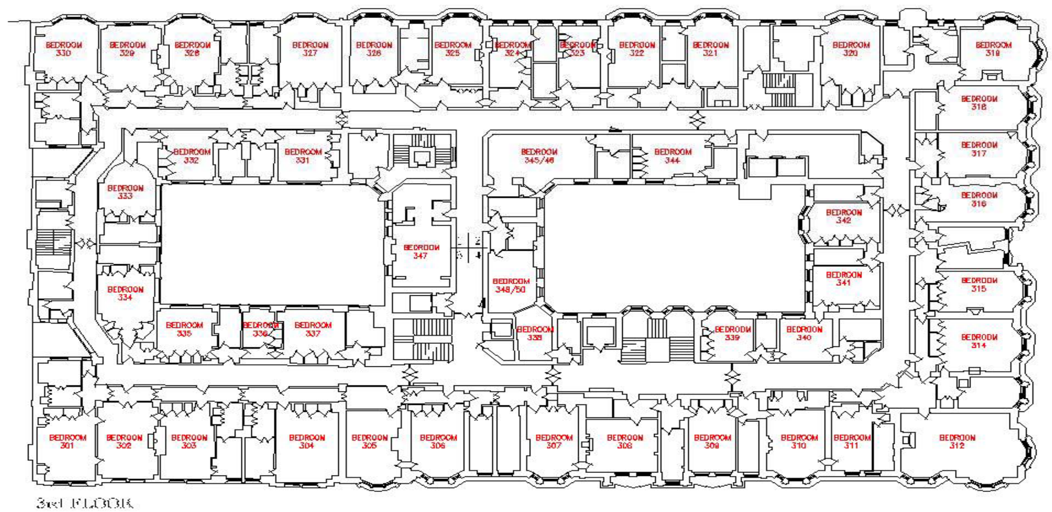
CLARIDGES

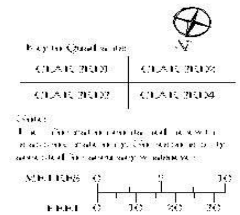
Location:

INDICATIVE LAYOUT OF SECOND FLOOR LEVEL

File Ref:

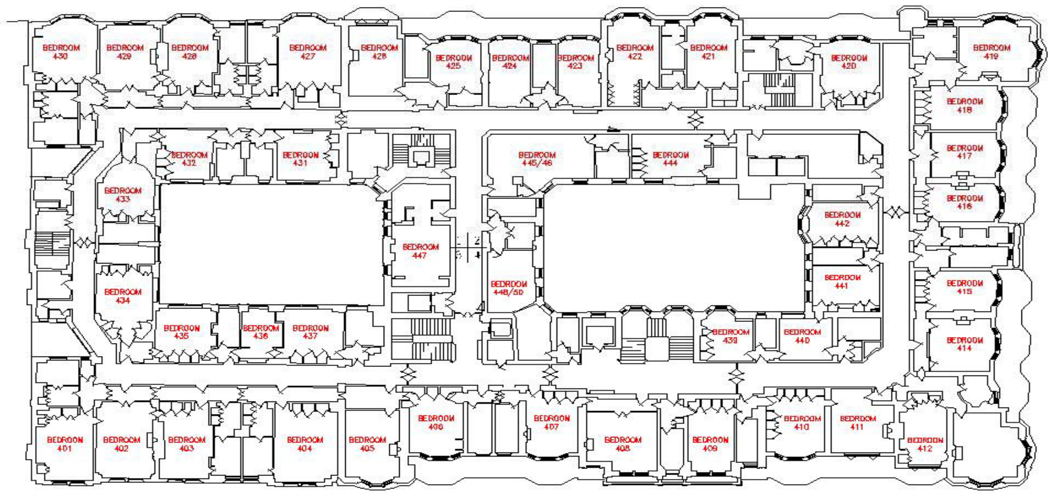
CLAR-2ND





Hotel:

CLARIDGES
Location:
INDICATIVE LAYOUT OF
THIRD FLOOR LEVEL
File Ref:
CLAR-3RD



4th FLOOR

Hotel:

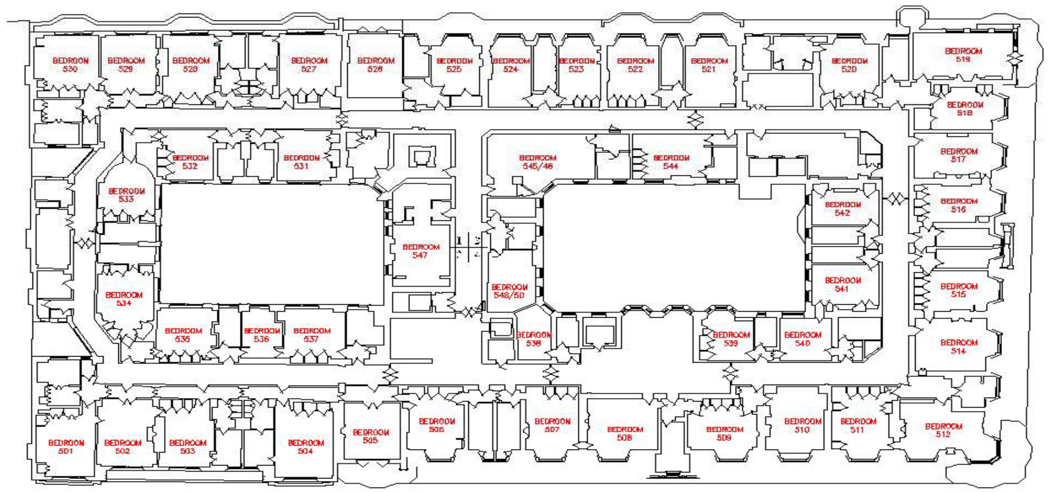
CLARIDGES

Location:

INDICATIVE LAYOUT OF FOURTH FLOOR LEVEL

File Ref:

CLAR-4TH



Hotel:

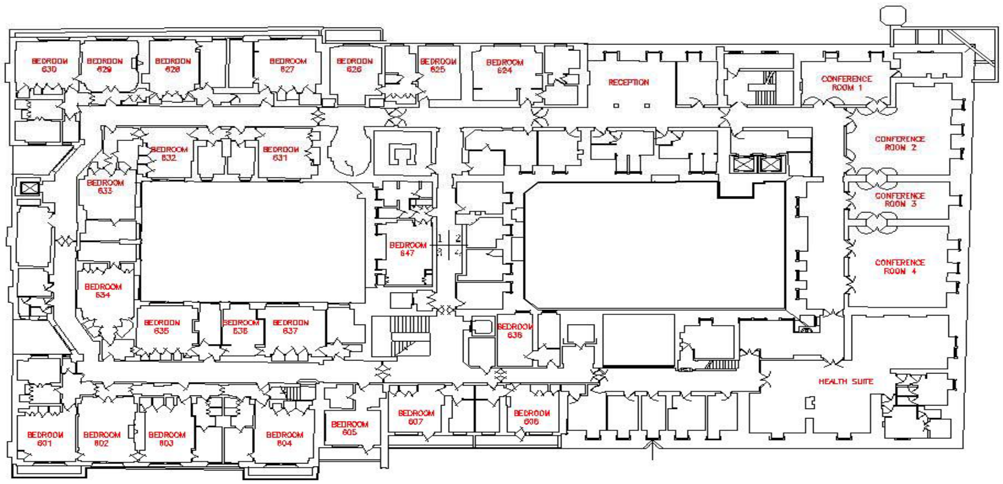
CLARIDGES

Location:

INDICATIVE LAYOUT OF FIFTH FLOOR LEVEL

File Ref:

CLAR-5TH



Hotel:

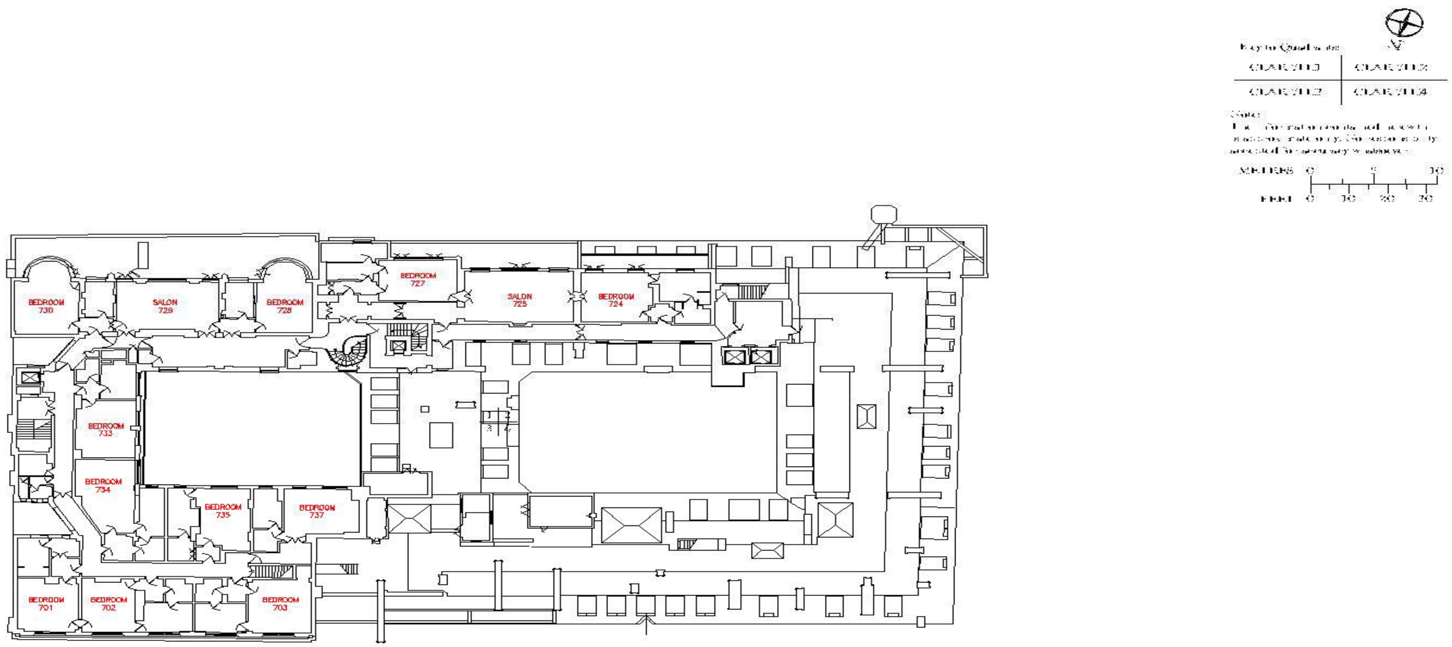
CLARIDGES

Location:

INDICATIVE LAYOUT OF SIXTH FLOOR LEVEL

File Ref:

CLAR-6TH



Hotel:

CLARIDGES

Location:

INDICATIVE LAYOUT OF SEVENTH FLOOR LEVEL

File Ref:

CLAR-7TH

HIS HOTEL IS ONE OF THE MOST FAMOUS HOTELS IN THE WORLD – BUT THAT DOES NOT MAKE IT THE BEST. THE ATTITUDE & CONSTANT STRIVING FOR PERFECTION FROM EVERY MEMBER OF STAFF IS WHAT HELPS MAKE IT THE BEST. I AM VERY IMPRESSED ABOUT OUR STAFF'S UNITARY ATTITUDE. THAT IS ………

THE ANSWER IS **'YES'**

NOW **'WHAT IS THE QUESTION?'**