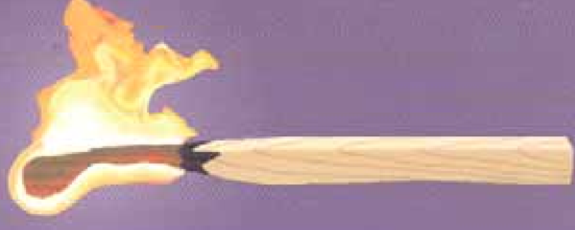
ENERGY
A Burning Issue



In the history of mother earth, the era of fossil fuels lasts no longer than the time to burn a match in the life of a human being.

The Hong Kong
Institution of Engineers
Electrical Division.

The Eleventh Annual Symposium
26th October 1993

THE HONG KONG
INSTITUTION OF ENGINEERS
ELECTRICAL DIVISION

The Eleventh Annual Symposium

Tuesday

26th October 1993

ENERGY - A BURNING ISSUE

at

Silver Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address
- Mr Peter Y.S. Wong
  Chairman, Electrical Division, The HKIE

09.05 Opening Address.Morning Session
- Prof. T.P. Leung
  President, The HKIE

09.10 Keynote Speech
- Prof. P.J. Lawrenson
  President (1992/93)
  The Institution of Electrical Engineers, U.K.

1. Energy Efficiency

09.40 Energy Efficient Pumping of Water
- Mr C.N. Watt
  Assistant Director
  Water Supplies Department
  Hong Kong Government

10.00 Energy Saving of KCRC Train by Computer Simulation
- Mr Albert Chui
  Rolling Stock Design Manager
  Kowloon-Canton Railway Corportion
  Hong Kong

10.20 Energy Efficiency in Vertical Transportation Systems
- Mr Har Boon Cher
  Project Manager
  Kone Elevator (Hong Kong) Ltd

10.40 Discussion

10.55 Coffee Break

2. Energy Management

11.25 Guangzhou Pumped Storage Power Station and Its Role in Energy Management
- Mr Charles Wong
Deputy Station Manager -
Pumped Storage Operation
China Light & Power Company Ltd, Hong Kong

11.45 A Model for the Evaluation of the Energy and Environment Security in Japan
- Mr Fumio Arakawa
Member, Board of Power & Energy Society
The Institute of Electrical Engineers of Japan

12.05 Discussion

12.20 Lunch

14.00 Opening Address-Afternoon Session
- Mr A Fretwell
Chief Engineer (Generation)
The Hongkong Electric Co. Ltd, Hong Kong

14.05 Keynote Speech
- Mr Kwok Ping Ki, JP
Director
Electrical & Mechanical Services Department
Hong Kong Government

3. Demand Side Management

14.35 Planning of Load Research for Demand Side Management
- Mr Gary C.K. Chang
Chief Engineer (Development & Planning) &
- Mr S.K. Sung
Senior System Planning & Statistics Engineer
The Hongkong Electric Co. Ltd, Hong Kong

14.55 Design and Management for Energy Efficient Building
- Mr Chris Hyland
Vice President
Parsons Brinckerhoff (Asia) Ltd, Hong Kong

15.15 Coffee Break

15.35 Status of Energy Saving in China's Industry
- Mr Chen En Jian
  Associate Research Professor & Deputy Director
  Guangzhou Institute of Energy Conversion
  Chinese Academy of Sciences, PRC

15.55 Demand Side Management - Selected U.S. Experience and Potential Application to Hong Kong
- Dr Carlos Guerra
  Director - International Programmes
  Burns & Roe Co., U.S.A.
- Mr K.W. Tong, Assistant Director &
  Mr T.H. Tai, Senior E&M Engineer
  Electrical & Mechanical Services Department
  Hong Kong Government

16.15 Discussion

16.30 Summing Up
- Symposium Chairman
  Mr Otto L.T. Poon
  Managing Director
  Analogue Group, Hong Kong

Closing Address
- Mr Ross Sayers
  Managing Director & Chief Executive Officer
  China Light & Power Co. Ltd, Hong Kong

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Mr C.N. Watt
Mr Albert Chui
Mr Charles Wong
Mr Fumio Arakawa
Mr Gary C.K. Chang
Mr S.K. Sung
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Paper No. 1
(Keynote Speech)

EFFECTIVE ENERGY MANAGEMENT

Speaker : Professor P.J. Lawrenson
President (1992/93)
The Institution of Electrical Engineers, U.K.

EFFECTIVE ENERGY MANAGEMENT

Professor P.J. Lawrenson
President (1992/93)
The Institution of Electrical Engineers, U.K.

ABSTRACT

Concerns about the problems of environmental damage and global warming suggest that the current use of energy needs to be constrained. Economic development and energy use are inextricably linked. There must therefore be a redistribution of energy use between the developed and developing countries. Both structural and commercial changes in the energy utilities are resulting in increasing emphasis on energy demand management. To this emphasis must be added the need to encourage the cultural change of favouring reduced total cost of ownership, rather than minimised initial investment.

For electrically-powered systems in particular, recent technical developments have shown that very significant energy consumption reductions are realisable at low cost without compromising output performance. The potential for energy-saving may be as high as 75% merely by exploiting already proven systems.

INTRODUCTION

What is now seen as a world-wide energy crisis stems for a number of factors, principally:-

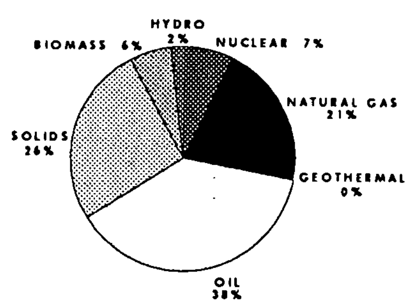
(i) the world's population is growing rapidly, from about 1 billion 100 years ago, to 7 billion currently;

(ii) individuals' expectations of services and products mean that energy consumption, per capita is increasing;

(iii) concern for environmental pollution generally and the green-house effect in particular means that there is pressure to decrease the burning of fossil fuels.

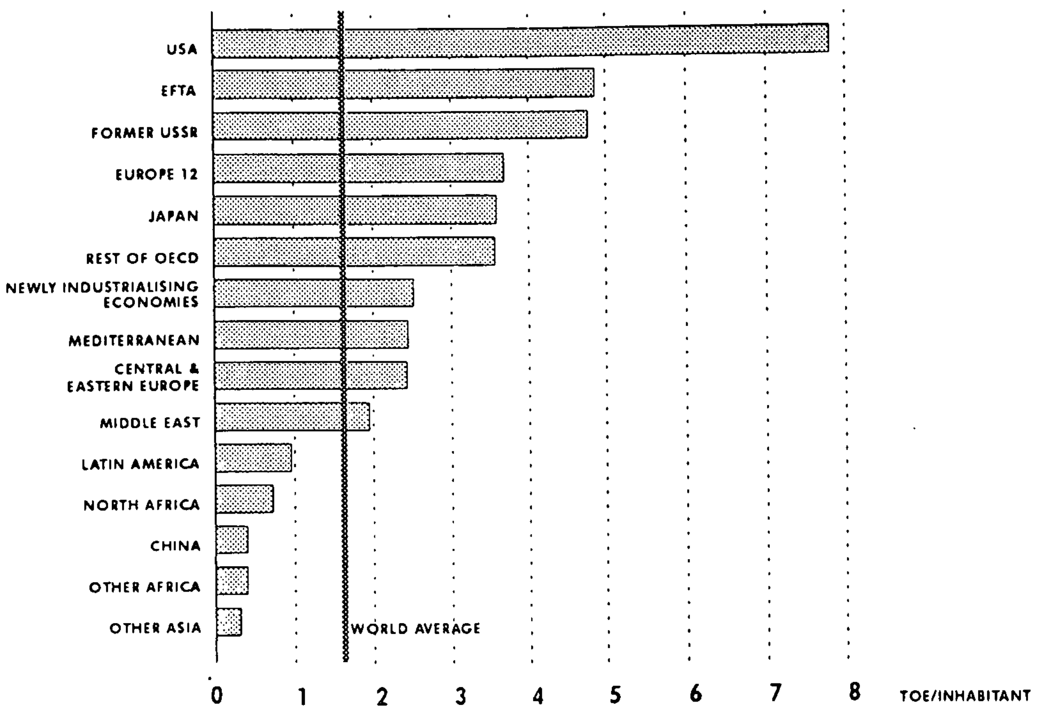
Fossil fuel consumption has been taking place at an alarming rate. In less than a human lifetime, the industrialised world has consumed more than 80% of its known oil and gas reserves. Figure 1 shows the distribution of current world consumption of primary fuels in 1991 [1]. 85% of the energy is derived by burning fossil fuels. Between 1985 and 1991,

FIGURE 1 : WORLD SHARES OF PRIMARY FUELS IN 1991



primary fuel consumption increased at an annual rate of 2.5%. More recently this increase has reduced somewhat, mainly because of the economic decline and reduced industrial activity in Central and Eastern Europe.

FIGURE 2 : ENERGY CONSUMPTION
PER CAPITA IN 1991



As can be seen from Figure 2, energy consumption per capita in 1991 varied significantly between the developed countries and third world/developing countries[1].

The relatively high consumption in the former USSR and other centrally planned economies resulted from the development of these countries being based upon energy-intensive industries which operated low efficiency plant and equipment.

Currently some 80% of the world energy resources are being consumed by only 20% of the world's population. It is quite clear from Figure 2 that the third world/developing countries will need to have a greater share of the energy cake in the future.

Figure 3 shows the variation in primary fuel consumption distribution in different parts of the world. For many of the poorer countries, increasing energy use will mean a burning of fossil fuels, mainly wood. If the overall CO_2 emissions are to be contained, the developed countries of the world will need to significantly restrict their use of energy and particularly their burning of fossil fuels.

Figure 3. Distribution of Primary Fuel Consumption by Region in 1991

Region %	Solids %	Oil %	Natural Gas %	Nuclear %	Hydro %	Geothermal %	Biomass %
Europe 12	22.1	44.8	18.6	12.9	1.1	0.2	0.3
USA	22.8	39.5	23.4	8.7	1.3	0.4	3.8
Japan	17.5	57.2	10.5	12.6	1.9	0.3	-
EFTA	7.7	40.5	7.8	19.9	14.0	0.2	10.0
Central and Eastern Europe	51.0	21.6	19.8	4.7	1.1	-	1.4
North Africa	2.8	58.2	34.8	-	1.2	-	3.1
Rest of Africa	34.2	19.5	1.5	0.9	1.5	0.1	42.3
China	73.2	17.2	1.8	-	1.3	-	6.5
Developing Asian countries	22.1	59.9	3.2	14.0	0.5	-	0.4
Mediterr-anean	9.1	90.6	-	-	-	-	0.3
Middle East	1.2	63.9	34.2	-	0.4	-	0.4
Latin America	4.6	54.2	16.7	0.7	7.4	1.0	15.6

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Figure 4 shows the energy consumption by sector and by fuel type in the UK, during 1991[2]. The sector distribution is typical of that for a developed country.

FIGURE 4(A): UK DELIVERED ENERGY CONSUMPTION BY SECTOR

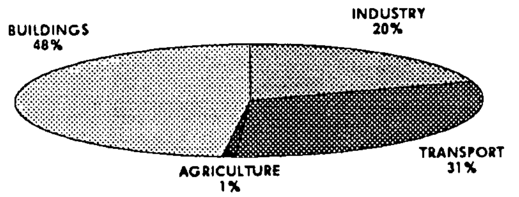
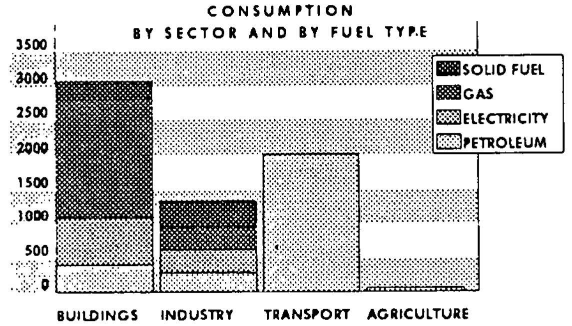


FIGURE 4(B): UK DELIVERED ENERGY CONSUMPTION BY SECTOR AND BY FUEL TYPE



It is noteworthy that energy consumption in buildings significantly exceeds that for transport and is double that for industrial use. Some 2/3 of the building sector consumption in within domestic properties where energy use is primarily for space heating, water heating, lighting, cooling and the operation of domestic equipment (washing machines, tumble dryers, freezers, refrigerators, dish washers etc.).

While in principle, petroleum products are the almost exclusive primary energy source for transport, in industry and buildings there is a mix of fuel types, with fossil fuels being used primarily for heating purposes. Understandably electricity, which is a secondary source of energy, is favoured for buildings and industrial use because of its great versatility and controllability.

USE OF ELECTRICITY

Electricity at the point of use, has few environmental disadvantages, its negative feature is its poor rate of conversion from a primary fuel and the pollution associated with that conversion process.

Electricity generation has shown a world-wide sustained increase of 3.5% per annum over the period 1985 to 1990[1]. The highest annual increases in electricity demand are occurring in Asia, particularly within the developing economics of South Korea, Taiwan, Hong Kong and Singapore.

Figure 5 shows the contribution of the different primary fuels for electricity production[1]. The use of oil for generation has been decreasing progressively, while natural gas usage has increased significantly, rising by nearly 5% per annum.

The moral pressure on the developed countries to reduce their consumption of energy perhaps impinges most strongly on electricity as a fuel. The structure of the generation/distribution industry is being radically altered in a number of countries resulting in a more detailed analysis of capital investment programmes and ongoing operating costs. In addition, technological developments

Figure 5. World-wide Use of Primary Fuels for Generation of Electricity

Primary Fuel	Fossil	Nuclear	Renewable
% Contribution	61%	15%	24%

associated with electrically powered equipment are now offering very significant efficiency-enhancement opportunities.

ELECTRICITY SUPPLY IN THE UK

The organisation and control of public utilities in the UK has been radically restructured in recent years in line with the current Government's thinking that virtually unfettered market control leads on to organisational efficiency and business prosperity.

Enthusiasm for this ideological concept has led to a series of market floatations of the nationalised utilility industries. To ensure a degree of regulation in the market and particularly to protect consumers, each service industry, gas, electricity, water and telecommunications, has come under the jurisdiction of an independent arbitrator or regulator. In the case of electricity, the Office of Electricity Regulation (OFFER) acts to ensure that market competition is free and fair and that the consumer is not disadvantaged. In addition the regulator has powers to require improvements to the standard of supply and to encourage improvements in energy efficiency - either in generation or in usage.

The new Electricity Act enabling the privatisation of the electricity industry came into force in 1989. In England and Wales, two generation companies, National Power and PowerGen were created from the old nationalised concerns. In Scotland, privatisation brought into being Scottish Power and Scottish Hydro. Because of economic uncertainties, particularly associated with the cost of decommissioning, the nuclear generating stations, remained under Government control. Bulk transfer of electricity over the National Grid system became the responsibility of National Grid Plc while the interface with the end users became the responsibility of the twelve Regional Electricity Companies (and Scottish Power and Scottish Hydro in Scotland).

The Regional Electricity Companies quickly began to exploit their freedom for action by embarking upon the building of a number of gas-fired power stations, both combined cycle, gas turbine and combined heat and power plants. This "dash for gas" has been seen as attractive because of :-

(i) the improved conversation efficiency;

(ii) the reduced environmental pollution (except for CO_2 emission);

(iii) the lower capital costs for construction as compared with conventional fossil fuel stations and

(iv) the shorter construction lead times.

The present upsurge in installation of generating capacity represents not so much an increasing demand for electricity, but rather, an exploitation of commercial activities by the Regional Electricity Companies and an opportunity to phase out older, less efficient generating facilities. The total utilised capacity is unlikely to increase significantly, particularly since regulatory pressure to enhance application efficiency is clearly set to increase.

DEMAND SIDE MANAGEMENT

Traditionally, electricity supply organisations have maximised their profit by selling as much electrical energy as possible. More detailed financial analysis of business options now demonstrates the attractiveness of demand-side management. Encouraging the use of more efficient equipment by users can avoid the necessity of investing in expensive new generation/distribution facilities. In the UK, the OFFER regulator has proposed that the regional electricity companies should spend each year GBP1 per customer on promoting energy efficiency. In total this amounts to GBP100M over the next four years. In addition he has also provided incentives which enable the electricity companies to make profits by being more efficient rather than just by selling more electricity[3].

Much of the development work on improving utilisation efficiency has been undertaken by the electricity utilities in the USA. Typical improvements in efficiency (i.e. reduced power consumption to obtain the same nett output) are shown in Figure 6(4). About a third of USA electric power utilities already have, and another third are in the process of shifting their mission and culture from a maximisation of kilowatt-hour sales. Their commitment now is to profitable production of customer satisfaction, to cutting costs more than

Figure 6. Potential saving in Electricity Usage in USA
by exploitation of high-efficiency systems

Reference to Loading in 1986

Application	Power reduction	% saving on individual installations	Cost of saving
Lighting	25%	92%	gain of 1.4 cents/kWh. (reduced maintenance)
Motor systems	25%	50%	0.5 cents/kWh.
Heating, household appliances, commercial/ industrial equipment	25%	80%	1.0 cents/kWh.

revenues and to earning profits from margin not volume. Pacific Gas and Electric Company in Northern California, has, for the first time in 40 years, not single conventional power plant in planning or construction. It sees its power supply requirements for the 90's being satisfied by improved customer efficiency topped up by input from renewable sources - sun, wind, water and biomass[5] In the UK, an interesting trial programme on demand management has recently been initiated in the town of Holyhead and the surrounding areas on the Isle of Anglesey in North Wales. The aim of this programme is to realise a sustainable reduction in peak demand of 1 MW (Current peak demand 9MW). This saving will be achieved by:-

(i) provision of two energy-efficient light bulbs per consumer at a subsidised price;
(ii) free hot water insulation to everyone who uses an immersion heater as their main source of water heating;
(iii) substantial cash rebates for customers replacing their electrical appliances with new high-efficiency devices;
(iv) lower cost insulation and draught proofing.

Related programmes are being introduced for commercial and industrial facilities. The benefit to the Regional Electricity Company concerned will be the avoidance of expensive increased supply capacity, as the current generation/distribution system is approaching its capacity limit.

CONCLUSION

There is no shortage of texts setting out full details of how to construct new energy-efficient houses, offices or factories (see for example references 2 and 6) or cost-effective means to retro-fit new efficient systems. Clearly it will take many years - decades - before even the reduced energy consumption benefits already technically proven are fully exploited. Major education and promotional campaigns are necessary to convince design engineers and scheme financiers world-wide that small increases in initial capital costs can result in dramatically lower engineering operating costs, as well as a positive contribution to solving the energy and pollution crises.

The need to combat environmental pollution, to avoid exacerbating the greenhouse effect and to provide a fairer sharing of the available energy on global basis will require active energy reduction policies associated with the efficient utilisation of energy. Fortunately, both commercial pressures and regulatory incentives are providing an impetus for utilities and users to adopt high-efficiency solutions. But achievement of a truly sustainable balance world-wide will necessitate also the establishment and acceptance of new measures of what constitute national progress and of what the 'true' needs of our societies are. Time is not on our side.

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(1) 'Energy in Europe: Annual Energy Review', Special Issue, April 1993, Directorate General for Energy (DGXVII), Commission of the European Communities.

(2) 'The CIBSE Guide, Volume G; Energy Efficiency', Chartered Institution of Building Services Engineers. To be published 1993.

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Paper No. 2

ENERGY EFFICIENT PUMPING OF WATER

Speaker : C. N. Watt
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ENERGY EFFICIENT PUMPING OF WATER

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ABSTRACT

The Water Supplies Department of Hong Kong Government is responsible for fresh and salt water supplies to a population of 5.8 million in the Territory consuming 2.5 million cubic metres of fresh water a day. Because of the hilly terrain, pumping is necessary for delivery of water to most consumers. Since the energy consumed by pumping constitutes a major element in the overall operational cost of water supplies, the Department has always been aiming at improving efficiency of its pumping system. This paper describes the ways and means of how this aim is achieved in the design and operation of a pumping system.

1. INTRODUCTION

With the rapid growth of population and economy in Hong Kong in the last few decades, there is an ever-increasing demand for water for industrial, trade and domestic purposes. Because of the hilly terrain, transfer of water in the territory requires pumping in many stages from raw water sources to water treatment works and then from water treatment works to primary, secondary and high level service reservoirs. Supply to consumers is normally maintained at sufficient pressure by gravity feed. However, for high rise buildings, further pumping of water to roof tanks is required by consumers.

The extensive reliance on pumping coupled with the need to reduce costs has focused our attention to optimising the use of pumping energy. In Water Supplies Department, many studies have been carried out recently with the view to minimising energy costs. This paper serves to provide a brief description of our findings and the methods adopted on improving the efficiency of our pumping system.

2. PUMP CURVE

For a centrifugal pump driven at constant rotational speed, the head H, the power absorbed P and hence the efficiency E, are functions of the flowrate Q. The head-capacity (H/Q) curve represents the relationship between the head generated by the pump and its flowrate. The relationship between these different values is represented by characteristic curves as shown in Figure 1.

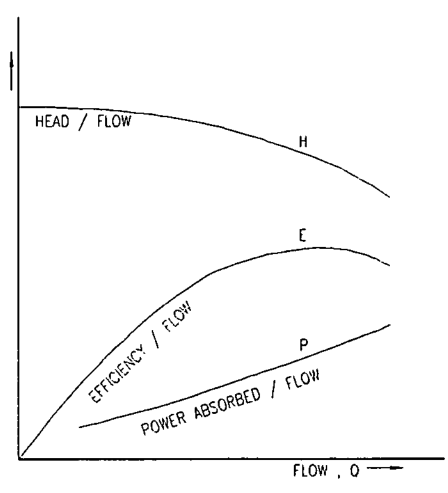

FIG. 1 - CHARACTERISTIC CURVES OF CENTRIFUGAL PUMP

3. SYSTEM CHARACTERISTIC CURVE

Each pumping system has a definite characteristic curve showing the total head requirement as a function of flowrate. The total head can be considered as the sum of the static head and frictional loss of the piping system since the velocity head losses at the suction and discharge sides of the pump are usually very small. The frictional loss is a function of pipe size, length and the number and type of fittings. In general the frictional loss varies as the square of the flowrate. Since frictional loss in a piping system forms a significant part of the total losses, engineers should take careful consideration in the design of the piping system in order to minimize head losses as much as possible. This can be achieved by optimum sizing of pipework, reduced number of pipe bends and valves and pumping at minimum constant flowrate to meet demand.

4. PUMP DUTY POINT

The duty point of a pump is the intersecting point of the pump curve with the system characteristic curve. This determines the flowrate Q which can be delivered by the pump through the system. It also determines the respective values of the pump absorbed power P and the efficiency E. The relationships between these values are shown in Figure 2.

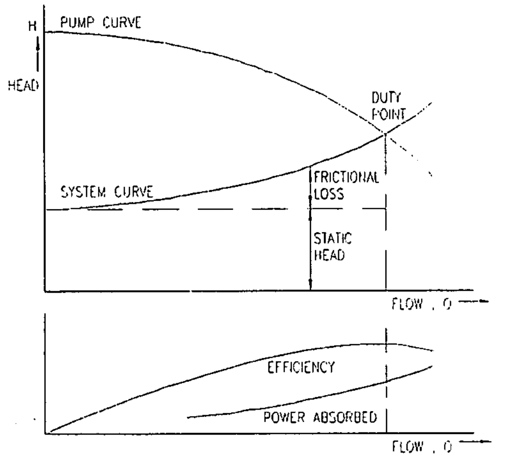

FIG. 2 - SYSTEM CHARACTERISTIC CURVE

5. PUMP FLOW CONTROL

Although it is ideal to operate a pumping system at constant flowrate, in practice, this can seldomly meet the demand which may vary daily, seasonally or increase progressively with the growth in consumption. For simple pump operation, the demand can only be met by 'on-off' control with the pump operating at a continual sequence of starting and stopping which may give rise to unnecessary stress on the motor and pump itself and surges in the hydraulic system. The alternative to frequent start-stop operating mode is to increase the volume of the balance tank or to design a system whereby the pump output can be varied, the latter may be achieved in many possible ways as follows :-

(i) Parallel operation of pumpsets.
(ii) Throttling valve.
(iii) Alteration to pump impeller size.
(iv) Variable speed drives.
(v) Dual speed drives.

6. PARALLEL OPERATION OF PUMPSETS

Fluctuation in demand can be met by operation of different combinations of pumpsets in parallel (see Figure 3).

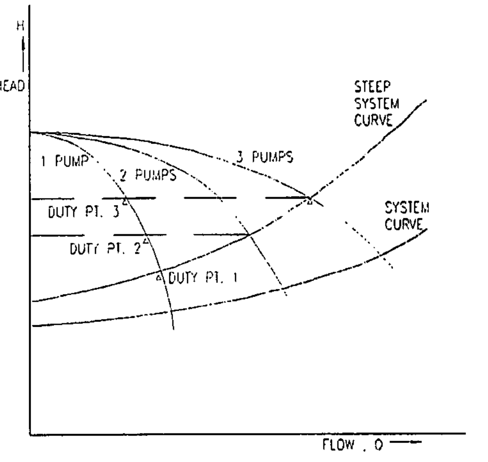

FIG. 3 - PARALLEL OPERATION OF PUMPS

The pumpsets can be of different capacity but the head generated should be similar to facilitate parallel operation. Because of its simplicity in design and operation, this method of flow control is widely used in many types of pumping station where head variations are relatively samll. For pumping system with large frictional loss (i.e. with steep characteristic curve) parallel operation of pumpsets may not be suitable because of the shift of the pump duty point to low output and efficiency.

7. FLOW CONTROL BY THROTTLING VALVES

The most common and convenient method of controlling flow is by the use of a control or throttling valve which restricts the flow in a pumping system. A typical example of this flow control is illustrated in Figure 4 where a pump is operated at duty point A with an output flow of Q. The flow is then controlled by a valve to Q1, with the pump duty point shifted to A1, with the pump duty point shifted to A1. The difference between the pump head H1 and the system head H2 is dissipated in the throttling valve. This method of flow control is essentially an energy wasteful process and should only be adopted for control of small flow changes. The other disadvantage is that if the pump is designed to operate at its optimum efficiency point at E, at reduced output, the pump efficiency will fall appreciably to E1, thus introducing further loss at the pump.

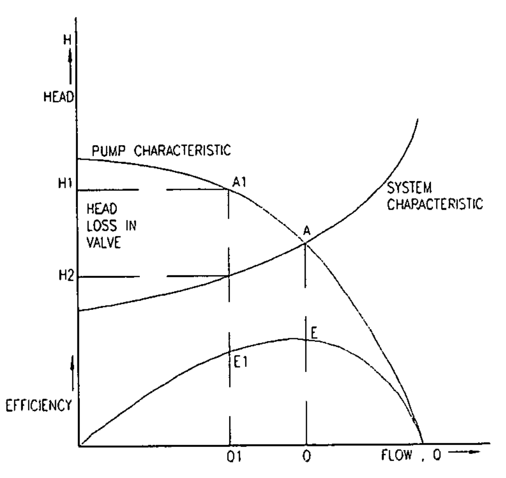

FIG. 4 - FLOW CONTROL BY THROTTLING VALVE

8. FLOW CONTROL BY ALTERATION TO PUMP IMPELLER SIZE

The flow of a radial flow pump can be reduced by reducing the diameter of the pump impeller. For minor changes made to the impeller, the following relationship applies with sufficient accuracy :-

$$\frac{Q_1}{Q}=\left(\frac{D_1}{D}\right)^2$$

The disadvantage of reducing pump impeller size to effect flow reduction is that there will be a noticeable drop in efficiency particularly for pumps with high specific speed. This method is not suitable for meeting daily or short term fluctuation in demand because of the time and effort needed for changeover of impellers. It is however suitable for situation where a permanent change in demand during the life span of the pump is required. For example a pump is designed to meet its ultimate demand with full size impeller operating at optimum efficiency. To cater for the initial period of low demand, a small impeller may be fitted so that the pump can be operated at a continuous and efficient mode.

9. VARIABLE SPEED DRIVES

Speed control is an ideal method for controlling the performance of a pump under varying operating conditions. For centrifugal pump, the relationships between speed, flow and head are as follows :-

Q proportional to n (speed)
H proportional to n^2

If a continuously variable-speed drive is used, the pumping rate can be adjusted to match the demand rate as close as possible with no unnecessary dissipation of energy in valves or in the pipeline due to high flowrate. It is also observed that by adjustment of speed, the pump itself still operates near its point of maximum efficiency. This mode of operation is particularly favourable when the pump duty point is required to vary over a wide range such as required by varying suction head and drawoff from the pumping main (see Figure 5).

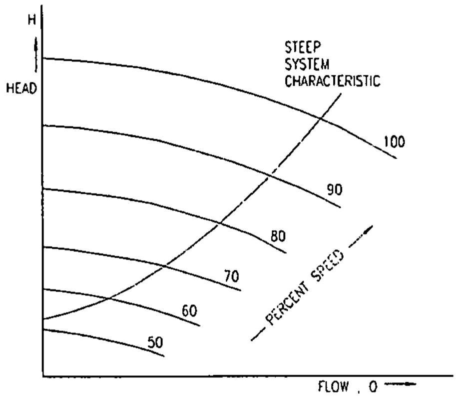

FIG. 5 - VARIABLE SPEED PUMP CURVES

The variable speed pumping system, however, suffers from the disadvantage of higher equipment and motor costs, extra energy losses in conversion equipment and higher motor losses. Further comparison on variable speed and fixed speed drives will be considered in the subsequent sections of this paper.

10. DUAL SPEED DRIVES

The use of dual speed drive for control of pumping rate is becoming more popular because of its simplicity in design and flexibility in operation. It has the advantage of a choice of speeds to meet rapid change in demand without sacrificing appreciably the pump and motor efficiencies. On the other hand, the plant has a lower capital and running cost and is generally more reliable than variable speed pumps. The only disadvantage of using dual speed motor is that it requires additional switchgear to effect change in speed. The common types of dual speed motor are dual winding induction motor and Pole Amplitude Modulation (PAM) motor. Both motors have an efficiency comparable to that of fixed speed induction motor.

11. SELECTION OF VARIABLE SPEED MOTORS

The slip-ring induction motor may be used when a limited range of speed control is required. The variation of speed is achieved by adjustment of an external rotor circuit resistance. For pump flow control purpose, the use of slip-ring motor is more efficient than the use of a throttle valve but a certain amount of energy is wasted in the external resistor.

The A.C. Commutation motor was favoured in the past for pump drive because of its smooth speed change characteristic suitable for automatic control from external signals. However, due to the use of brushes and commutator for speed adjustment, this type of motor has a high maintenance cost and low efficiency when compared with fixed speed induction motor.

The application of D.C. motors as drives for pumps has been confined to special cases such as drives on shipboard or for emergency pumps using batteries as power sources. In recent years, D.C. motors have achieved a position of some importance for variable speed drives because of developments in semi-conductor power conversion equipment. However the high capital cost of the motor and conversion equipment plus the energy loss in the conversion equipment has made this type of drive less attractive.

The variable frequency A.C. motor drives are becoming more popular in the recent years due to improvements in power electronics. In addition, the use of A.C. motor gives the advantage of higher reliability and lower maintenance cost over the D.C. motor. Operation of this motor is typically from A.C. mains through solid-state power inverter and with variable frequency and voltage output controlled by electronic circuits to achieve the desired variable speed. The drawback of the system is its additional maintenance cost and power loss in the conversion equipment. It will also generate harmonics in the supply line which may not be acceptable to the power company.

12. SELECTION OF FIXED - SPEED INDUCTION MOTORS

The squirrel-cage induction motor is the simplest and cheapest type of electric drive and is naturally the first choice for fixed speed pump. The motor has a starting torque and a pull-out torque matching the requirements of the centrifugal pump (see Figure 6). It runs at high efficiency and steady speed over a wide range of loading condition and is suitable for continuous and arduous duty requiring minimum maintenance.

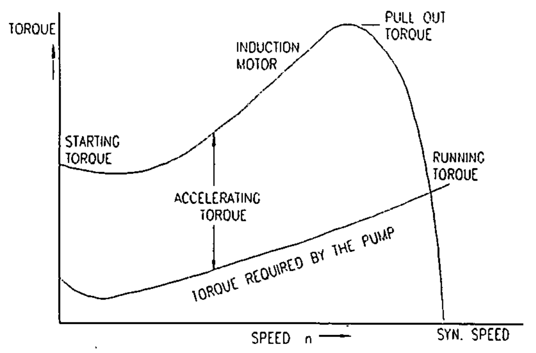

FIG. 6 - INDUCTION MOTOR

It is widely recognised that the major benefit of using induction motor is its high efficiency. In recent years, it has become more apparent that the rate of rise in running costs (electricity charges) is higher than the increases in capital costs (metal prices). It is interesting to note that an induction motor of any size running continuously could incur electricity charges which exceed the capital cost of the motor by 3 to 4 times in one year. Obviously, motor manufacturers should concentrate more effort in producing motor of higher efficiency than to reducing costs in materials. High efficiency motor requires more materials, for example, an increase in the size of stator and rotor winding will reduce copper loss and an improved core construction and material will reduce eddy current loss.

The efficiency of induction motor varies with frame size, speed and voltage. Since motor size and speed are dictated by the requirements of the pump, the design engineer should make a sensible selection of voltage in order to achieve the best motor efficiency. The following table illustrates the range of motor efficiencies achievable under different voltages.

Table 1 : Motor efficiency, 6 poles induction motor

Motor Size	Full load efficiency (%)		
	at 3.3 kV	at 6.6 kV	at 11 kV
500 kW	94.5	92.5	92.0
1000 kW	95.0	94.0	93.0
1500 kW	95.3	94.5	94.0
2000 kW	95.7	96.0	95.0
2500 kW	96.0	96.5	96.0

It should be noted that in the choice of voltage for economic operation of pumpsets, the supply source impedance and the cost of voltage step-down transformers should also be taken into consideration. With the Power Company's distribution voltage standardised at 11 kV, it is almost certain that any motor of size exceeding 1000 kW would have to be operated at 11 kV although 11 kV motors are generally more costly than motors of lower voltages.

13. SELECTION OF ELECTRICITY TARIFF SYSTEM

Electricity cost can be economized by selecting the most beneficial tariff to suit the load and operating pattern of a pumping station. A thorough understanding of the tariff structure is essential in order to maximise saving in the electricity cost.

The industrial Bulk Tariff is based on measurement of two components, namely, the maximum demand in kVA and the energy unit in kWhr. To reduce the maximum demand charge, the normal practice is to install power factor correction capacitors in the induction motor circuits such that the overall station power factor is corrected to an economical value of 0.93 to 0.96. On the operation aspect, it is desirable to limit the number of pumps running simultaneously whilst maintaining even rate of pumping as far as possible. If trimmer pumps are installed they should be operated to augment peak demand instead of calling a main pump to run for short period.

For large pumping station with high loading factor, it is often more economical to adopt the `Large Power Tariff'. However, certain operating conditions as stipulated by China Light & Power will have to be met in order to enjoy the benefit of this tariff.

These conditions are :-

(i) Maximum demand not less than 3000 kVA.

(ii) Winter demand should not be less than 50% of the summer demand.

(iii) The off-peak demand is at least 90% of on-peak demand.

Since the night time energy charge and the off-peak demand charge in excess of the on-peak demand are at lower rates, station operators should aim at maximum pumping during the off-peak hours. A computer programme has been developed in Water Supplies Department to analyze the financial benefit of adopting Large Power Tariff over that of the Bulk Tariff. Alarm codes are set in the computer programme to signal failure of the station load to meet the conditions of the Large Power Tariff or when the financial benefits derived from Large Power Tariff have ceased to exist. When this alarm is triggered, the station operator should immediately re-schedule his pumping pattern to minimise the financial penalty as quickly as possible.

14. PLANT MAINTENANCE

Regular maintenance is essential in order to upkeep performance of the pumping plant. A basic motor maintenance programme involves periodic inspection and among the items to be checked are insulation, vibration, bearing condition lubrication, ventilation and the presence of dirt. The excessive wear in the motor bearings and the build up of dust in the windings and ventilation slots will certainly cause the motor to overheat resulting in reduced motor efficiency.

Similarly excessive wear in the pump bearings, rings and bush will cause deterioration in the pump efficiency. It should be emphasized that substantial reduction in efficiency will occur if excessive erosion is found in the impeller or pump casing. In recent years, a new flaked glass re-inforced polyester resin coating has been developed for refurbishment of pump internals where erosion and/or corrosion had occurred. This coating was applied to some of the sea water pumps of the Water Supplies Department where serious corrosion was found in the pump casings. After the application of the coating, it was found that the efficiency of the pumps had increased dramatically by 3 to 4%. In view of the proven durability and qualities of this process material, its application is now extended to refurbishment of valves and station pipeworks.

15. CONCLUSION

It has been the aim of this paper to highlight the fact that in order to achieve efficient pumping, all design factors and options will have to be considered at the planning stage. The design work begins with an accurate prediction of a system characteristic curve followed by the projection of pumping demands and determination of duty points for various stages during the life span of the plant. For pump drives, although at first sight there appears to have a wide choice of electric motors, closer examination reveals that fixed speed induction motor usually provides the most economic solution both in terms of capital and running costs. It is therefore concluded that unless the pumps are required to meet a wide margin of pumping heads, operation of a combination of fixed speed pumps in parallel would generally meet the pumping duties at lowest overall cost and highest reliability.

All industrial types of electricity tariff provide financial incentive for proper load management such as high power factor, high load factor and high consumption at off-peak hours. To ensure maximum saving in electricity costs, operation of the pumping plant should be well planned to take advantage of the tariff structure while maintaining sufficient flow to meet the demand of consumers.

Last but not least, the importance of plant maintenance has been emphasized in the paper with an example of successful up-keeping of pump efficiency by coating of the pump internals. The advantage achieved by this process is not only in the reduction of pump operating costs but also in the extension of its service life.

Paper No. 3

ENERGY SAVING OF KCRC TRAIN BY COMPUTER SIMULATION

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ENERGY SAVING OF KCRC TRAIN BY COMPUTER SIMULATION

Albert Chui
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ABSTRACT

The KCRC commenced electrification of full system in 1983 with the introduction of Electric Multiple Units (EMU) trains. Over the last 10 years, more and more trains have been acquired to cope with increasing patronage demand. To date, the total fleet size is 117 3-car EMU units or 351 cars with 150,000 car-kilometerage daily.

Being one of the largest electricity consumers in Hong Kong, KCRC was determined to take positive steps to explore and implement measures to reduce train energy consumption. So far a package of measures have been explored and implemented over the last 18 months including the improved driving practice, modification to trainborne lighting and air conditioning controls, rationalisation of time table and power factor correction.

As a result, a saving of 5% to 10% of train energy consumption was achieved, amongst which 3% (460 MWh or HK$230,000 monthly) is attributed to improved driving practice. (See Appendix 1)

The improved driving practice was achieved with the aid of a computer program by which the optimum coasting (switching off traction motor) speed is determined. Train drivers could then follow the recommended coasting speeds irrespective of passenger loading in adhering to the time table run as compared with previous conventional practice for which the transitions from motoring to coasting were based on experience and practice.

On top of the energy saving through improved driving practice, the average monthly saving on brake pad consumption has been about 18% or HK$200,000.

Further development work has been carried out to enhance the improved driving practice by the provision of an audible device to automatically advise the train driver when to coast and an anticipated further saving of about 1% of train energy is expected.

1. INTRODUCTION

The definition of optimum driving practice is to utilise minimum traction energy to achieve a run between two stations within the defined time period. In the past, the train operator drove the train as 'hard' as possible in the peak hours when the train was fully loaded and the acceleration was relatively low, thus the time in the motoring mode was relatively long.

In non peak hours, trains can accelerate faster and if using the hard driving practice, the train will arrive at the next station earlier than scheduled. This is undesirable as some motoring energy is unnecessarily consumed. When the train arrives at next station earlier, more energy is wasted on train air-conditioning since the doors remain open for a prolonged time. Some passengers may feel impatient having to wait in the train for one or two minutes.

In order to achieve optimum driving skill using minimum traction energy in adhering to the time-table, the train operator shall be given some indication when or where to coast (shut off motoring power).

In this paper the concept of the optimum driving is analysed, and the software and hardware development and implementation are introduced.

2. CONCEPT

The concept of optimum driving is not difficult to understand. On a railway with Automatic Train Operation (ATO), usually the coasting vector (coasting speed, coasting distance) principle is used to achieve optimum automatic train operation. For each inter-station run, the train is given a coasting vector data from trackside so that whenever the train has actually reached the coasting speed and coasting distance, motoring power will be automatically shut off by the ATO controller.

A train simulation program was developed specifically to establish the optimum coasting vector for KCRC EMU, by which a means of indication in the driving cab could be given to remind the train operator when and where to coast. The simulation results suggested it was appropriate, for simplicity, to give an optimum speed indication only, neglecting the distance factor.

A simulation program was therefore developed to calculate the optimum coasting speed. Moreover, by optimization of the train coasting speed, brake pad consumption can be saved.

3. THEORETICAL MODEL

In developing the simulation model, the following assumptions were made :

(a) The whole train was treated as a point mass moving on the track.

(b) Distribution of train mass over the train length was not considered for simplicity.

(c) The horizontal alignment was also not considered as its effect is negligible as compared with that of the vertical alignment.

The heart of all train performance is based on the Newton's Second Law of Motion :

Force = mass x acceleration
kN = tonne (t) x metres/second^2 (m/s^2)

The basic equations are :

The tractive effort available for accelerating the train is

Tn = Te - Tr -Tg --------------(1)

Where Tn = Nett tractive effort
Te = Tractive effort available from the motors
Tr = Train resistance
Tg = Force due to gravity

The train tractive effort (see fig. 1) and braking effort were specified by the train manufacturer. Two more effects shall be taken into account, before the acceleration or deceleration can be deduced, i.e., the train resistance and the force due to gravity.

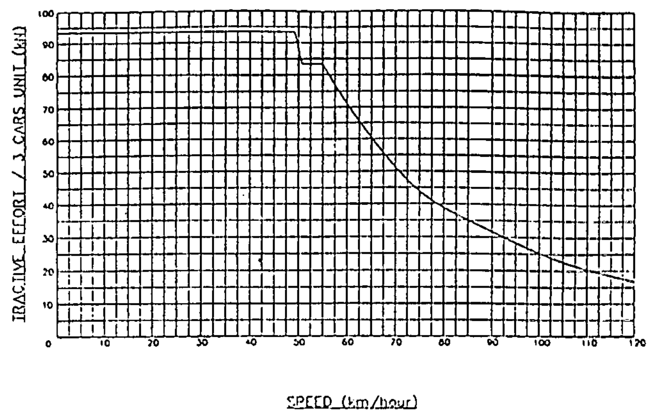


Fig. 1 EMU Tractive Effort (Per 3 Car Unit)

Train resistance

The train resistance composes of three components, namely the mechanical & track resistance, the aerodynamic drag, and the head and wake resistance.

It is very difficult to predict the rolling resistance from theoretical calculations and the figures used in calculations are based on experimental measurements.

A further component of friction is accociated with the train passing round curves and referred to as curve resistance. Again it is in reality a complicated and negligible effect , therefore was also ignored.

Gradient

Trains are heavy and require substantial effort to propel them up slopes. If a train of mass m on a slope making an angle α to the horizontal, the vertical force Mg (g is the acceleration due to gravity, 9.81 m/s^2) can be resolved into :

(i) Mgsin α along the track and,

(ii) Mgcos α perpendicular to the track.

Gradients on railways are small and usually expressed in the form 1 in X, where X is the horizontal distance moved to rise 1 unit.

4. SIMULATION PROGRAM

To calculate the optimum coasting speeds, a simulation program was devised. The program was written in Lotus-1-2-3 Version 3.1 as it was the most easily available and suitable software in KCRC at that time. A simplified program flow chart was produced and attached in Appendix 2 to illustrate the basic programming principle.

The program was written in the user-friendly way. The user needs only to input the required journey and the number of passengers to start the simulations. Furthermore, the user is able to change the journey time and track profile if required.

Look-up tables for the train tractive effort, train resistance, journey time and the force due to gravity were created and built-in the computer program. (see fig. 2.1, 2.2, 2.3 & 2.4)

tableTr

Speed km/h	rm N/tonne	rw N/vehicle	Ro N/train
0.00	65.67	0.00	0.00
8.05	11.47	64.05	644.90
16.09	12.35	75.62	667.20
24.14	13.27	99.64	693.89
32.19	14.36	130.77	738.37
40.23	15.32	171.69	809.54
48.28	16.55	215.28	934.08
56.33	17.51	266.88	1130.10
64.37	18.82	322.03	1334.40
72.42	19.96	382.53	1645.76
80.47	21.45	453.70	2001.60
88.51	22.68	524.87	2401.92
96.56	24.17	607.15	2846.72
104.60	25.61	689.44	3327.10
112.65	27.06	784.63	3825.28
120.70	28.54	882.48	4323.46
128.74	30.12	987.46	4892.80

Fig. 2.1 Train Resistance Look-up Table

tableTe

Speed km/h	Te kN (3 car unit)
55.00	84.00
60.00	70.00
65.00	58.00
70.00	50.00
75.00	44.00
80.00	39.00
85.00	35.00
90.00	31.00
95.00	28.00
100.00	25.00
105.00	22.00
110.00	20.00
115.00	18.00
120.00	16.00
125.00	15.00
130.00	14.00

Fig. 2.2 Tractive Effort Look-up Table

UN to TP	0.00	100.00	1253.40
	100.00	1100.00	0.00
	1100.00	1900.00	-497.64
	1900.00	2150.00	0.00
	2150.00	2350.00	1281.00
	2350.00	2400.00	-469.00
	2400.00	3200.00	0.00
	3200.00	3475.00	399.00
	3475.00	3575.00	310.00
	3575.00	3725.00	299.00
	3725.00	3875.00	252.80
	3875.00	4075.00	-500.00
	4075.00	4625.00	-200.00
	4625.00	6275.00	0.00
	6275.00	6625.00	200.00

Fig. 2.3 Gradient table for journey University to Tai Po

tableTime

Journey	Time	Dwell Time	
KL to MK	3.00	0.50	Up train (min)
MK to KT	2.00	0.50	
KT to TW	4.00	0.50	
TW to ST	2.00	0.50	
ST to FT	2.00	0.50	
FT to UN	3.00	0.50	
UN to TP	6.00	0.50	
TP to TO	2.00	0.50	
TO to FL	4.50	0.50	
FL to SS	2.00	0.50	
SS to LW	3.50	--	
MK to KL	3.50	--	Down train (min)
KT to MK	2.00	0.50	
TW to KT	4.00	0.50	
ST to TW	2.00	0.50	
FT to ST	2.00	0.50	
UN to FT	3.00	0.50	
TP to UN	6.00	0.50	
TO to TP	2.00	0.50	
FL to TO	4.50	0.50	
SS to FL	2.00	0.50	
LW to SS	3.00	0.50	

Fig. 2.4 Journey Time Table

The nett tractive effort for any specific train speed is calculated from equation (1), and the train acceleration, and travelling distance can then be obtained.

Having established the instantaneous acceleration, average distance over the speed increment can be calculated and the time required to travel through this distance increment is also known. By repeating this process, train performance can be obtained. Braking and coasting can be calculated in a similar manner as motoring by this repetitive process.

In order to make the iteration faster, the Bisection Iteration method was used. The average program running time on 80486 PC is about 2 minutes per inter-station run, depending on the number of iterations.

A typical simulation result is shown in fig. 3.

JOURNEY

request		UN to TP
total_dist	m	6625.00
travel_time	sec	330.00
dwell_time	sec	60.00

TRAIN CONDITION

passenger loading	tare	
total train mass	tonne	480.00

SIMULATION RESULTS (Speed limit)

coast_speed	km/h	84.00
coast_dist	m	518.07
brake_speed	km/h	73.00
brake_dist	m	3253.29
motor_speed	km/h	60.00
motor_dist	m	3325.00
coast_speed	km/h	88.00
coast_dist	m	3836.48
brake_speed	km/h	82.00
brake_dist	m	6351.68

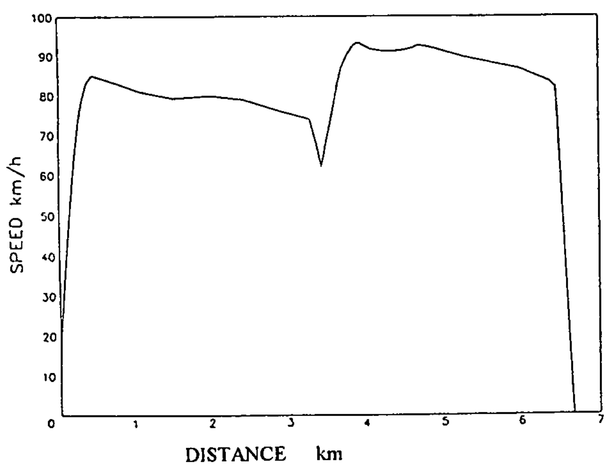


Fig. 3 Simulation Results

Several ride tests had been carried out to verify the simulation results.

In the ride tests, the simulated coasting speeds were used and the journey time discrepancies from the time-table were measured. The test results showed maximum time error was only ± 3 seconds.

5. EARLY STAGE DEVELOPMENT

At present, the optimum coasting speeds for all inter-station runs are marked on a small card. The train operator has to refer to this card to coast the train in the initial period. The card soon becomes unnecessary as the operators became familiar with the system since there are only 13 stations on KCR line.

When the optimum coasting speeds were worked out by the simulation run, they were based on the full-load condition. In actual fact, when the train is tare (no passenger) or lightly loaded, the actual coasting speed could be lowered. It was initially recommended as a speed based on all in full-load condition. However, as the driver has no means to detect the loading condition of the train, the recommendation of full-load condition ensures that the train will arrive the station on time in the fully loaded condition. Consequently in light load or tare condition, the arrival time will be earlier.

In order not to confuse the operators, it was also recommended to have all coasting speeds rounded up to nearest 5 km/h instead of odd figures.

As a result of introducing the improved driving practice, an average saving of 3% train energy consumption (460MWH or HK$230,000 monthly), and 18% (HK$200,000 monthly) brake pad consumption has been achieved.

6. AUDIBLE DEVICE DEVELOPMENT

To have an effective way to alert the train operators, an audible device is being developed. The system is illustrated in fig. 4.

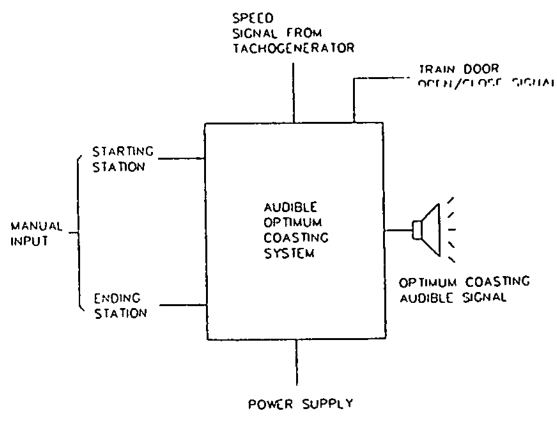


Fig. 4 Block Diagram for Audible Device

The train operator is required to give a re-set signal to identify the starting station by the driver after he enters into the cab at the terminal station.

The audible optimum coasting system can automatically detect the gross train weight by making reference to the mass detection look-up table (see fig. 5) which is generated by a simulation program.

Train mass (tonne) / Journey	Time(Sec) to achieve 27 km/h			
	480	559	637	716
KL to MK	10.97	12.82	14.69	16.58
MK to KT	10.97	12.82	14.69	16.58
KT to TW	11.47	13.51	15.60	17.74
TW to ST	9.66	11.07	12.44	13.77
ST to FT	10.97	12.82	14.69	16.58
FT to UN	10.87	12.69	14.52	16.36
UN to TO	11.08	12.98	14.90	16.84
TP to TO	11.73	13.88	16.10	18.39
TO to FL	10.97	12.82	14.69	16.58
FL to SS	10.97	12.82	14.69	16.58
SS to LW	10.62	12.35	14.08	15.80
LW to SS	10.73	12.50	14.27	16.04
SS to FL	11.34	13.33	15.36	17.44
FL to TO	10.97	12.82	14.69	16.58
TO to TP	10.97	12.82	14.69	16.58
TP to UN	10.30	11.91	13.51	15.09
UN to FT	10.85	12.67	14.49	16.32
FT to ST	11.06	12.95	14.86	16.80
ST to TW	10.97	12.82	14.69	16.58
TW to KT	12.68	15.22	17.93	20.82
KT to MK	10.55	12.26	13.95	15.64
MK to KL	10.97	12.82	14.69	16.58

Fig. 5 Mass Detection Table

The train door "open" and the speed signal are used to identify the start of journey, and the system will automatically search for the coasting speed from the built-in optimum coasting speed look-up table (see fig. 6), and once the speed is reached, and audible signal is created to alert the train operator.

Train mass (tonne) / Journey	Coast speed (km/h)			
	480	559	637	716
KL to MK	80	80	83	85
MK to KT	70	70	73	75
KT to TW	88	88	88	88
TW to ST	90	95	95	100
ST to FT	75	80	80	90
FT to UN	68	68	70	70
UN to TP	84, 88	84, 88	84, 88	84, 88
TP to TO	75	85	90	90
TO to FL	100	100	100	110
FL to SS	52	53	55	55
SS to LW	75	75	75	75

Fig. 6 Coasting Speed Look-up Table

By providing an audible optimum driving device, the following benefits can be realised : -

a) It will be more user-friendly to driver. The audible device will automatically indicate the coasting speed without having to make reference to the card or their own memory.

b) The coasting speed will be more precise instead of being rounded up to nearest 5 km/h. This will lead to marginally more energy saving.

c) The device will be able to sense the train loading condition by checking the time required to reach a certain speed. Variable coasting speeds in discrete steps commensurate with different loading condition could be provided. This will lead to quite significant additional energy saving since the current optimum speed are all based on the fully-loaded condition, where this device could offer a range of 0 to 15 km/h coasting speed reduction in the light load condition.

By means of this enhancement, 1% (153MW or HK$77,000 monthly) further saving on train energy is anticipated.

7. FUTURE WORK

Whilst the energy saving results from the initial stage are encouraging, we are confident the second stage audible device would achieve further savings with a pay-back period of less than one year.

This is however not the end of the exercise. In peak hours, the optimum driving practice quite often has to be abandoned mainly due to system instability arising from prolonged dwell time at some stations. 'Hard Driving' practice has to be used with frequent starting and stopping to keep headway short. It is envisaged that such situation could be further improved when the new Automatic Train Protection (ATP) System is implemented by 1996. Through the bi-directional communications between train and trackside and with the aid of either trainborne or trackside computer, the train could coast at lower speed to nullify the train bunching effect and to save energy.

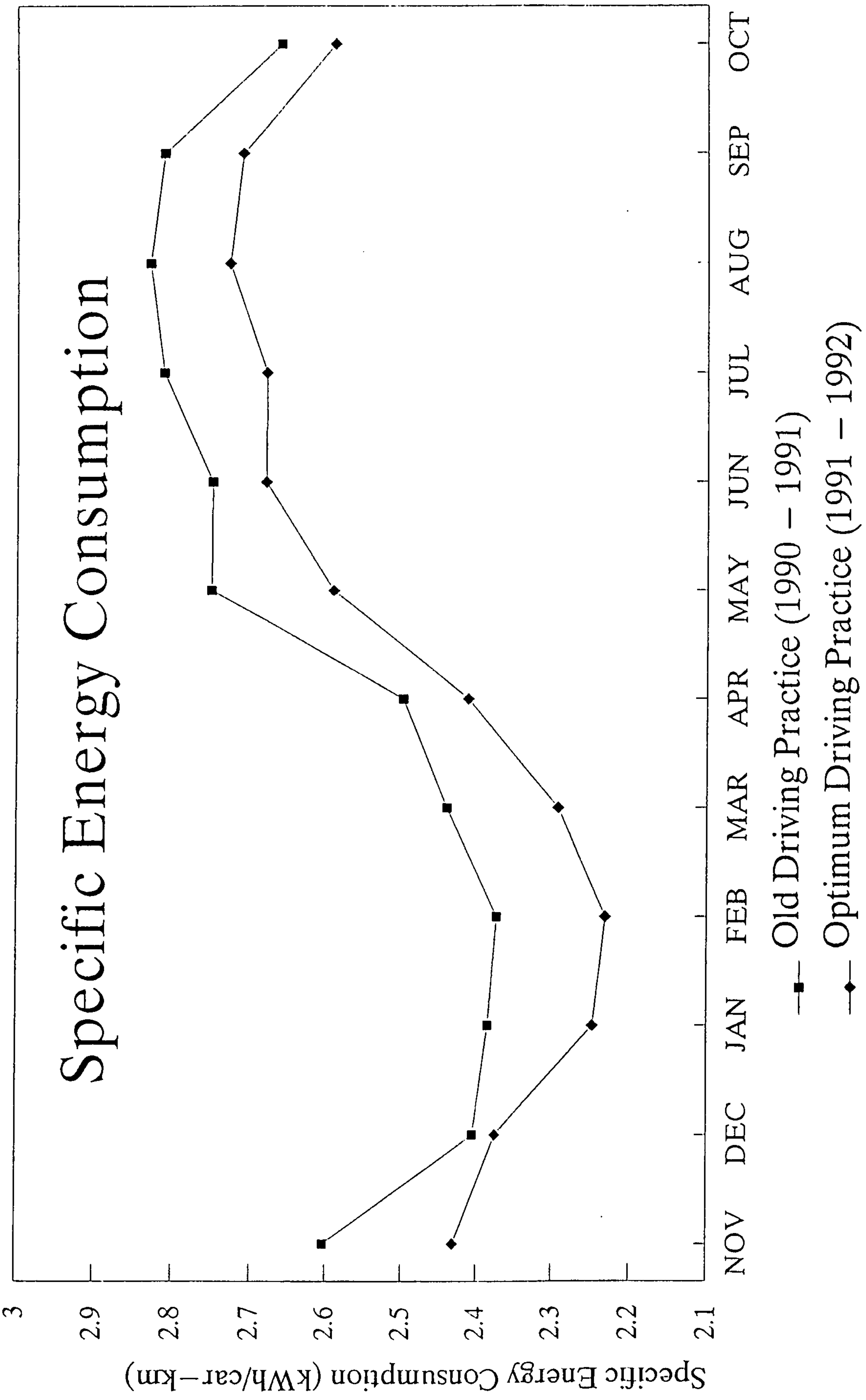
8. CONCLUSION

This paper has shown the concept of energy saving through the optimum train driving, and the implementation of the concept by the simulation program and the audible optimum driving device has been illustrated.

9. ACKNOWLEDGEMENT

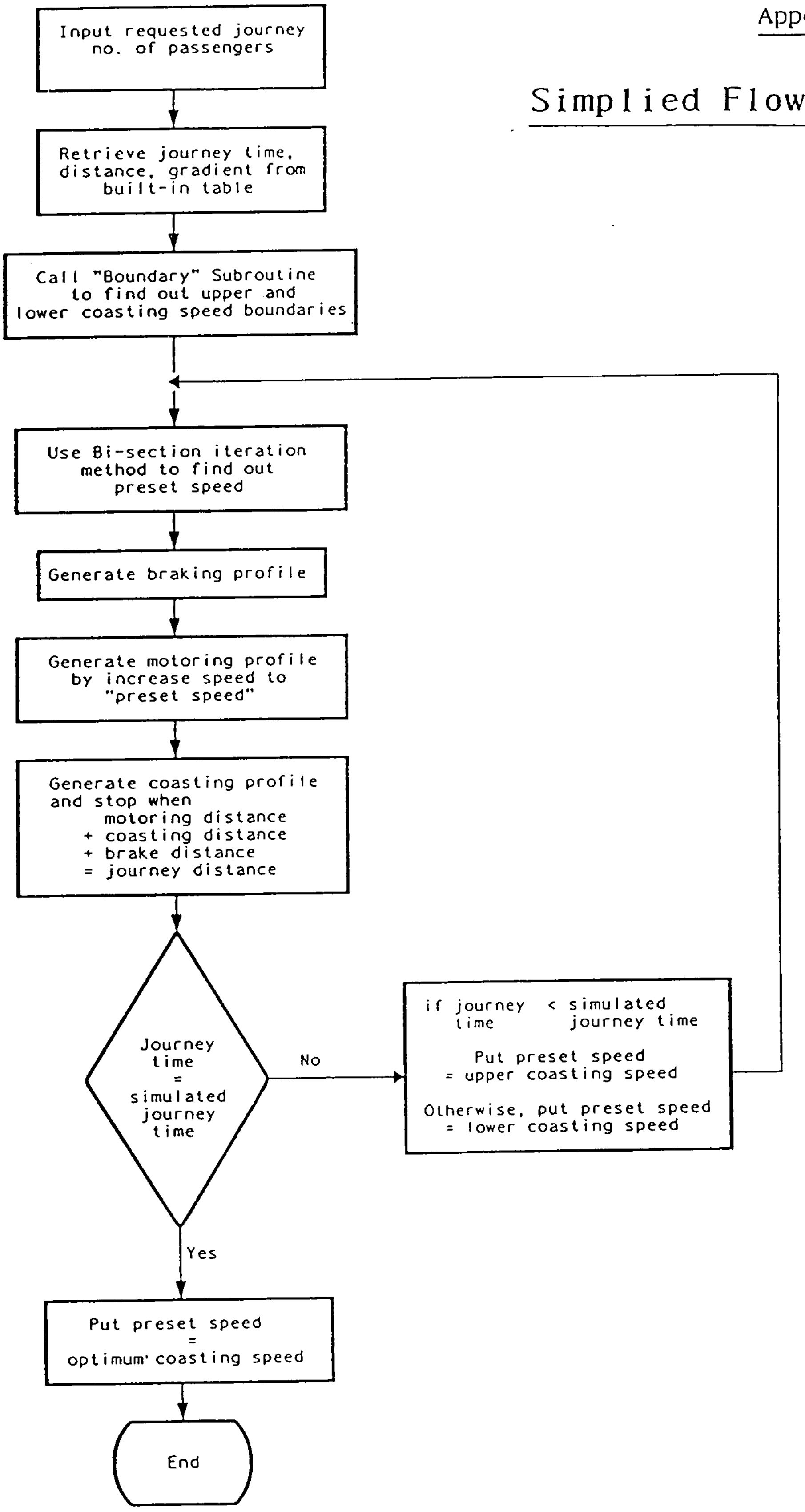
Thanks to Dr. Thomas Chow of Hong Kong City Polytechnic for his much help in developing the hardware of the audible optimum driving device.

Appendix 1


Specific Energy Consumption
Specific Energy Consumption (kWh/car−km)
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
Old Driving Practice (1990 − 1991)
Optimum Driving Practice (1991 − 1992)

Appendix 2

Simplied Flowchart



Paper No. 4

ENERGY EFFICIENCY IN VERTICAL TRANSPORTATION SYSTEMS

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ENERGY EFFICIENCY IN VERTICAL TRANSPORTATION SYSTEMS

Har Boon Cher
Project Manager
Kone Elevator (Hong Kong) Ltd

ABSTRACT

This paper introduces two common vertical transportation systems, the elevator and the escalator, in a modern building. A comparison of commonly used elevator drive systems (namely, DC with motor generator, AC variable voltage, DC with static converter and Variable Voltage Variable Frequency) and their inherent energy utilisation characteristics is presented. Areas where energy losses occur are discussed and the energy consumption of some of the typical elevator configuration is also presented.

INTRODUCTION

Since the time man began to construct buildings with more than one floor, he has given consideration to some form of vertical transportation. With the development of high rise modern buildings in recent times the need for efficient vertical transportation is even more important. In a typical building, be it an office tower, commercial complex or a residential apartment building, there might exist several vertical transportation systems to efficiently move people to where they wanted to go. Most of these systems, if not all, rely on electrical power to work. Though the energy efficiency of these systems is a relevant concern given the current effort to conserve resources, an objective view must also be taken as elevator system takes up no more than 1.5% to 3% of a total building power consumption.

This paper will look at some of the main types of vertical transportation systems used in today's modern building and to look at the energy efficiency of these systems. Also discussed will be some elevator control features developed in recent years and how these features impact on the power efficiency of the overall system.

TYPES OF VERTICAL TRANSPORTATION SYSTEMS

The elevator is the most common form of vertical transportation system one would find in a modern building. The first electric elevator was installed in New York in 1889 and since then substantial developments have taken place which improve its safety and efficiency in moving people up and down a building.

The escalator is another item of vertical transportation commonly found in places where large number of people need to be transported over a relatively shorter distance. Its applications are normally found in busy mass transport facilities such as railway stations, airports and shopping centres.

ELEVATORS

To users, all elevators are the same and do the same task, i.e. to efficiently get them to the right floor that they wanted to go. However, not all elevators are driven in the same manner and how they are driven depends on the type of traffic it must carry and other performance considerations. Basically elevators can be classified into two broad categories according to the drive system employed.

- Traction Elevator - Traction principle is a means of transmitting lifting force to the hoist ropes of an elevator by friction between the grooves in the machine drive sheave and the hoist ropes (See figure 1). The ropes are simply connected from the elevator car to the counterweight and wrapped over the machine drive sheave. Within this group of traction elevators, there are several variations based on the types of motor drive used and the roping arrangement employed (See Table 1).

- Hydraulic Elevator - Unlike the traction system described above the hydraulic elevator operates using hydraulic cylinder (could be one or several) as the drive mechanism. The hydraulic cylinder pushes the elevator car upwards and is powered by a pump rotated by an electric motor. Similarly to traction elevators, there are also variations within this type of elevators (see Table 1).

ENERGY CONSUMPTION OF AN ELEVATOR

Though there are several variations of elevator system, the energy consumption efficiency of an elevator system can be looked at from two areas, namely, direct energy efficiency of the equipment (hardwares) and the energy consumption due to operational (logic) efficiency of the elevator control system.

Energy consumption by the equipment can be categorized into the following broad areas:

- Friction losses of guide shoes and other "shaft" losses
- Diverting losses
- Door system losses
- Controls and signalisation
- Machine and drive system

FRICTION OF LOSSES OF GUIDE SHOES

There are two main types of guide shoes in used today - the roller guide shoes and the sliding guide shoes. The energy losses due to these are normally small. Only in specific circumstances will they be taken into account, for example in special goods elevator applications. These guide shoes are needed to guide the elevator travel up and down the shaft and because of the very efficient bearings in the rollers and the low friction between the sliding shoes and the guide rail, the energy expended (to overcome friction) is normally small.

OTHER "SHAFT" LOSSES

In addition to the above losses there are other losses within the confine of the shaft. The most obvious is the energy expended to overcome the air resistance as the elevator car moves up and down the shaft. Though there is a provision for shaft vents to lower pressure build up, especially for high speed elevators, there will still be losses. Improvements in recent years to reduce these losses include making the shape of the car more streamlined to improve the air flow over the car. This reduces the drag coefficient of the car and hence reduces the energy needed to overcome the air resistance. In total, losses in shaft can account up to 10% of the overall energy consumption by the system.

DIVERTING LOSSES

Diverting losses are attributed to the roping arrangement which in some installations can be rather complex. Figure 1 shows a typical 1 to 1 roping where only one diverting pulley is used. For those more complex arrangements (Figure 3), there can be more than one diverting pulleys involved and these contribute to more losses as more friction will need to be overcomed. In addition to such pulley related losses, longer ropes also result in rope extension which absorb some of the energy put in by the drive system. Though it is difficult to put a figure against the various roping arrangements the magnitude of such losses between a 1:1 and 2:1 roping systems, including losses due to extra rope weight, can amount to 5%.

DOOR SYSTEM LOSSES

Each time an elevator stops at a landing to pick up or discharge passengers the elevator car doors and the landing doors will have to be opened and closed. Though the energy consumed by friction in each door operation is not significant but given the great number of times the doors open and close the total can be significant. Older door system operate with a lever mechanism which generated more losses than the newer systems which utilise electronically regulated DC motors coupled to a belt drive.

CONTROLS AND SIGNALISATION

The consumption of the control system, illumination, signalisation and ventilation are estimated by their nominal input power. Features that cut down some of these consumptions include : autocut off of light and fan in the elevator car when it is not in use, utilising more energy efficient display systems such as electroluminence display and use energy efficient light bulbs for shaft lighting.

MACHINE AND DRIVE SYSTEM

Of all the components in an elevator system the motor and the drive system consume the most power. Hence the focus of most elevator companies has been to develop better and more efficient drive systems which aimed not only at improving the energy efficiency but also to provide a more responsive system to give a better ride comfort for the passengers. The following sections will briefly explain the various drive control systems currently in use in elevator installations and a comparison is made of energy consumption associated with each.

DC DRIVE WITH MOTOR GENERATOR

The old DC Drive with motor generator set operates on direct current which goes through many stages before finally being converted into movements of the motor (Figure 4). The alternating current from the mains is used for operating a primary motor that runs almost continuously. The primary motor runs a DC generator that produces direct current for the main elevator motor. The speed of rotation of the elevator motor is directly dependent on the DC voltage from the generator. The adjustments are made by changing the excitation of the DC generator. This is done either electronically or by using a resistor and a damping motor. Such a drive system is highly inefficient as the MG is usually set to run even when the elevator is not in use. The rationale for this is to enable a faster respond by the elevator car when a car call is made without having to start the motor generator first.

AC VARIABLE VOLTAGE

The power electronics behind the AC Variable Voltage drive system is basically a set of thyristor bridges which control the feeding of current into the main elevator motor winding (figure 5). The speed profile of an ACVV drive is maintained by a tachnogenerator mounted on the main motor shaft which provides the speed feed-back for the electronic speed control. Constant rate acceleration to full speed is achieved by feeding thyristor controlled AC current to the main winding and if braking torque is needed the motor winding is fed with thryristor controlled direct current which will generate eddy current braking action in the main motor.

IMPROVED DC DRIVE (STATIC CONVERTER DRIVE)

The improved DC Drive system which was developed in the 1970's offers energy advantages over the old DC MG drive system. Instead of using a motor generator to produce DC for the main motor the improved DC Drive converts the AC from the main directly into DC using thryristors. The system alters the DC voltage input to the main motor by adjusting the angle of opening of the thyristors. In this way, the speed and direction of rotation of the main elevator DC motor can be adjusted as these depend directly on the DC voltage and its polarity. The advantage of this direct conversion, without intermediary stages, is that less energy is lost in the process and the control over the motor is improved.

VARIABLE VOLTAGE VARIABLE FREQUENCY

We have seen from the above that most of the drives utilise some adjustments of voltage to change the main motor speed. This approach is "common" but if only voltage is adjusted the rotor will start to lag more and more because the torque imposed on the rotor by the rotating magnetic field diminishes. This system will lead to substantial losses of energy : the efficiency is poor and the energy consumption is high. If frequency is adjusted, the torque of the magnetic field remains the same (and can in fact be increased). In such a case, a decreasing speed does not imply that the torque is weakened. Adjusting the frequency of the electric current fed to the motor has for some time been a difficult practical problem. But with developments in power electronics it is now possible to produce alternating current with the desired frequency using a method called Pulse Width Modulation (PWM). Hence the development of Variable Voltage Variable Frequency system or V3F in short. A V3F drive system basically rectifies the supply current to direct current and then inverts it back to alternating current with required frequency (figure 6).

GEARED AND GEARLESS SYSTEM

Drive system can either be geared or gearless ie. the motor's rotary action can either be transmitted to the main drive sheave directly or through a system of reduction gears. In a geared system, the motor usually runs at a higher axial rotation but with a lower torque compared to a gearless system. The torque required to power the sheave in a geared drive is obtained through a system of gears. There are two main types of gears used in modern elevator installation.

- Worm Gear - these have been in use for a long time and though significant improvements were made in the worm wheel geometry, precision machining and overall design, the efficiency of such a gear still remains low. Efficiency of worm gears range from as low as 0.6 to about 0.8. Higher efficiency is achieved through more efficient tooth contacts and better arrangement of worm on the worm wheel. The higher efficiency worm gears are not common and are used in special cases due to high production cost.

- Helical Gear - these type of gears have been in use in other industries over a number of years, but only relatively recently in the elevator industry. Helical gears are more efficient than worm gears because of its design, but it is also more difficult to produce as it needs fairly sophisticated machining to achieve the right profile. If such gears are not up to quality standard it can give problems during prolonged operation in terms of higher vibration and noise level. But the efficiency of helical gears can go up to 98% and it is gaining popularity in some of the lower speed elevator applications today.

The advantages of a geared system over gearless one are that a geared system uses a smaller motor which saves space in the motor room. This can be important in an installation which has space constraint. A smaller motor also means a lower starting current which requires lower main connection. Also a smaller motor gives off less heat and hence the amount of energy loss is correspondingly lower. A smaller motor is also cheaper.

But there is a limitation to the use of a geared system. It is not suitable for higher speed elevator systems because the noise from the geared motor running at high speed can be considerable. As such most of the geared systems are usually found in elevator systems with speed up to 2.0m/s, whilst some helical gear installations run to 4.0m/s. Given the present demand for quieter drive performance the use of geared system is not advisable above 2.0m/s installation.

A gearless drive has less moving parts and thus less mechanical losses. But it will need a bigger and more expensive motor to generate the torque required. In general, a gearless system is preferred over a geared system for higher speed installation (>2.5m/s) where quiet performance of the motor is important.

TOTAL SYSTEM EFFICIENCY

To estimate the total efficiency of an elevator system, the losses due to all the above are taken into consideration. Tables 2 and 3 show a summary of the efficiency for each component and the typical system efficiency for various different elevator system configurations. It must be noted that these coefficients are indicative and use only for comparison between different configurations. The actual efficiencies are often difficult to quantify as there are many other design factors which vary from case to case. Factors such as, the speed and the number of stops, the load capacity that it is designed to carry and the type of traffic pattern the system is exposed to.

ENERGY CONSUMPTION COMPARISONS

To put some figures to the actual energy consumption of some of the systems, a series of energy consumption curves are presented in figures 7 to 10. Note that these graphs are based on the assumptions indicated. For calculations of these curves, the typical number of runs per annum for different types of buildings are assumed to be :

- low rise residential buildings : 100,000 journeys
- high rise residential buildings : 200,000 journeys
- normal commercial and hotel buildings : 400,000 journeys
- busy commercial and hotel buildings : 600,000 journeys

These figures vary for different parts of the world due to different traffic profiles and usage patterns. In Hong Kong, they are usually higher ranging from 600,000 to 1,000,000 journeys a year for high rise residential and commercial buildings respectively.

From the graphs it can be seen that V3F system offers the most efficient energy consumption while hydraulic system is the most inefficient. With heavier load, the gap between V3F and the other systems increases. For 0.63m/s speed, the energy consumption for V3F at 1600 kg is at least 11% less than an ACVV system. It is even better (at 19%) for speed of 1.0m/s.

For elevator speed of 1.6m/s, hydraulic systems become very inefficient and are not considered. The two common drive systems used for this speed range are the ACVV and the V3F. Again the energy consumption of V3F (for 1600kg) is about 40% better than ACVV. This translates to about 17,000 kWh per year for a three car group.

ENERGY LOSS

Most of the energy losses take place in the motor room in the form of heat and noise. As such, a more efficient system will not only bring benefits in lower running cost due to smaller power consumption, but also a lower cooling requirement for the motor room. This will help reduce the total energy consumption for the building.

Figures 11 and 12 show the current drawing characteristics of some of the systems. In all cases, the initial starting current for 2 speed AC and ACVV is much higher than those required for the V3F. This is one of the factors that makes V3F more energy efficient. The high starting current also impacts on the cable requirement for the motor as well as the size of the fuses needed. Table 4 shows a comparison of the cable and fuse requirement for 2 speed AC, ACVV and V3F installations.

MODERN ELEVATOR GROUP CONTROLS

The following sections discuss the various features that are now available in a modern elevator control systems and the possible energy impact they may have on the overall system.

The area where group control plays the most important role is the quality of passenger service call times, passenger waiting times and also the ride times. The reason is that in elevator bank operation round-trip time and also car loads are almost constant, irrespective of employed control system, but the sequence in which calls are served is dependent on the "intelligence" of the group control - ie serving the right calls at the right times. An intelligent system can reduce daily average call waiting times by 15 to 25% compared to some of the older control systems.

CALL ALLOCATION WITH "ENHANCED SPACING PRINCIPLE"

Elevator cars bunching can occur during heavy traffic flow, for example during morning up peak traffic where all cars can arrive at the lobby at the same time. This might cause suboptimisation in the carrying capacity of the elevator system. An advanced group control system using elevator spacing control logic can prevent this from happening. Spacing the elevator cars makes the system more efficient in moving people up the building during such peak periods. In addition, the service quality of the system also improves because passengers do not have to wait to near the round-trip time for an elevator to call. In an installation by KONE in Australia, it was found that using this new spacing principle, the average call time was cut to about half, the maximum waiting time was also halved and the number of calls with waiting time of more than 60 seconds was reduced by about 1/10th.

TRAFFIC FORECASTING AND LEARNING CAPABILITY

Another recent development for elevator control system is the application of *Artificial Intelligence* to forecast traffic demand and learn the traffic pattern. This feature can forecast traffic flow within a building and in doing so anticipate landing demand, due to specific pattern, to be served with an elevator car readily parked nearby. This forecasting and learning feature modifies normal operation to favour dominant traffic flow and optimises the system transportation capacity during traffic peaks by avoiding idle cars and build up of queues. The downside this feature is that it may cause elevator cars to be running more frequently and may result in a higher number of total starts. This could lead to higher energy consumption although an offset is that more efficient 'car to call' allocation reduces total car starts.

ESCALATORS

The operating principle of the escalator is different from the elevator. Instead of moving a car mass and a counterweight mass up and down, the escalator motor drives a continous loop of steps and handrails to transport people up or down. Energy losses within an escalator system are attributed mainly to the motor drive loss and the mechanical loss of its many moving parts. The steps of an escalator are usually designed to run at about 0.5m/s though it can be higher at 0.65m/s. To achieve this speed the escalator motor must drive through a series of reduction gears - from 1500rpm at the primary motor axial to about 25rpm at the step drive shaft. For most escalators this is done through a set of worm gears. As mentioned earlier worm gears are not very efficient hence the focus by leading manufacturers of escalators to reduce this losse. At the same time, manufacturers are also developing new operational features so that escalators need not run all the time and in doing so reduce overall frictional losses.

NEW DRIVE AND GEAR TECHNOLOGY FOR ESCALATORS

One of the improvements in the drive technology for escalators is the use of inverter motor control technology similar to that used in the elevators drive system. Motor slip due to varying loads can now be reduced with the new technology. Power factor of the drive system can now be kept close to 1 for all loads. Together with this is the development of a new and more efficient gear system. One such system is the "planetary" gear system developed jointly by O&K of Germany and KONE Elevators. It is a three stage gear system featuring a first stage helical gear followed by two stages of spur gears. This new gear system has an efficiency of at least 96% over older systems which was about 80%.

ENERGY SAVING FEATURES OF ESCALATORS

In addition to better drive systems there are now several energy saving features available for escalators.

- Standby speed feature - When an escalators is turned on it runs regardless of whether there are people on the steps or not. This has resulted in considerable energy loss for installations which have periods where there is no traffic at all. It would be ideal to stop the escalator when there is no traffic and turn it on automatically when someone approaches it. This has been done in some installations using sensor mat or other activation systems. But this has caused some discomforts to users as people tend to avoid using a stopped escalator not knowing whether it is turned off or that it will start when approaching it. Manufacturers have therefore developed a 'reduced standby speed' feature for their escalator. By reducing the speed to about 0.2m/s during no load situation manufacturers have managed to reduce energy consumption of a typical escalator (that runs all the time) by about 20% and yet not causing any discomfort to users.

  Lower operating speed - Another area where potential energy saving can be achieved is the lowering of the step speed. In a research done on London Underground it was shown that escalator can be designed with a slower speed and yet it will not have a significant impact on the actual carrying capacity. A slower speed escalator offers considerable energy savings. By lowering the speed to 0.4m/s from 0.5m/s it can actually reduce energy consumption by 30%. This is in part due to less energy is needed to drive the step and that there are less frictional losses because of lower speed operation.

To quantify some of the possible energy savings which can result with the full implementation of the above features, an installation in UK was monitored over a period of two weeks. It was found that a total saving of about 45% can be achieved for the installation. With a typical escalator energy consumption at about 4.5kW per hour, the saving per year per escalator can amount to 4,500kW per annum.

THE FUTURE

From the above discussion, it is clear that drive systems have the biggest impact on energy consumption of vertical transportation systems. To develop a better and more efficient motor is one area for future research and development.

This has resulted in the current focus to develop a new generation drive systems based on linear motor. Work is currently going on to develop a ropeless system based on permanent magnet linear sychronous motor system. Without counterweight, such a system will saves shaft space but it also needs higher torque for the drive and thus it may not be more energy efficient than today's rope-type elevator. An alternate development going on is the "roped" linear motor system (ie with counterweight). This system has more potential for energy saving as the drive torque is about the same as the present day system but with the added advantage of fewer wearing parts.

CONCLUSION

Basically elevator systems should need only a small amount of energy. As the elevator car travels up with a load it converts the electrical energy into potential energy and "imparts" it to the load. In its downward travel this potential energy should be converted back into electrical energy. This in some instances have been done through the V3F technology where energy regeneration by the motor system can put some energy back into the building's power line. But presently, there is still no efficient way to do this.

In conclusion, given the level of technology we have today for elevator system there are still some areas which elevator companies can focus on.

- Proper installation of guide rails - minimise the energy losses due to friction. Directly a good guide rail installation will also bring about a better ride for passenger.

- Proper balancing of car mass during commissioning - this effectively reduces the out of balance load which the elevator drive needs to overcome and hence a more efficient utilisation of the energy.

- Sensible layout - avoid complex roping arrangement. This may not be always possible as building designer too have their own constraints. Nevertheless, a closer collaboration between building and lift system designers at the early stage of design will certainly help.

- Use more energy saving features - incorporate energy saving features such as auto switch-off of fan and lights in elevator cars when it is not in use and standby speed on escalators.

- Design elevator system with appropriate elevator speed - an elevator will not reach its designed speed when it has to stop at every other floor. A balance between elevator speed and the number of floors serve must be considered carefully.

- Consider zoning of floors to improve traffic efficiency and carrying capacity. Zoning reduces the round trip time and hence more trips - if elevators are made to call at every floor the number of stops increases so does the number of starts per lift.

Traction	*Motor Drive* • Geared • Gearless
	Drive Control System • AC Variable Voltage • DC with Motor Generating Set • DC with Static Converter • Variable Voltage Variable Frequency
	Roping Arrangement (see figure 2) • Single Wrap • Double Wrap • 1:1 roping / 2:1 roping

Hydraulics	• Direct acting
	  • 1/2/4 cylinders
	• Indirect acting (rope hydraulics)
	  • 2:1 roping

Others	• Rack & Pinion • Screw Lifts • Scissor Jacks

Table 1 - Classification of Elevator Type

Shaft losses	**Drive System losses**	**Motor losses**	**Gear losses**
• Guide shoes (8% to 10%) • Ropes & others (5% to 8%)	• DC with MG (40% to 50%) • ACVV (30% to 35%) • Improved DC (4% to 6%) • V3F (less than 2%)	• AC motor (20% to 25%) • DC motor (20% to 25%)	• Worm gear (35% to 20%) • Helical gear (2%to 5%)

Table 2 - Efficiency of Different Components

Total System Efficiency For Typical Elevator Configuration

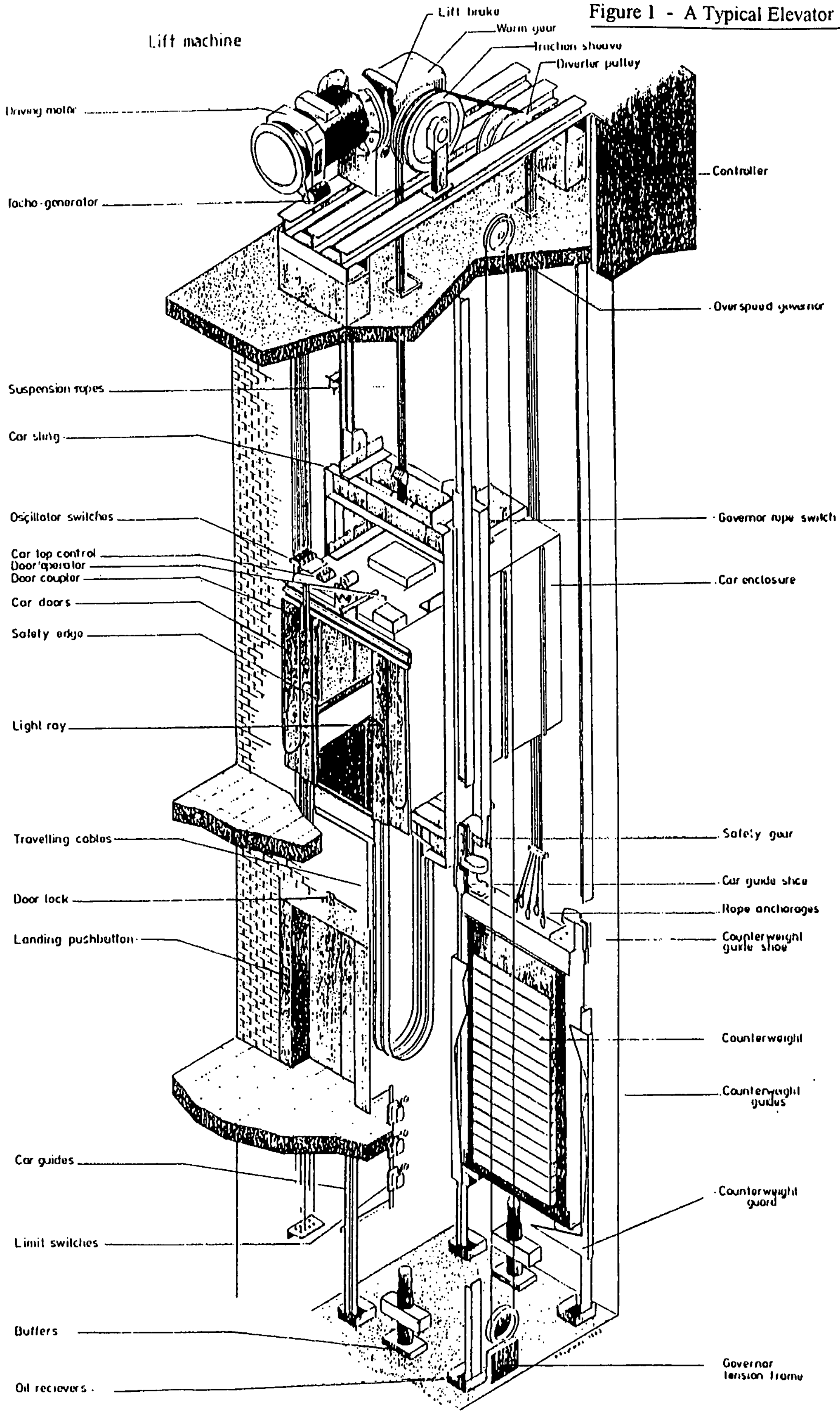
System Configuration	Total Efficiency	Ideal Application Range Elevator Speed
• Geared (worm) with V3F drive	0.5	≤ 2.0 m/s
• Geared (worm) with ACVV drive	0.35	≤ 1.75 m/s
• Geared (Helical) with V3F drive	0.64	≤ 2.5 m/s
• Geared (Helical) with ACVV drive	0.45	≤ 1.75 m/s
• Gearless with V3F drive	0.71	2.5m/s to 6.0m/s
• Gearless with Improve DC drive	0.65	4.0 m/s to 8.0m/s

Table 3 - Typical Total System Efficiency

Drive Type	Cables Size	Fuse Requirement
For 630 kg capacity and 1.0m/s speed • 2 Speed AC • V3F	 $4mm^2$ $4mm^2$	 25A 20A
For 1000kg capacity and 1.6m/s speed • ACVV • V3F	 $16mm^2$ $10mm^2$	 63A 35A

Table 4 - Cable Size and Fuse Requirement

Figure 1 - A Typical Elevator Installation



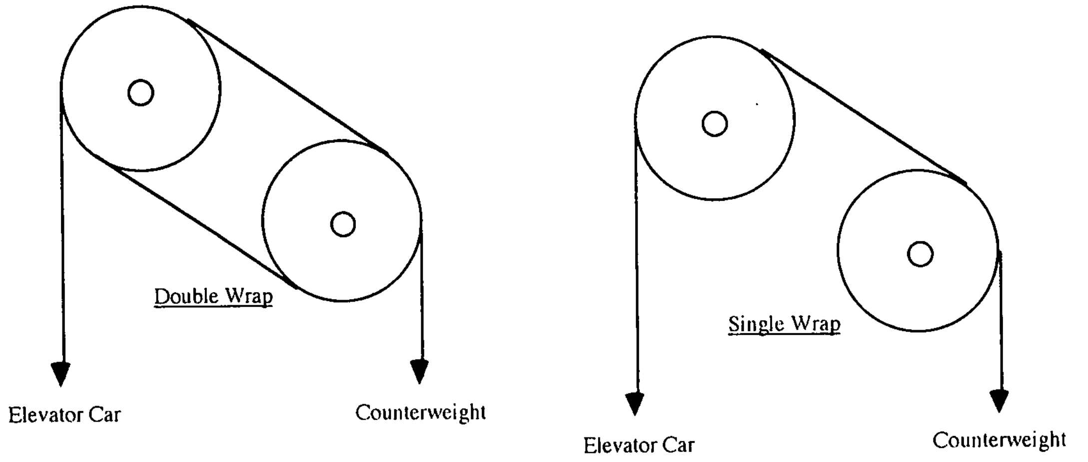


Figure 2 - Single and Double Wrap Rope Arrangement

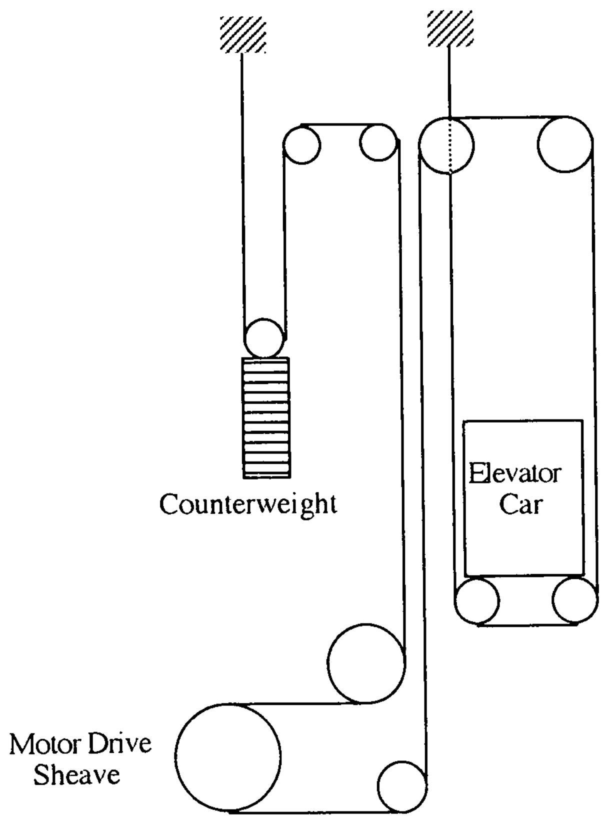


Figure 3 - An underslung, motor room below arrangement

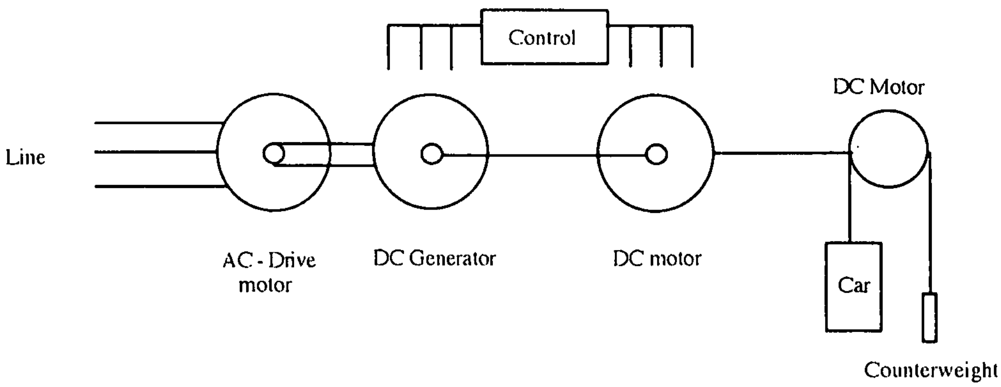


Figure 4 - DÇ Motor with Genenerator Set

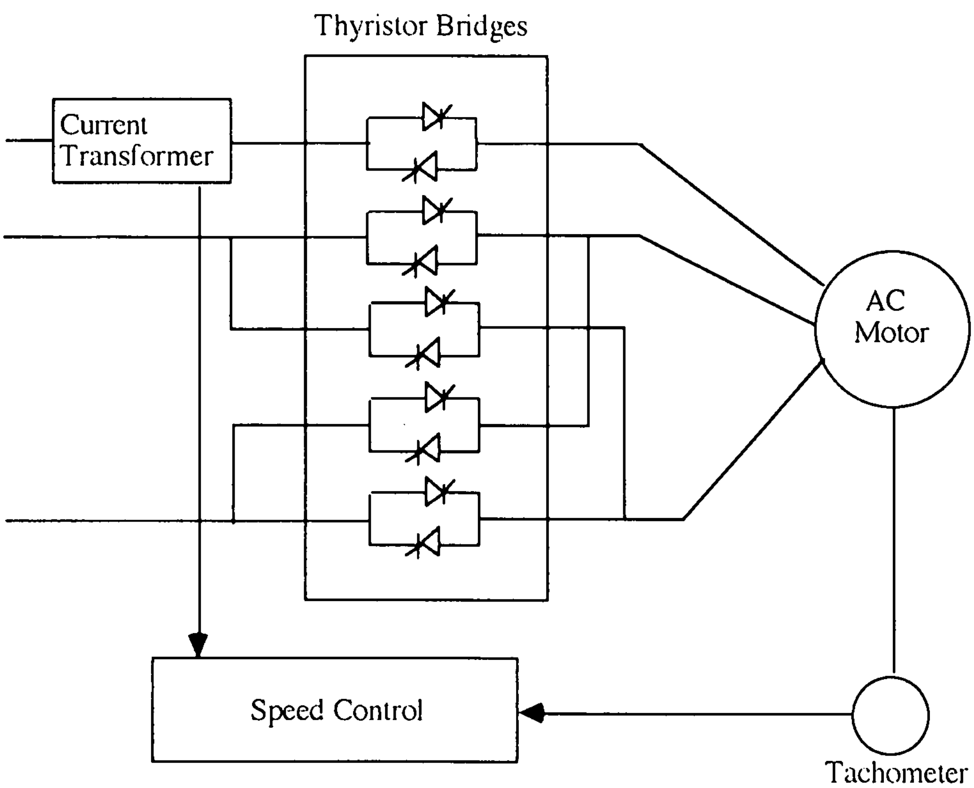


Figure 5 - AC VV Drive Control System

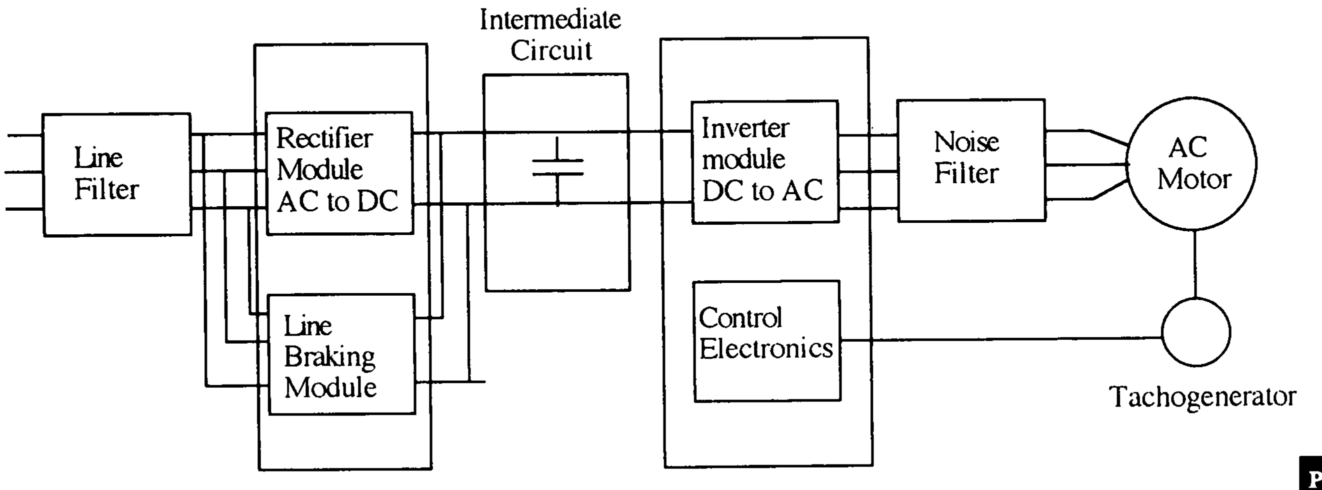


Figure 6 - Variable Voltage Variable Frequency Drive Control System

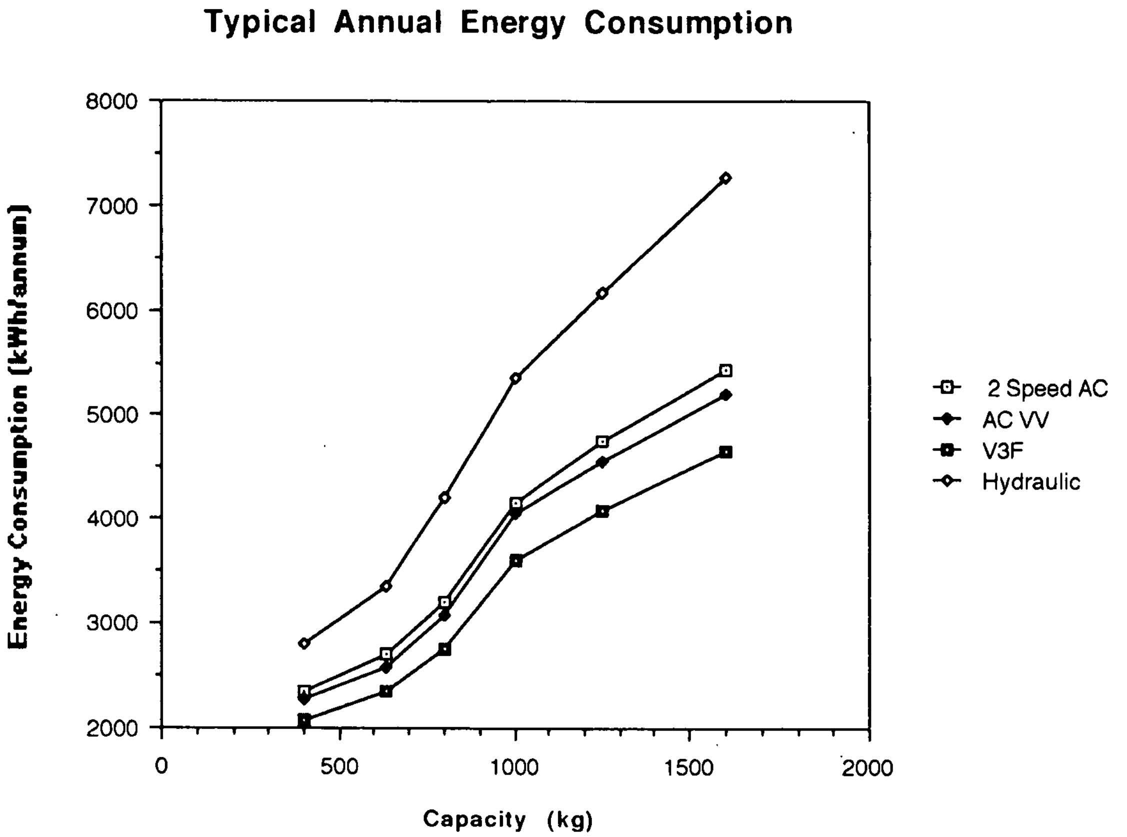


Figure 7

Notes : The above graphs are estimation of typical energy consumption of elevators with the following specifications :

- 0.63 m/s
- 100,000 starts per annum
- Typical run : 9 m (15s)

The estimations are based on theoretical calculations.

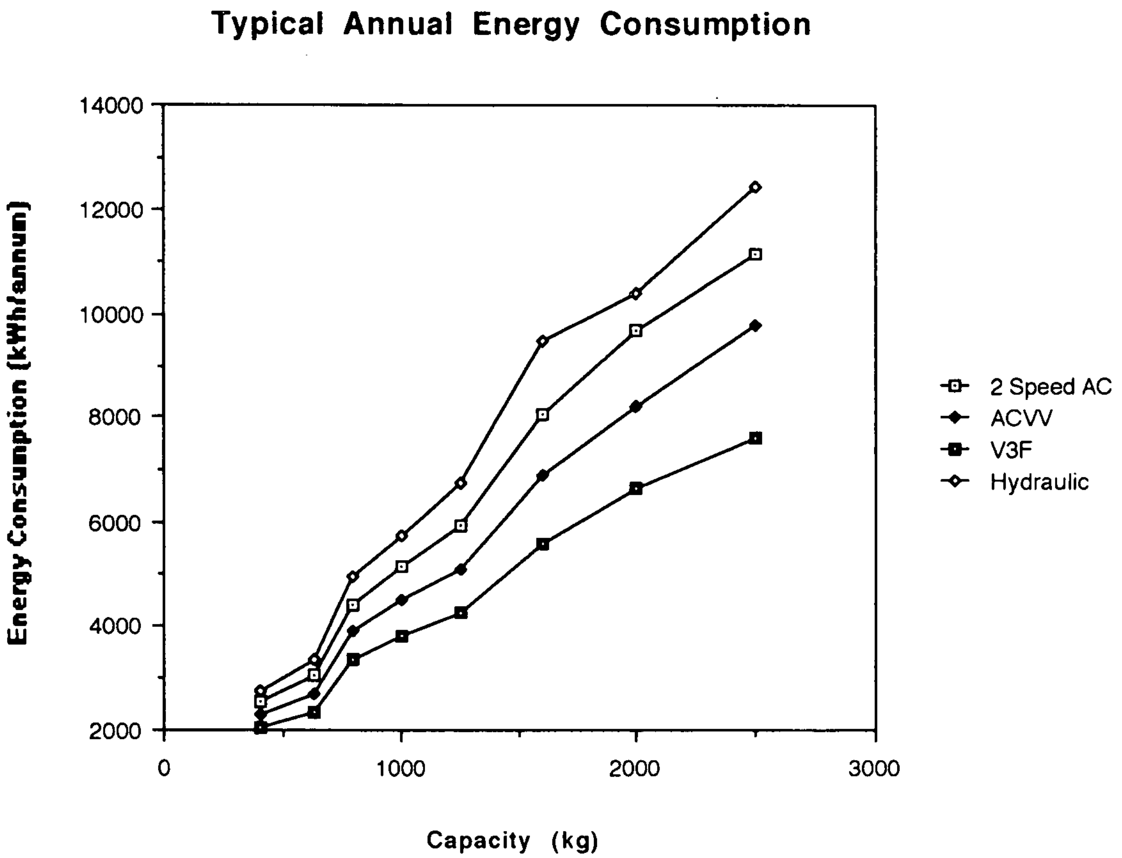


Figure 8

Notes : The above graphs are estimation of typical energy consumption of elevators with the following specifications :

- 1.00 m/s
- 100,000 starts per annum
- Typical run : 9 m (15s)

The estimations are based on theoretical calculations.

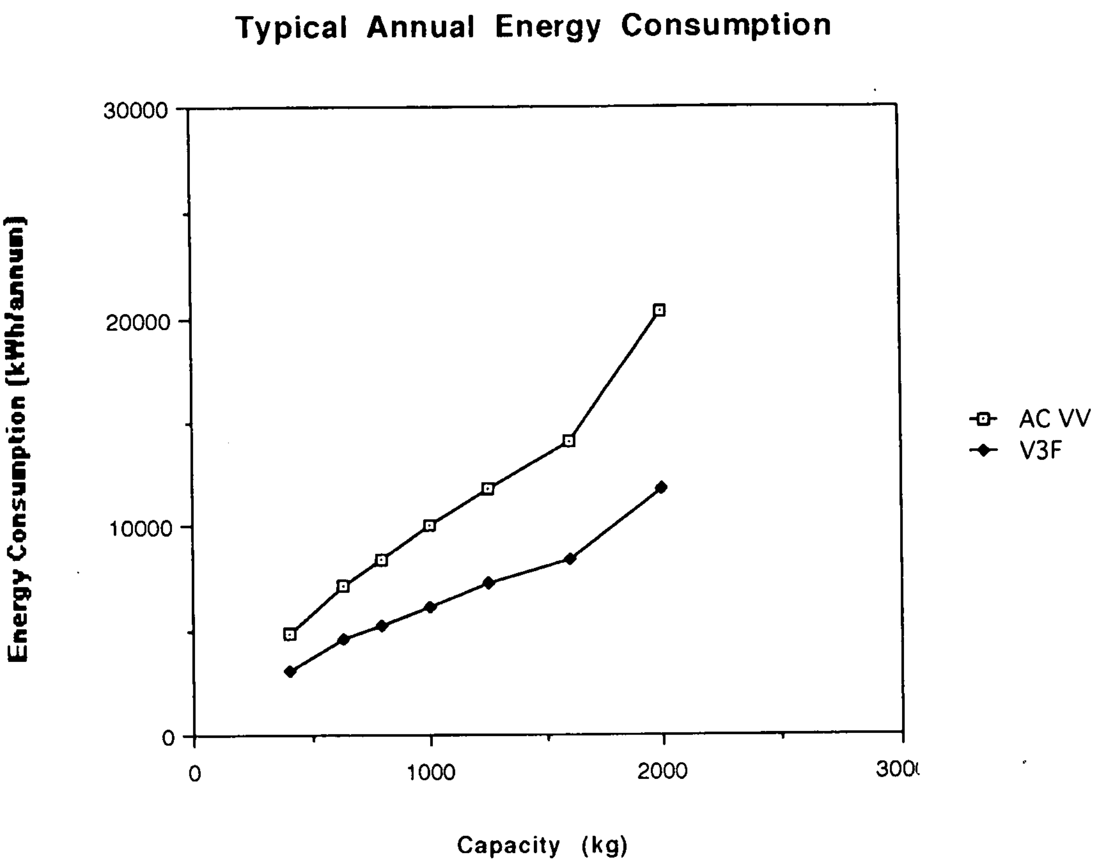


Figure 9

Notes : The above graphs are estimation of typical energy consumption of elevators with the following specifications :

- 1.60 m/s
- 200,000 starts per annum
- Typical run : 12 m (7.5s)

The estimations are based on theoretical calculations.

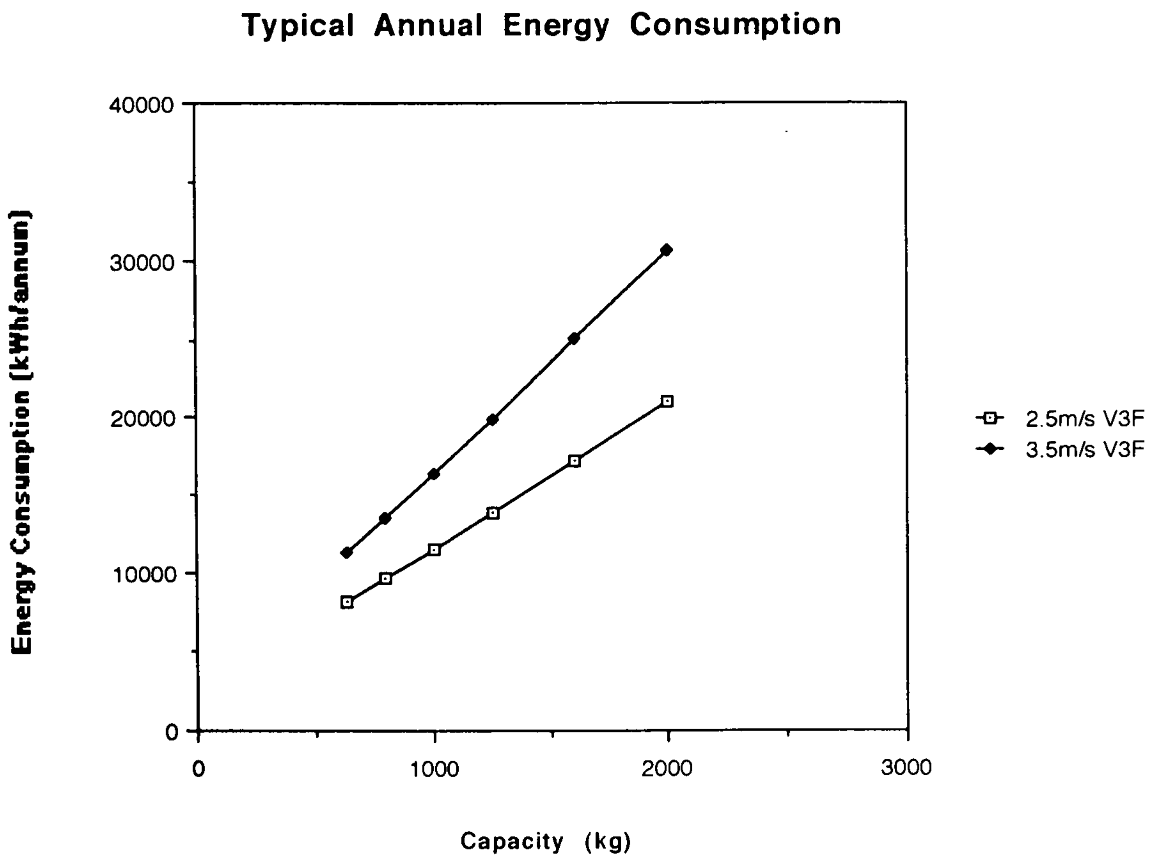


Figure 10

Notes : The above graphs are estimation of typical energy consumption of elevators with the following specifications :

- 2.5m/s and 3.5 m/s
- 400,000 starts per annum
- Typical run : 5s (2.5m/s) and 4.5s (3.5m/s)

The estimations are based on theoretical calculations.

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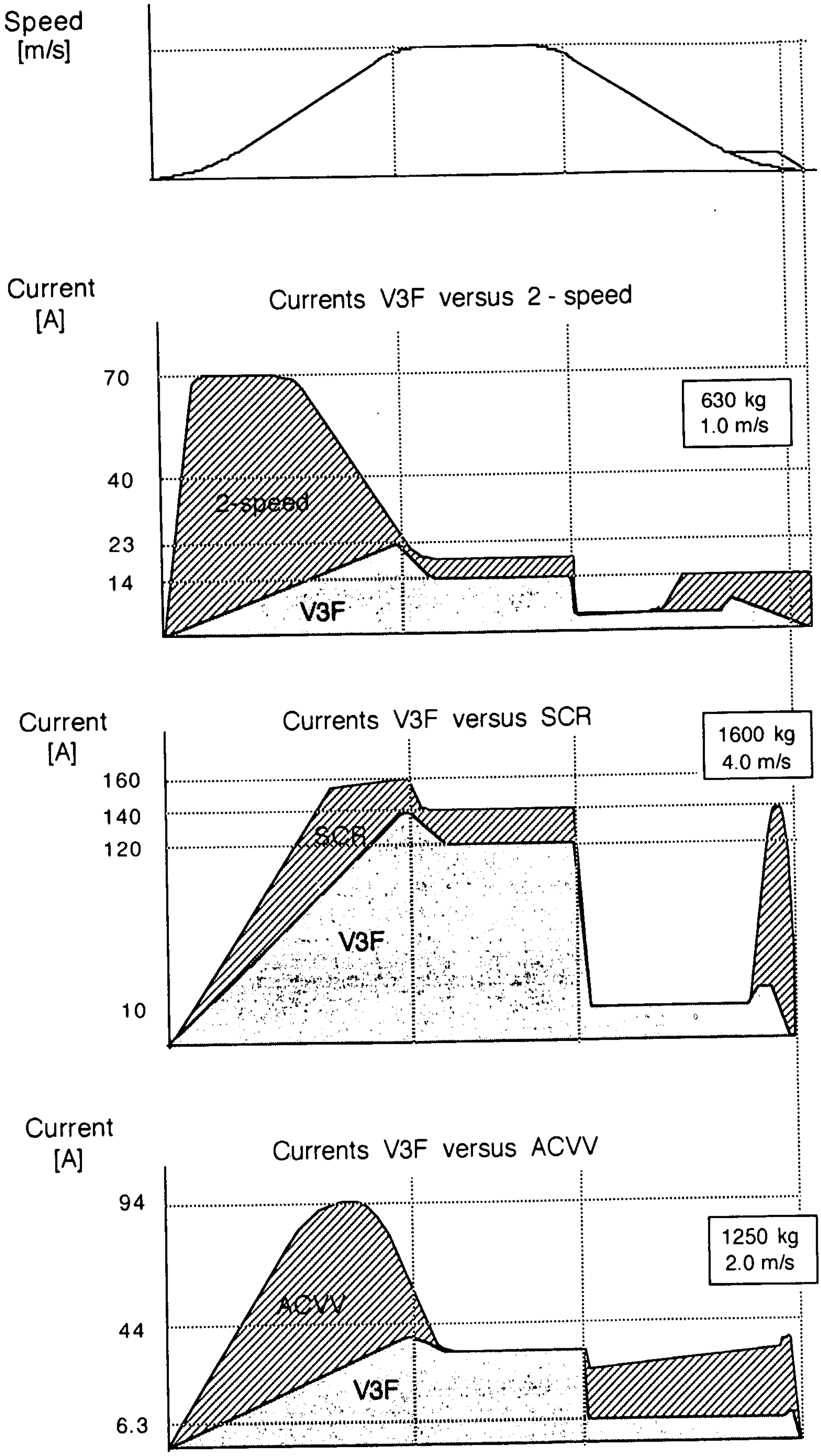

Figure 11 - RMS line current

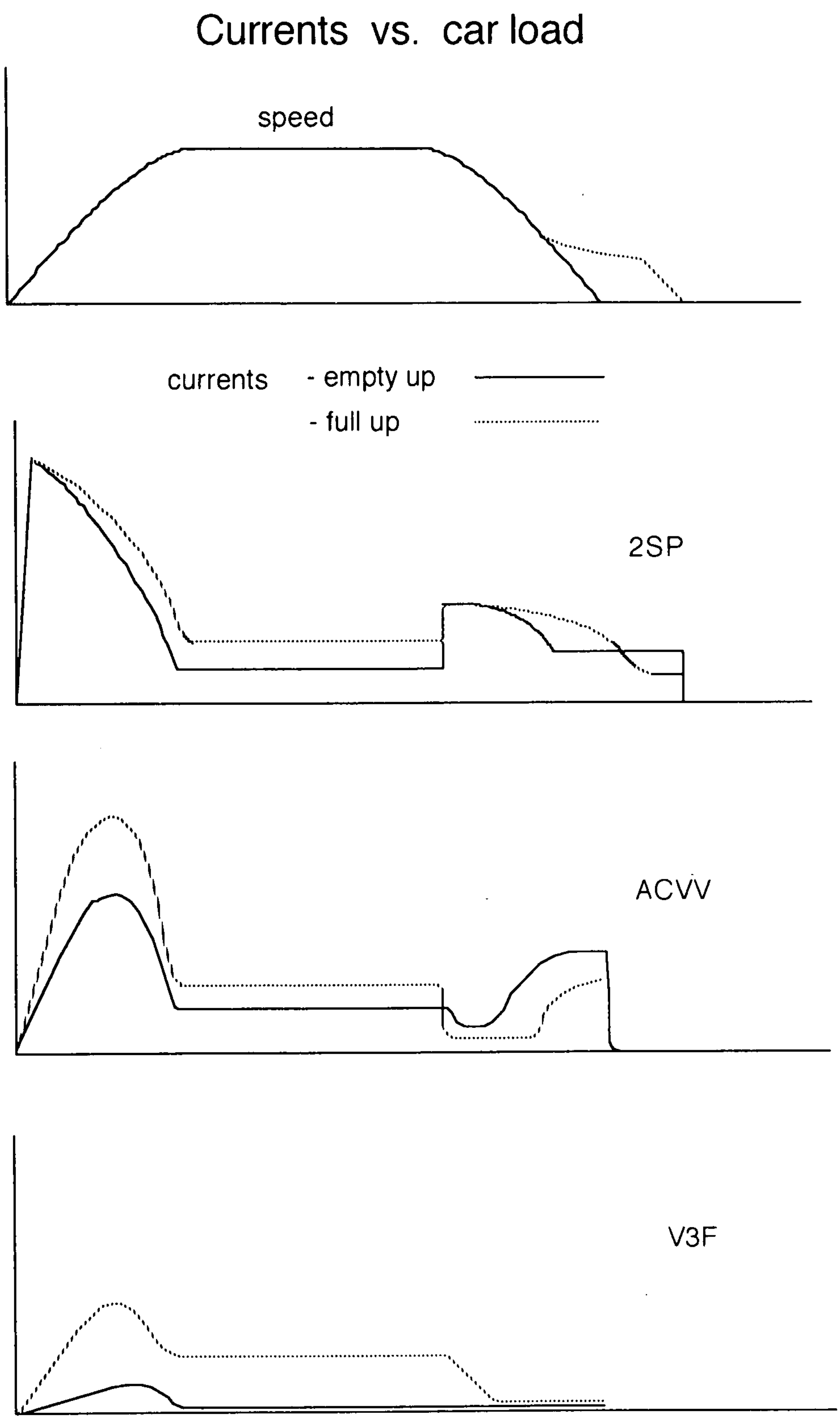

Figure 12 - Currents vs Car Load

Paper No. 5

GUANGZHOU PUMPED STORAGE POWER STATION AND ITS ROLE IN ENERGY MANAGEMENT

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GUANGZHOU PUMPED STORAGE POWER STATION AND ITS ROLE IN ENERGY MANAGEMENT

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ABSTRACT

The Guangzhou Pumped Storage Power Station is one of the largest pumped storage facilities in the world. When commissioned, it will play a major role in the interconnected systems of China Light and Power in Hong Kong and the Guangdong General Power Company in China. In connection with the nuclear power plant with Daya Bay, the Guangzhou Pumped Storage Power Station will have a major impact in terms of capacity and operating flexibility. This paper describes the relationships as well as some of the special features of the power station in achieving that goal.

1. INTRODUCTION

Electricity is one form of energy that must be used the instant it is produced. This characteristic makes it difficult for a utility to manage the daily loads because it means that generating resources are strained during peak demand periods and underutilized during off-peak hours. Pumped Storage is a form of large scale electricity storage to enable utilities to better match its generating resources to customers' demands.

2. PUMPED STORAGE BASICS

A pumped storage power station consists of two bodies of water (reservoirs, lakes, rivers, etc.) at different elevations. One or more 'pipelines' called penstock(s) connect the upper body of water to the powerhouse where the generating units are installed. As the water from the upper pool travels down the penstock through the units, potential energy is converted to mechanical and in turn, electrical energy. After exhausting its energy, the water exits into the lower pool through the 'tailrace tunnel'. During pumping operation, the process is reversed. Electrical energy from the power system is used to drive the turbines (now acting as pumps) to send the water from the lower reservoir back into the upper reservoir. Except for the ability to reverse directions, a pumped storage power station is functionally identical to a conventional hydroelectric power station.

Pumped Storage has been technically viable for over 70 years. In the early years, a pumped storage station usually consisted of a conventional hydroelectric power station and a conventional pumping station, perhaps on the same physical site. In the 1930's, with the experience gained from larger and higher head equipment primarily in Europe and South America, separate pumping/generating equipment were combined to become the single stage reversible units commonly found today. This two-in-one approach has the advantage of reduced costs at a slight loss of operating flexibility.

Paper No. 5

3. PUMPED STORAGE AND THE POWER SYSTEM

A pumped storage power station can be thought of as a large 'electricity bank'. During periods of high demand, water stored in a reservoir is released through water turbines to generate electricity to add to the available electricity supply. For a utility, this may mean that more expensive options such as gas turbines can be avoided. When demand is low, excess electricity not required for supply to customers can be used to run the same water turbines (backwards, acting as pumps) to put the water back to the reservoir, ready for use again during the next period of high demand. This effectively increases the overall utilization of the base load units. Combining the avoided costs during peak periods and the increased utilization during off-peak periods, the overall benefit to the power system can be substantial. When nuclear units are involved, pumped storage units play a even more significant role. Since nuclear units are best operated at constant high output levels, pumped storage acts as a vital buffer between system supply and demand.

Throughout the world, utilities face increasing difficulties in bringing new nuclear and fossil-fuel plants to meet increasing loads. Although some relief can be expected through conservation, it is clear that there must be better and more flexible use of existing generating resources. For a power system, flexibility is enhanced through the addition of hydropower because of it's ability to load quickly. Pumped storage units, in addition to their quick response, can store relatively inexpensive base energy for use during peaking, a feature which in itself adds to the operational flexibility of the system.

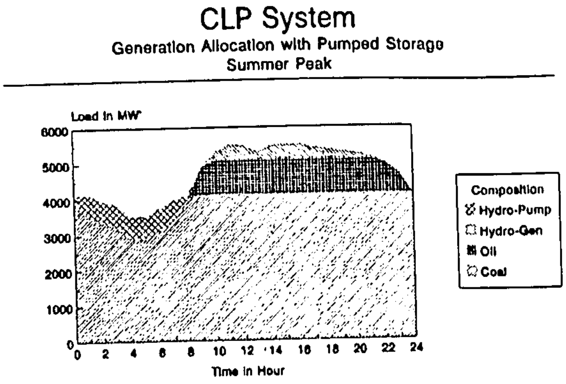

Figure 2

4. PUMPED STORAGE AND THE HONG KONG SYSTEM

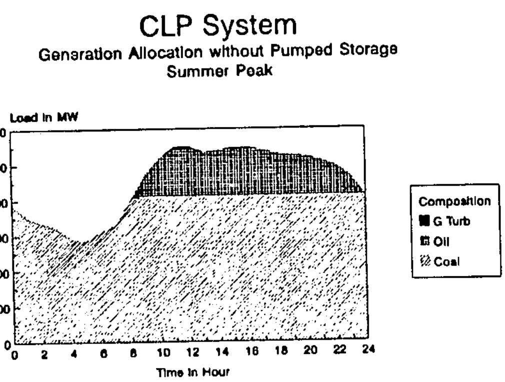

Figure 1

Figure 1 shows the daily load pattern for the China Light system during summer peak without Pumped Storage. It also shows the mix of generation required to meet the load. It can be seen that at loads up to approximately 4,100 MW, coal is the primary fuel used. Moreover, during the early morning hours, the output from these coal fired units would have to be reduced to keep in step with the reduced demand. As the load rises beyond 4,100 MW during the day, oil fired units have to be put on line. When the load approaches the daily maximum, gas turbines are brought into service. In relative terms, when the demand is satisfied by coal fired units, the per unit cost of electricity tends to be lower. Conversely, when oil fired units and gas turbines are used, the per unit cost of electricity is higher.

It would be ideal if consumers can be convinced to maintain a uniform load throughout a 24 hour period. In fact, through special tariff structures and incentives, this can be effected to some extent. With pumped storage, the distribution of daily load can be changed considerably by the utilities themselves. They can in fact creating a large block of demand of their own during the trough period. It is one form of demand side management. Instead of reducing the output from coal fired units during this period, demand is kept artificially high with any excess absorbed by the pumped storage plant. Overall efficiency of the coal fired units are improved because of the increased utilization. During peak periods, supply can be met by the pumped storage units, now running as generators, thereby displacing the need to use higher cost oil-fired units and/or combustion turbines (see Figure 2). The per unit cost is therefore lower. During the summer peak, this ability to 'transfer' of electrical generation is estimated to reduce the overall fueling cost of China Light by about 2%.

5. PUMPED STORAGE AND THE GUANGDONG SYSTEM

The Guangdong system suffers from chronic shortage of electrical power. Load management is accomplished largely by cutting off supply to consumers. With the rapid growth in the region, the situation is expected to continue for the foreseeable future. In spite of this, pumped storage can still play a major part.

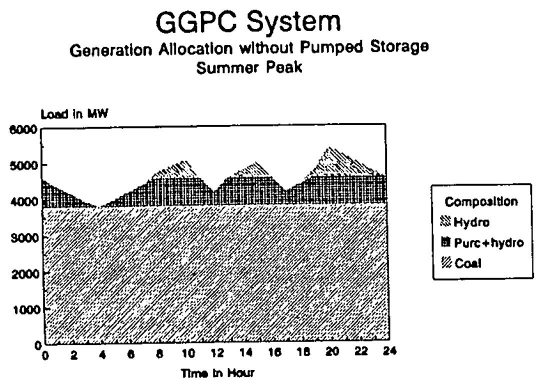

Figure 3

As in Hong Kong, the baseload in Guangdong is supplied from coal fired units. However, when the load rises through the day, purchase of electricity from Hong Kong and other indigenous hydro plants are used to make up the deficit. Figure 3 shows the daily load pattern in Guangdong. Since large percentage of the actual demand is simply not supplied to customers, the diagram is not a true representation of **total** load, particularly during peaking periods. Nevertheless, the pattern is valid.

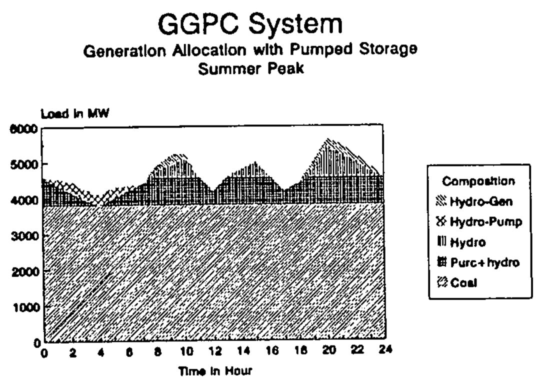

Figure 4

With the addition of pumped storage, it can be clearly seen in Figure 4 that the peaking capability is enhanced. However, due to the overall shortage, there is not much excess available for pumping. Therefore, pumping cannot be scheduled as rigorously as that for the Hong Kong system. It is a case of pumping whenever energy is available, even for short periods. Overall, when compared with Hong Kong, pumped storage usage in Guangdong will tend to be more sporadic and frequent and for shorter periods, a good demonstration of the benefits of the 'flexibility' aspect. When the nuclear units at Daya Bay are commissioned, some relief can be expected because a large portion of the coal fired generation would be displaced. In the longer term, as more nuclear plants are built, the value of pumped storage would also rise.

6. GPSPS PARTICULARS

Located in LuTien County about 90 kilometers north of Guangzhou, the Guangzhou Pumped Storage Power Station (GPSPS) is classified as a 'pure' pumped storage power station. This means that there is no natural bodies of water involved. The upper and lower reservoirs are created by damming two natural basins some 550 meters different in elevation. Collected rainwater is used as the working fluid. Nearly everything else is housed underground. Except for the reservoirs and the associated intakes, very little is visible from the outside.

A single headrace tunnel, 9 meters in diameter and 1.8 kilometers in length brings water from the upper reservoir to the underground power cavern which houses the four pump-turbine units as well as most of the auxiliary equipment. The cavern measures 22m by 45m by 147m. The tailrace tunnel which carries water from the powerhouse to the lower reservoir is 9 meters in diameter and 1.5 kilometers in length. Some of the key characteristics are shown in the following table.

Number of units	4
Type	Single stage reversible
Rotational speed	500 RPM
Maximum head	522.85m
Minimum head	500.61m
Turbine rated output	306 MW
Turbine rated flow	68.73 m^3/s
Pump maximum input	326 MW

7. PERFORMANCE

While pumped storage units generally have more problems than conventional hydro units because of more their more demanding operating regimes, they are very reliable and robust machines. The average time between overhauls is about 10-15 years with only very minor maintenance and inspections requirements in between. Usually designed for a service life of 40 years, there are units over 60 years old still operating. Dependable and flexible, they are unmatched when it comes to response time. From full shut down, the Guangzhou Pumped Storage units will be able to deliver their full output of 300 MW per unit in under 2 minutes. From standby, full output can be achieved in about 20 seconds. Similar performance can be expected for pumping operation as can be seen from the following table.

Mode change times	Time (less than)
Full shut down to speed-no-load	95 sec
Speed-no-load to full load	25 sec
Full shut down to pump-no-load	340 sec
Pump-no-load to full load pumping	140 sec
Pump full load to generating full load	360 sec

This kind of flexibility allows system managers to respond more precisely to changing system conditions, particularly when the power system is relatively small.

Guangzhou Pumped Storage was designed from the beginning to be fully remote-capable. Each unit has its own unit computer and all four unit computers are in turn controlled by a plant computer. Thus, control of each unit can be exercised at the individual unit level as well as at the plant level. Maximum loading rate is possible through this particular arrangement since instructions to each unit can be sent in rapid succession to individual unit computers that are fully functional and independent.

Another unique control feature is that of Dual Dispatch Remote Control. Since the capacity at Guangzhou is destined for both GuangDong and Hong Kong, the Station Control Computer was designed to accept commands from the system control centers of both China Light and GGPC. During normal operation, daily generation plans from the two dispatch centers would be sent directly into the Station computer. The computer will check for conflicting requests, unauthorized or abnormal requirements. Afterwards, the units would be automatically loaded and unloaded based on the generation/pumping plans of the two power systems. Should circumstances call for departures from the initial plan, either dispatch center can also send direct quick acting load requests. These would be executed immediately upon receipt.

8. CONCLUSION

With Phase 1 rated at 1,200 MW, Guangzhou Pumped Storage Power Station is one of the largest in the world. Construction of Phase 2 which commenced in April, 1993 will eventually double the overall capacity to 2,400 MW, making it the largest pumped storage station currently planned. For the first time in the history of electricity supply in Hong Kong, there is non-polluting hydropower. Power that is clean, dependable and above all, when excess hydropower is available from elsewhere during rainy seasons, renewable.

9. ACKNOWLEDGMENT

The author is indebted to Mr. CF Chow of China Light and Power and Mr. YS Liu of Guangdong General Power Company for their valuable advice and assistance.

Paper No. 6

A MODEL FOR THE EVALUATION OF THE ENERGY AND ENVIRONMENTAL SECURITY IN JAPAN

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ABSTRACT

A macro-econometric model has been developed which involves five primary energy resources, eight secondary energy categories and three final demand sectors. Various scenarios in the future are chosen by the Cross Impact Method to evaluate the security of Japanese energy systems through simulation. In this framework the model generates the total volume of carbon dioxide emission, including the case of charging carbon emission tax, the demand for each primary energy source, the loss of consumers' surplus, etc. in the case of "oil supply crisis" (sudden and serious oil supply failure) and of change in energy supply structure.

1. INTRODUCTION

"Energy Security" is defined as such an issue to balance the supply and demand of energy for the maintenance of energy system stability. It is one of the most critical issue for the government and industry in every country from not only economical but also political and social point of view. The current dynamic change in geopolitical structure of the international society makes the issue much more complex and uncertain. (1) (2)

Environmental problem is another critical issue to maintain the stability of energy systems. The new concept of "Environmental Security" to include the global environment into energy systems is needed for the positive conservation of global environment under the sustainable development.

The object of this paper is to establish a strategic planning method through the evaluation of "Energy and Environmental Security" by the quantitative analysis of energy systems. To achieve the goal a model is to be developed which can reflect dynamic changes of energy systems, taking their circumstances and effects of possible threat into account. The Energy Security Model (the Model) developed in this paper is composed of five primary energy supply sources, eight secondary energy products and three end use energy demand sectors, in accordance with the flow of energy. The relationship between sectors is expressed by demand functions.

Quantitative analysis of energy systems, so far, has been conducted by either the extraction of past data or the scenario to show possible trend. To meet with the need of strategic planning under the current uncertainty in energy systems, it is quite important for planners and decision makers to join in cooperative analysis of the situation on the basis of objective quantitative data. This paper introduces "Cross Impact Method" (XIM) for the joint work between the two.

2. MODEL STRUCTURE

There are many macro-econometric models in the world for the evaluation of energy/economy/ environment circumstances, most of which solve the problem of long term balance between supply/demand and the price. (3) (4) The Model developed in this paper is not such a kind but the one for short term dynamic analysis to simulate the effect on energy systems of such impact as supply crisis, change in tax system and introduction of new technologies.

It must be clearly recognized that goal in working with the Model is not to forecast the future correctly but to develop a reasonable and consistent plan which reflects the past data correctly and is applicable to evaluate the effect of those impacts. Functions expressing the model structure in this paper are formulated on the basis of energy data given by the statistics in the year from 1970 to 1987. The introduction of XIM will give the framework of consistency in dealing with many complicated impacts on energy systems.

As is shown in the Fig. 1, the primary energy sector consists of oil, coal, LNG, LPG and non-fossil fuel generation of hydro and nuclear power. The secondary products of energy include naphtha, gasoline, light oil, kerosene, heavy oil, coke, city gas and electric power. For simplicity the demand sector is grouped into three of transportation, industrial and residential end use, each composed of heat and power demand. Since energy demand, energy price and gross domestic product (GDP) closely effect each other, a block in the Model to deal with economic activity is essential. The economic concept of this Model is simple but ideally indicates the GDP growth by given oil price change.

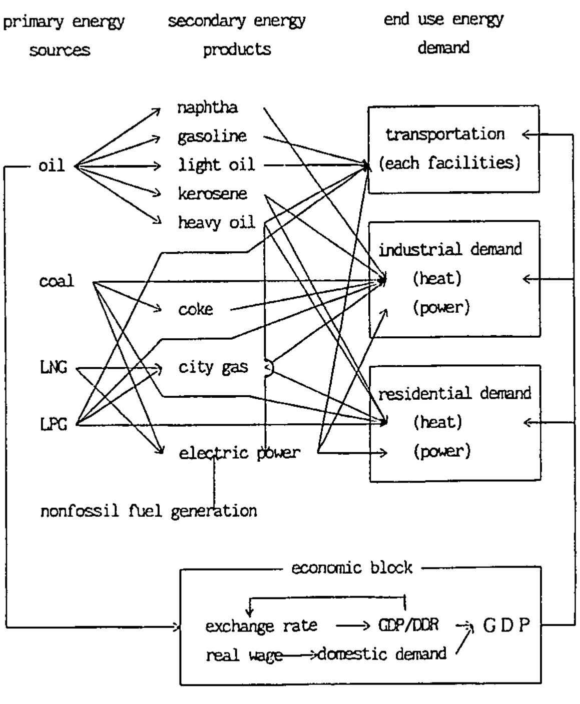

Fig. 1 Skeleton of the energy system model

One of the major objectives of the Model is to provide planners and decision makers with a tool for establishing the strategy in order to face with critical energy issue like oil supply crisis. Supply failure is formulated in the Model as a shift of supply function shown in Fig. 2. But this formulation is not directly applicable to the Model because supply of the primary energy and the final demand of the secondary energy demand is not correlated directly in the Model. In order to cope with this difficulty the Model follows the procedure explained below.

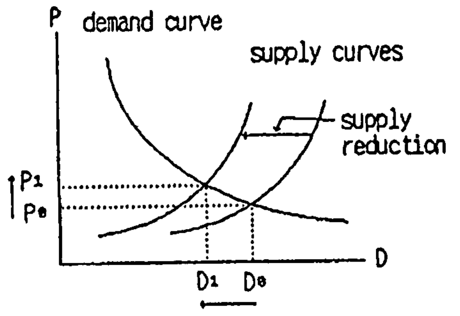

Fig. 2 Supply function shift and the loss of consumers' surplus

The simulation procedure for evaluation of a supply crisis is shown in Fig. 3. The reduction in supply causes price changes and demand declines until it coincides with supply reduction. It is assumed in the Model that a reduction in primary energy causes price changes at the same rate for all corresponding energy products. Input share change follows through the relative price changes. Since the mean energy price for the end use demand sector is then defined, one can compute the end-use energy demand according to short term demand functions. The end-use energy demand and the input share give data to calculate the required primary energy inputs. The price difference will drive the cyclic procedure to the equilibrium until the primary energy demand coincides with the given energy supply.

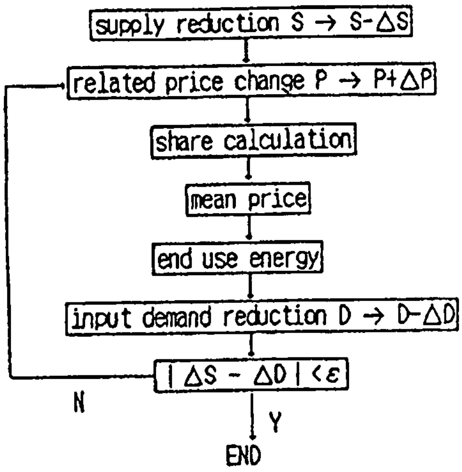

Fig. 3 Procedure for the equilibrium between supply and demand under supply reduction

There are several factors to evaluate the loss of social benefits caused by an impacts on energy systems. In case of oil supply crisis the loss of consumers' surplus will be one of the appropriate factor. The loss of consumers' surplus is the amount shown by the area surrounded with P_0, P_1, D_1 and D_0 in Fig. 2.

The structure of the Model is built with a set of demand functions for each energy product and end use energy. Demand functions introduced in the Model are such type as is shown in Formula (1), which has a time adjustment term "C".

$$\ln D_t = \alpha \ln D_{t-1} + \beta \ln Y_t + \tau \ln P_t + C \quad \ldots\ldots (1)$$

where D : demand in the term "t", Y : GDP in real term, P : price deflated in 1985, respectively. Parameters in functions are estimated as shown in Table 1 in reference to the energy statistics in the year from 1970 to 1987.

Table 1 Estimated parameters of the energy demand functions

	α	β	γ	C	R^2
demand sectors	.738	.116	−.162	4.16	.939
	(6.80)	(1.20)	(4.74)	(2.36)	6.55
industrial heat	.490	.392	−.162	4.73	.905
	(3.44)	(4.05)	(2.83)	(3.08)	1.57
industrial power	.524	−.139	···	6.10	.512
	(2.53)	(1.58)		(2.33)	1.84
naphtha	−.005*	.633	.083	10.14	.766
	(2.30)	(6.37)	(2.24)	(28.5)	1.26
coke	.700	.139	−.034	3.32	.923
	(6.02)	(1.23)	(.750)	(3.47)	2.80
residential power	.773	.296	−.032	1.30	.994
	(7.09)	(1.84)	(.532)	(2.34)	2.14
residential heavy oil	.255	.052	−.153	8.12	.711
	(1.49)	(.492)	(3.19)	(4.43)	1.83
residential coal	.381	−1.48	−.04	12.33	.872
	(1.47)	(2.23)	(.249)	(2.12)	2.04
light oil for transportation	.227	1.038	−.154	3.75	.990
	(1.99)	(7.43)	(3.80)	(8.13)	2.08
gasoline	.796	.1049	−.045	2.11	.983
	(6.99)	(1.26)	(.710)	(3.76)	2.57
LPG	.294	.0560	.0146	4.74	−.05
	(1.09)	(.317)	(.204)	(2.55)	1.74
power for transportation	.812	.1326	−.059	1.28	.978
	(6.77)	(2.19)	(1.65)	(1.41)	2.86
jet fuel	.922	.113	−.098	1.26	.978
	(9.40)	(.808)	(1.98)	(3.81)	2.59
heavy oil for transportation	.815	.1294	−.145	2.41	.752
	(6.65)	(.871)	(2.33)	(2.00)	1.59

Note 1: Numbers in the blacket show *t* value. Numbers in the lower column in R^2 row show D.W. Ratio.
Note 2: α number for coke is a factor for the year.
Note 3: β numbers for naphtha and coke are factors for P.I. of chemical and steel industry respectively.

Paper No. 6

In dealing with energy system model it is quite important to coordinate alternative fuels due to price shift and the change in total energy demand. The Model formulates fuel composition rate of thermal energy in each demand sector by the multi-logit model (5) defined by the unit price per kilo-calory (¥/kcal) of each fuel.

$$Si,t=\frac{A_i \exp(\alpha_i P_{i,t}) S_{i,t-1}{}^{\beta}}{\sum_k A_k \exp(\alpha_k P_{k,t}) S_{k,t-1}{}^{\beta}} \quad \cdots\cdots\cdots (2)$$

where Si, t and Pi, t are composition rate and price of energy "i" in the term "t" respectively. Parameters in functions are estimated as shown in Table 2.

Table 2 Estimated parameters of the Logit share function models

		coal	kerosene	heavy oil	gas (total)
industrial heat	A	1.000	.762 (2.52)	1.246 (3.32)	.534 (2.72)
	α	−.207 (.672)	−.519 (2.36)	−.736 (2.99)	−.465 (2.59)
	β	.765 (8.55)			R^2 = .962
		coal	heavy oil	LNG	
tharmal power generation	A	1.000	.878 (7.75)	.285 (1.317)	
	α'	−.238 (1.60)	−.605 (8.93)	−.255 (1.847)	
	β	.848 (18.2)			R^2 = .974
		kerosene	gas (total)		
residential heat	A	1.000	−.352 (2.26)		
	α	−.275 (1.98)	−.140 (1.42)		
	β	.437 (1.63)			R^2 = 0.855

Note 1: Numbers in the blacket show t value.
Note 2: Gas (total) is the sum of LNG and LPG.

Energy demand is then calculated in accordance with the average price of total input of energy. As the result coordination between alternation among fuels due to price shift and the change in total energy demand is consistently made in the process of "price shift of each fuel → fuel composition rate → average price of total input of energy → total energy demand → demand of each fuel".

The electric power is supplied by fossil fuel as well as hydro, nuclear and geothermal power generation which is not necessarily controlled by the market. This is the reason why the Model provides the growth rate of non-fossil power generation as exogenous variables. The Model calculates the price of power supply (Pe) with the following simple function formulated by the past trend and average price (P_f, ¥/kcal) of fossil fuel supplied to thermal power generation.

$$\left.\begin{array}{l} \ln P_e = 0.314 \times \ln P_f + 0.0355 \times \text{year} + 0.0591 \\ \qquad (5.94) \qquad\qquad (7.86) \qquad\qquad (0.149) \\ R^2 = 0.960 \qquad \text{D.W.} = 1.72 \end{array}\right\} \quad \cdots\cdots (3)$$

where numbers in ( ) are t value.

The key factor to sumilate the case of oil supply crisis is the reciprocal relation among fossil fuel prices. Table 3 is the result of the relation calculated by logarithmic single recurrent model. In this case only price increase of oil is considered. In accordance with the result the Model handles relations between oil products, LNG and oil price increase.

Table 3 Relations among fossil fuel prices

fossil fuel	heavy oil price	constant	R^2	D.W.
coal	.190 (1.06)	7.64 (4.20)	.104	1.24
coke	.213 (2.46)	7.30 (8.08)	.230	.482
kerosene	.856 (20.7)	1.83 (4.26)	.962	.801
light oil	.529 (15.5)	5.72 (16.1)	.934	.446
gasoline	.423 (17.0)	7.31 (28.2)	.944	.769
naphtha	.982 (10.3)	.088 (.089)	.861	.290
LPG	.800 (7.20)	2.30 (1.99)	.749	.684
LNG	.954 (16.4)	.557 (.919)	.940	.852

Note: Numbers in the blacket show t value.

The economic block is formulated in the Model by a set of equations as follows :-

$$\ln DD = -0.058 \times \ln PH + 0.364 \times \log PL + 0.0250 \times \text{year} + 5.53$$
$$(2.77) \quad (3.45) \quad (6.28) \quad (29.2)$$
$$R^2 = 0.0986 \quad D.W. = 0.997 \qquad \cdots\cdots(4)$$

$$\ln PL = 0.741 \times \ln PL(-1) + 0.154 \times \ln Y(-1) - 0.585$$
$$(16.8) \quad (3.39) \quad (2.76)$$
$$R^2 = 0.998 \quad D.W. = 2.39 \qquad \cdots\cdots(5)$$

$$\ln(Y/DD) = 0.319 \times \ln(Y/DD)(-1) + 0.140 \times \ln(¥/\$)(-1) - 2.51$$
$$(8.91) \quad (5.00) \quad (7.44)$$
$$R^2 = 0.871 \quad D.W. = 1.50 \qquad \cdots\cdots(6)$$

$$\ln(¥/\$) = 0.816 \times \ln(¥/\$)(-1) - 1.78 \times \ln(Y/DD)(-1) + 0.924$$
$$(5.60) \quad (1.90) \quad (1.17)$$
$$R^2 = 0.899 \quad D.W. = 1.62 \qquad \cdots\cdots(7)$$

where PH : price of heavy oil, DD : domestic demand, PL : real wage, Y : GDP in real term, (¥/$) : exchange rate, (-1) : value in one term before.

The Model built in such a manner as explained above fits to the historically actual results in Japan as shown by the high number of R^2. Fig. 4 is one of the example to show precise fitness of the Model in case of fossil fuel demand shares for electric power generation.

The model sets some assumptions and procedures in order to evaluate the cogeneration into energy systems. The capacity of cogeneration in the year 2000 and 2020 can be estimated freely for scenario setting. A quadratic function is introduced to give the capacity for each year so that it fits to actual value of 1.28 GW in Japan in 1989 and values in 2000 and 2020. Load factor and thermal efficiency of cogeneration, thermal power generation efficiency and boiler efficiency are assumed as 50%, 80%, 40% and 90% respectively. Heat is assumed to be supplied in cogeneration from residential sector. Fuel for cogeneration is assumed to be LNG only. Procedures to maintain energy balance in the Model are :-

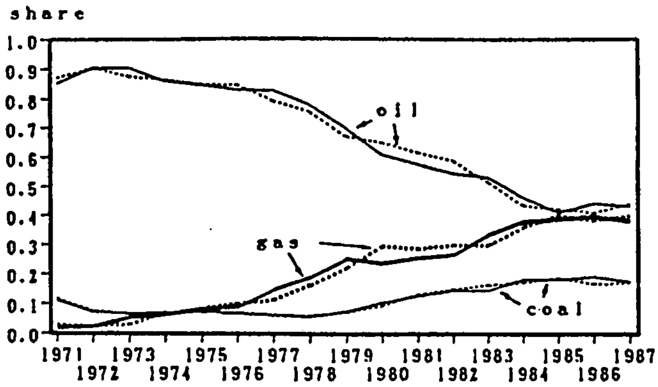

Fig. 4 Historical and theoretical fossil fuel demand shares for electric power generation

i) deduct the heat demand of cogeneraton from residential heat demand,

ii) deduct the cogeneration power supply from total power demand,

iii) add cogeneration demand of LNG to total demand of LNG.

3. SIMULATION STUDY

In order to evaluate the security of Japanese energy systems under the many uncertainties the following four incidents are considered as examples of critical events affecting energy systems :-

A : Oil supply to fail.

B : Tax on fossil fuel consumption (carbon tax) to be levied.

C : Regulation on nuclear power to be reinforced.

D : Promotion of cogeneration

For the simulation study using the Model several scenarios are set by the combination of four incidents. In this case it is important to make the combination consistent, though incidents are interrelated in a complex manner. The Cross Impact Method (XIM) is one of the most appropriate method in dealing with this kind of problem. [6] In the first place occurrence probabilities of each incident in the year 2000 are estimated by the subjectivity of an expert. Then their interrelations are given as shown in Table 4. XIM converts the probability numbers into such as consistent with each other by the minimum involution. The results are shown as modified second order occurrence probabilities in Table 5, which compose the basis for putting scenarios into order of four dimensional occurrence probability as shown in Table 6.

Scenarios with higher probability are (9), (13), (1) and (14). Scenarios (9) and (13) mean to be no supply crisis nor carbon tax and that cogeneration is to be promoted. Since the difference between regulation on nuclear power to be reinforced or not is little, scenario (9) is chosen for simulation study as CASE-5 in Table 7. Scenario (1) is the reference. It is interesting to compare scenarios (14) and (10) which mean oil supply crisis to happen but no tax to be imposed on fossil fuel consumption. There is a remarkable difference in probability whether to regulate nuclear power or not in this case. As this is the interesting result of XIM, scenario (14) is also chosen for simulation study as CASE-7 in Table 7.

Table 7 shows parameters of simulation cases. As a reference scenario (1) is set as CASE-0 in which a coefficient for the year (the third term in Formula (4)) is defined by 2.5% and 1.75% so as to make GDP growth rate approximately 3.5% till 1999 and 2.5% after 2000. In CASE-3 carbon tax is imposed in 1993 with initial rate of 4000¥/C-t and annual increase of 2000¥/C-t. CASE-1 and -2 are set for simulation study with 15,000Ml of oil supply reduction in the year 1995 and 1996, which is 7% of the Japanese oil import in 1990. The impact of supply crisis is affected by the inclination of supply function in Fig. 2, which is the price elasticity of oil. In CASE-1 it is set at 0.0 and 0.3 in CASE-2, 0.1 in

Table 4 Probabilities of incidents and interrelationss P (i -- j)

	A	B	C	D
A	.3	.1	.35	.75
B	.25	.15	.6	.73
C	.5	.12	.5	.75
D	.25	.20	.55	.7

Table 5 Single and second order probabilities

	A	B	C	D
A	.300	.034	.184	.210
B	.034	.150	.079	.119
C	.184	.079	.500	.379
D	.210	.119	.379	.700

Table 6 Range of scenario probabilities and maximized entropy probabilities

	scenario	min.	max.	X^*
(1)	(0000)	.0572	.1783	.1192
(2)	(1000)	.0000	.0906	.0409
(3)	(0100)	.0000	.0306	.0153
(4)	(1100)	.0000	.0306	.0031
(5)	(0010)	.0000	.1210	.0652
(6)	(1010)	.0000	.0906	.0431
(7)	(0110)	.0000	.0306	.0093
(8)	(1110)	.0000	.0306	.0039
(9)	(0001)	.1340	.2809	.2034
(10)	(1001)	.0000	.1163	.0641
(11)	(0101)	.0063	.0709	.0447
(12)	(1101)	.0000	.0340	.0087
(13)	(0011)	.1164	.2714	.1950
(14)	(1011)	.0593	.1840	.1184
(15)	(0111)	.0145	.0791	.0474
(16)	(1111)	.0000	.0340	.0183

Table 7 Parameters of simulation cases

Respective Scenario	(1)-1	(2)-1	(2)-2	(3)	(5)	(9)	(1)-2	(14)
incident	CASE-0 Reference	CASE-1 Oil Supply Crisis-1	CASE-2 Oil Supply Crisis-2	CASE-3 Taxation	CASE-4 Regulation on Nuclea Power	CASE-5 Promotion of Co-Generation	CASE-6 Low Growth of Economy	CASE-7 Complexed Scenario
annual growth of demand	2.5% 1.75%	←	←	←	←	←	1.8% 1.2%	2.5% 1.75%
growth rate of non-fossile fuel generation	3.45% 3.45%	←	←	←	2.0% 2.0%	3.45% 3.45%	←	2.0% 2.0%
supply failure of oil (price elasticity)	×	O (0.0)	O (0.3)	×	×	×	×	O (0.1)
co-generation capacity in the year 2000 (top) and 2020 (bottom)	5 GW 15 GW	←	←	←	←	8 GW 30 GW	5 GW 15 GW	8 GW 30 GW
introduction of carbon tax (done: o, undone: x)	×	×	×	O	×	×	×	×
loss of consumers' surplus, 10^{12}¥ (see note 3)	—	96.6¥/l	32.1¥/l	—	—	—	—	55.6¥/l

Note 1: Common scenario is composed under the condition that annual growth rates of net price for oil, coal and gas are 3%, 1% and 3% respectively.
Note 2: Numbers in each column show the case before 1999 (top) and after 2000 (bottom).
Note 3: Numbers at the bottom in the column for loss of consumers' surplus show its annual average by one litre of oil failed to supply.

CASE-7. The consumers' surplus explained in Section II is calculated for each year so that the difference with that of CASE-0 is to be the index of loss in Japanese economy due to supply crisis. Numbers at the bottom column in Table 7 show accumulated amount of the loss till the year 2025 and its annual average by one litre of oil supply failed.

Some examples of the result in simulation study are shown in Fig. 5, Fig. 6 and Fig. 7 for total CO_2 emission and loss of consumers' surplus. Interesting and valuable information gained from the study through the operation of the Model are as follows :-

i) Comparison between CASE-0 and CASE-5 shows that introduction of cogeneration contributes to CO_2 emission reduction by 0.96 ~ 0.99 C-t/yr/kW in case of 50% load factor.

ii) Comparison between CASE-0 and CASE-4 shows that regulation on nuclear power will increase CO_2 emission, if there is no change in energy demand structure.

iii) Comparison between CASE-0 and CASE-1, -2 shows that effect of oil supply crisis on oil demand will be cleared soon as shown in Fig. 5 but its effect on Japanese economy

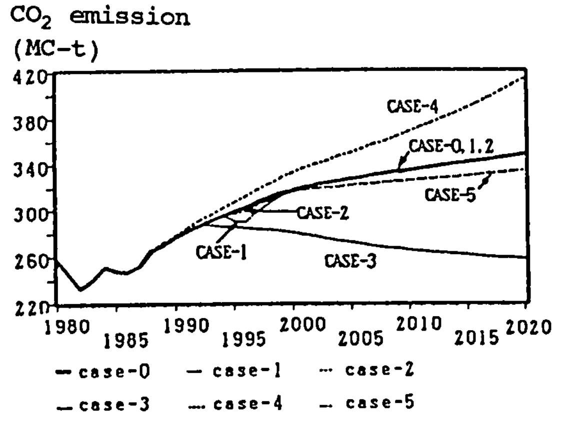

Fig. 5 Simulation result on total CO_2 emission of Japan (1)

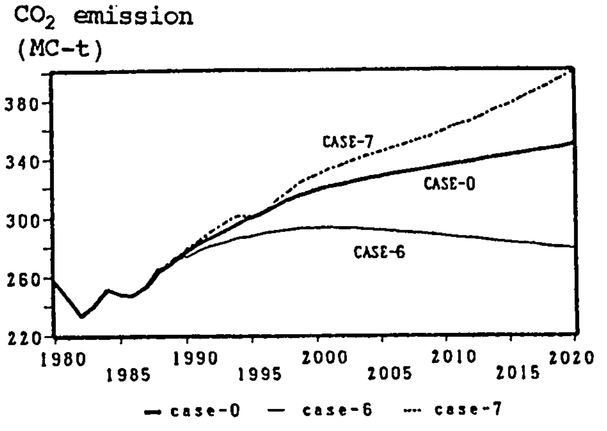

Fig. 6 Simulation result on total CO_2 emission of Japan (2)

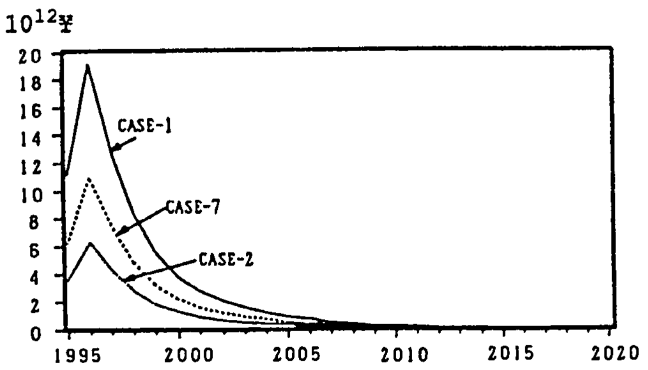

Fig. 7 Consumer's surplus loss change under oil supply crisis

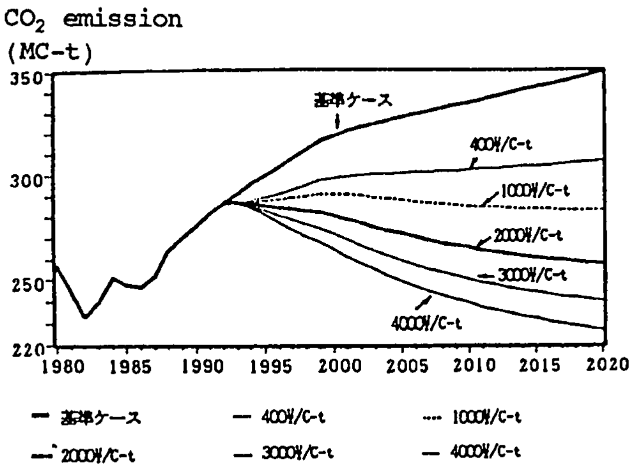

Fig. 8 Changes of CO_2 emission corresponding to the changes of carbon emission tax

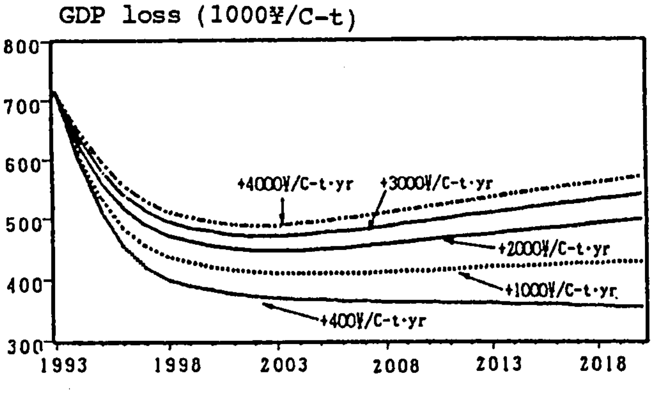

Fig. 9 The changes of loss of GDP per carbon ton CO_2 emission reduction (thousand Y/MC-t)

will be sustained pretty long as shown in Fig. 7. The higher price elasticity will make the loss smaller.

iv) Comparison between CASE-0 and CASE-6 shows that lower GDP growth rate will make CO_2 emission lower.

Fig. 8 and Fig. 9 show the result of simulation study for the case of carbon tax rate change from 400¥/C-t to 4000¥/C-t. In the Model it is necessary to increase carbon tax rate by 1000¥/C-t annually from the initial rate of 4000¥/C-t in 1993 in order to suppress CO_2 emission under its level in 1993. If the social cost of CO_2 emission reduction is estimated by the decrease of GDP par unit C-t emission, it amounts 450~500k¥/C-t as shown in Fig. 9. This implies the difficulty of CO_2 emission reduction by tax system only.

4. CONCLUSION

Current international relation is changing the shape of its geopolitical structure to make the energy and environment security issue much more complicated and uncertain. To solve this kind of problem a quantitative analysis is necessary so that the planner can provide decision makers with data for dynamic and intelligent policy making. (7) This paper gives a solution to the problem through the development of "Energy and Environmental Security Model". Simulation study to operate the Model shows that the solution provides positive opportunity to deal with the following requirements on this kind of model needed for a quantitative analysis of energy and environment security :-

i) Actual post result to be precisely reflected.

ii) Effect of introducing new technology and regulation to be estimated.

iii) Any happening like supply crisis to be easily simulated.

iv) Complicated reciprocal effect among those happenings to be analysed.

v) Change in energy supply demand structure to be flexibly introduced.

The next step to be achieved for the expansion of the study is to develop a tool of decision support system to be provided to planners and decision makers for their joint work of dynamic and intelligent policy making.

It is the last but not the least to express the highest appreciation and acknowledgement to the excellent joint work done by Professor Dr. Shunsuke Mori of Tokyo University of Science.

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Pap
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Paper No. 7
(Keynote Speech)

AN OVERVIEW FOR ENERGY EFFICIENCY AND CONSERVATION IN HONG KONG

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Director
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AN OVERVIEW FOR ENERGY EFFICIENCY AND CONSERVATION IN HONG KONG

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1. INTRODUCTION

1.1 Energy is the life-blood for this dynamic and modern city, yet Hong Kong derives all of its energy requirements from coal and oil products which are imported from numerous overseas sources. In 1992, the primary energy requirement is 505,584 TJ, an increase at the rate of 7.0% per annum from 1982. The per capita consumption of primary energy also rose from 46,924 MJ (13138 kwh) in 1982 to 86,997 MJ (24359 kwh) in 1992, an annual growth rate of 6%. This is closely related to our GDP growth rate of 6% in the same period.

1.2 **Energy** not only relates to **Economy**, but it also affects the **Environment**. These famous '3E' are now key elements integrated in major national policy decision process in advance countries throughout the world. Hong Kong, with growing awareness of and participation in environmental protection, is by no exception in such policy making. The Convention on Climate Change, promulgated at the "Earth Summit" in Rio de Janeiro in 1992, set a target for developed countries: return greenhouse gas emissions to 1990 levels by the year 2000. Energy efficiency and conservation would be a viable approach to sustain the present living environment for this new challenge.

1.3 The community must therefore consider both the environmental consequences as well as the economic implication of the energy plans and efficient use of energy in Hong Kong. This will involve re-examining the way most of us use energy, the way our energy needs are met, and the way energy costs are paid for. This will require the government, commerce and industry, and the community to rethink attitudes towards the use of energy. The following paragraphs review our energy position which will provide the basis for arriving a more comprehensive energy efficiency and conservation policy.

2. AN ENERGY OVERVIEW

2.1 Table 1 shows a simplified version of the overall energy balance (OEB) for 1982 and 1992 extracted from the 'Hong Kong Energy Statistics'. 'Primary energy requirements' (PER) refers to the overall energy consumption within a geographical region which includes both the region's indigenous energy sources and the imported energy commodities consumed. In Hong Kong, it is calculated from the retained imports of coal and oil products net of bunders' usage and export of electricity, and after adjustment of stock changes. 'Final energy requirements' (FER) refers to the amount of energy consumed by the final users for all energy purposes such as heating, cooking and driving machinery, but excludes non-energy usages such as using kerosene as a solvent. The difference between PER and FER accounts for the energy used or lost in the energy transformation process and the energy lost in the distribution process. It is noted PER increased by 105% between 1982 and 1992, while FER increased to a lesser extent by 75% in the same period. This shows a change in thermal efficiency of the local energy sector from 60% in 1982 to 52% in 1992.

2.2 Figures 1 & 2 show the distribution of PER and FER in 1992 respectively. Coal products account for 67% in PER of which the majority (99.9% by weight) is steam coal used for power generation. The other products include wood charcoal, anthracite and coke/semi-coke. Figure 3 shows the quantity of retained imports of coal products (1982 - 1992). The main sources of steam coal import are Australia, South Africa and China.

2.3 Electricity accounts for 36% of FER in 1992 and is mainly derived from steam coal by the 2 power companies in Hong Kong. Figure 4 shows the local consumption increased by type of users from 1982 to 1992. In 1992, the largest users were the commercial users, taking up 51% of local consumption and represents an increase of 6% over the previous year; the industrial usrs consumed 26% and their consumption decreased by 3%; the domestic users consumed 23% and the consumption increased by 5%. The production of exports of electricity to China grew from 2% of the total electricity generated at plant in 1982 to 14% in 1992.

2.4 Oil products account for 36% and 57% in PER and FER respectively in 1992. They include aviation gasoline/kerosene, motor gasoline (leaded and unleaded), kerosene, gas/diesel oil, naphtha, fuel oil and liquified petroleum gas and Figure 5 shows the quantity of retained imports of oil products. There was a significant decrease of fuel oil consumption as a result of enactment of the Air Pollution Control (Fuel Restriction) Regulation in 1990. The introduction of more statutory air quality control zones will sustain this trend, but the year 92 showed a rebound which is believed to be the result of increasing sea freight activities. Many industrial users will also switch to other fuel like gas/diesel oil and this is reflected by the increasing trend of gas/diesel oil.

2.5 Towngas is derived from naphtha, one of the oil products as shown in the OEB and is manufactured by The Hong Kong and China Gas Co. Ltd. It accounts for 7% of FER in 1992 and is used mainly for heating and cooking. Figure 6 shows the local consumption increase by type of user from 1982 to 1992. About 50% of towngas produced was consumed by the domestic users, 45% by commercial users and 5% by industrial users. This pattern was rather stable in the past ten years. The growth at an average rate of 14% during 1982 to 1992 might be due to the extension of the gas distribution networks into the previously unreached parts of the territory, particularly to new town areas. It is also noted the share of towngas rose from 41% in 1982 to 60% in 1992 as compared to its competitor, LPG.

2.6 We recognize our data limitation in OEB, in particular the breakdown of final energy requirement by end-user when compared to a typical composition of energy balance table as shown in table 2. Although statistics on local consumption of electricity and gas by type of user are given, there is still plenty of room to improve data collection and classification for detail planning and analysis purposes.

3. PROGRESS IN PROMOTING ENERGY EFFICIENCY AND CONSERVATION

3.1 Energy efficiency has always been on of the prime objectives of the Electrical and Mechanical Services Department (EMSD) in the design, installation, operation and maintenance of engineering systems under the purview of the Department. However, the problem is not one for government alone, but for the community as a whole. In 1991, the government has identified the need to improve energy efficiency and therefore established an Energy Efficiency Advisory Committee (EEAC) to advise on proposals to improve energy efficiency in Hong Kong as well as to formulate a comprehensive energy efficiency policy in the long term. The EEAC has established four working groups to deal with specific tasks and has recommended several measures, both on short and long terms. They are the Existing Building Working Group, the New Building Working Group, the Energy Data Working Group and the Educational Campaign Working Group. The role of the EEAC was affirmed by ExCo in March 1992.

3.2 It soon became apparent that the EEAC required significantly more data on Hong Kong's energy profile before it could make substantial recommendations on such issues as a comprehensive code of practice for reducing energy consumption. Work has already been started on compiling such data and a report on the energy consumption patterns in the commercial sector was produced in early 1993. Further research into the patterns of energy consumption in other major energy-using sectors, such as the domestic and transport sectors, will be completed by early 1994. In the meantime, measures which do not hinge on the collection of such data have been recommended and implemented.

3.3 An education campaign on energy efficiency began in March 1993. The objective of this campaign is to introduce to the community the environmental problems that arise from the profligate use of energy and to suggest ways in which energy can be conserved. To help the public and professionals to appreciate the importance of using energy more efficiently and to demonstrate such use, advisory notes for the commercial sector were distributed in March 1993. Similar notes are now being prepared for the domestic sector and will be available in early 1994. Energy managers, the key personnel resource, would play an important role in improving energy efficiency through the close monitoring of energy consumption in buildings. The infrastructure for the training and accreditation of qualified energy managers is the area we should closely look into. Regarding institutional setup to promote energy efficiency, an energy efficiency information centre is a good idea to give expert advice on ways and means to improve efficiency together with free distribution of related information. The determining factors are source of funding as well as management of such organisation.

4. ELECTRICITY SECTOR

4.1 Electricity is the best form of energy known in our profession. Its importance should not be overstated in energy efficiency and conservation policy if we recall the figures of coal and electricity in the OEB. Today's Symposium is in fact a main focus on this area, and prominent topics like demand side management from power utilities, efficient energy usages in different sectors like pumping, lift, buildings as well as KCRC are all relevant local cases. The contribution by our fellow professional engineers in these areas should be recognized by the community and I would like to add a few topics not yet mentioned today for efficiency in electricity production and usage.

4.2 Efficiency improvement from supply side of the power industry hinge on technology development. The proposed new power station at Black Point which utilizes piped natural gas to fire combined cycle plant is a timely technological choice. The project makes use of the cleaner fuel on combined cycle technology which would achieve a much higher thermal efficiency of about 52% as compared to the 36% with the existing coal fired units. This represents a 50% reduction in carbon dioxide emission and 37% saving in fuel energy.

4.3 Coal, however, would remain as the main fuel for power generation both locally and globally in the next century because of its abundant reserve on the earth. Clean coal technology, which include coal gasification and integrated combined cycle with either fixed bed or fluidized bed with thermal efficiency of around 45%, is under research and development in over 20 countires. Hong Kong should keep track of the development and application of clean coal technology.

4.4 Efficiency at the other extreme end of electricity usage is related to appliances. Energy efficient appliances are now available from most manufacturers, and most of them are not only energy efficient but the performance is better than their

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standard equivalent. The success of promoting appliance efficiency depends very much on sunsumer awareness and attitude as well as the proper information for consumers to exercise their choice in purchasing. An energy guide book or directories of energy efficient products, published by either Government or Consumer Council, will be the right bridge for the gap. Legislation to introduce appliance energy efficiency labelling is another angle of thought so that consumers could have sufficient product information in the market for their choice.

5. TRANSPORTATION SECTOR

5.1 Transportation is another important energy sector with limited data. It includes freight and passenger activity; the former is associated with industry/trading while the latter is part of economy and social activity. Figure 7 shows a Japanese comparison of energy efficiency by mode on passenger sector and rail transportation proved to be the most efficient. In this connection, it is glad to see that the Railway Development Study commissioned by Transport Branch recommends a plan for further developing railway structure in Hong Kong up to the year of 2001. In Hong Kong, different types of rail transportation of passenger total including tramway, peak tram, KCRC, LRT and MTRC are all electrified. MTRC alone last year spent about HK$270M on electricity (about 550,000 MWh) which is 40% of her operating expense, the second major component besides staff costs. It is thus not surprising to see the commitment in search for energy efficiency.

5.2 On the other hand, Hong Kong is such a small and dynamic city that automobile will remain as the dominant mode of transport. This is supported by the increased number of licensed motor vehicle from 289,000 in 1987 to 415,000 in 1992. Automobile efficiency which was once a key subject in the 70s' oil crisis, is not in our hands as all our automobiles are imported and efficiency is dictated by manufacturers. Figure 8 shows the mileage change of Japanese passenger car by '10 mode' which is the Japanese standard method of measuring passenger car efficiency introduced in 1973. The flow based 10 mode mileage improved rapidly until 1982. This showed the car manufacturers' commitment to efficiency in response to oil crisis. After 1983, the oil price dropped and Japanese people showed preference for larger size car for comfort and performance. Hong Kong is no doubt following this trend. Here, we note a large size car consumes 25% more energy than small one in the 10 mode mileage. Although we have limited choice to improve automobile efficiency, we should not neglect the development of electric vehicle and should pay particular attention to its overall contribution to our '3E'.

6. INDUSTRIAL SECTOR

6.1 Although limited data is available to evaluate the energy usage pattern in industrial sectors, we all recognize industrial development is declining as more and more factories are moving to the Pearl Delta area for cheap labour and land. Nevertheless, combined heat and power in the form of cogeneration will be a promising area for energy efficiency and conservation in industrial sector. Wheeling, the mechanism to allow surplus electricity from cogneration to sell back to the utility's grid will play a deciding factor for the success of this option. In addition, the change of fuel to meet the statutory requirement for better air quality also provides golden opportunity for manufacturers to adopt modern energy efficiency technology, like efficient burner, waste heat recovery systems, effective recovery of steam condensate, etc.

7. THE WAY FORWARD

7.1 Via its membership of the Energy Project Group of the Asia-Pacific Economic Cooperation, the Government will continue to monitor the progress of research in both energy efficiency from traditional sources of energy and in alternative energy sources which are economically and envvironmentally sound. In particular, in 1993/94 the Electrical and Mechanical Services Department will strengthen the Energy Efficiency Division, leading to the creation of a full scale Energy Efficiency Office in the following year. This will be an appropriate organization to assist the government in examining further measures for energy efficiency and conservation and further pursue the directive of ExCo in March 1992 that all potential areas of improving energy efficiency should be investigated in order to formulate a comprehensive strategy on energy efficiency.

7.2 The role of meanagement in operation and maintenance of existing buildings and industrial processes should be clearly emphasized in promoting energy efficiency and conservation. This top down approach is essential to keep up the efficiency by motivating all staff and operators in pursuing the goal. Depending upon the size and complexity of the buildings and organization, it may be desirable to set up energy management committee with appointment of energy manager to formulate and monitor the workplans to meet the objectives. Energy audits shall be carried out by competent professionals. This will be the key step to collect and analyse the energy consumption data which will identify potential area for improvement and recommend action plans. EMSD is taking the lead in this direction in providing this energy service to other departments through her operation and maintenance function on different engineering systems.

7.3 It is also important to consider the necessary legal framework to backup the implementation of energy efficiency and conservation policy. Legislation on overall thermal transfer value (OTTV) control for air-conditioning buildings will have great challenge to architects and building services engineers regarding the design on building envelope and air-conditioning respectively. The success of cogeneration will also hinge on the legal framework to open up ower companies' grids to accept the surplus electricity from cogenerating plants at a reasonable price. Last but not the least, statutory requirements for manufacturers to provide energy efficiency labelling to their electrical appliances will play an important role in promoting energy efficiency and conservation from the consumer side. These regulatory approach will provide a good base to facilitate the implementation.

7.4 The community shall look into the potential application of renewable energy, in particular solar energy. Although it is generally accepted that there is limited application of renewable energy in Hong Kong, there are in fact some government trial projects utilizing solar energy mainly on water heating from small scale bathouses to larger scale swimming pool in the past ten years. Solar energy application in the form of water heating may not be commercially viable to our local high-rise building environment with a normal pay back period over 10 years. Yet, it may be an attractive option for some specific installations, like bungalow or village type houses in the New Territories. Photovoltaic generation of electricity from solar energy has also been developed rapidly in recent years and output has steadily increased to over 25 KW. This may be used for small power generation at isolated stations or light towers. The Government should always keep track of the development of renewable energy through her international connection to look for potential application in Hong Kong.

7.5 A successful implementation of energy efficiency and conservation policy requires not only professional inputs and set up of the necessary institutional and legal framework, but also the positive response and cooperation from the community i.e. consumers. Public education through different means and channels is vital and support from large organizations in various sectors on any major campaign to promote awareness of energy usage will also be essential. However, we need to have a coordinated approach from different sectors, environmental groups and energy companies so that the single message 'Save energy now, leave something for the future' is clearly communicated to every consumer.

7.6 Energy efficiency and conservation is rapidly integrating into our lives. Our fellow engineers should keep contributing to the community with professional dignity. Although the overall equation is simple in getting more for less, I am sure it is an exciting and challenging field with technical complexity for our professional satisfaction. We can contribute to the global goal of energy conservation by ensuring that our use of energy is as efficient as possible. I conclude my speech with that single message again - 'Save Energy Now, leave something for the future'.

Figure 1 Distribution of PER in 1992

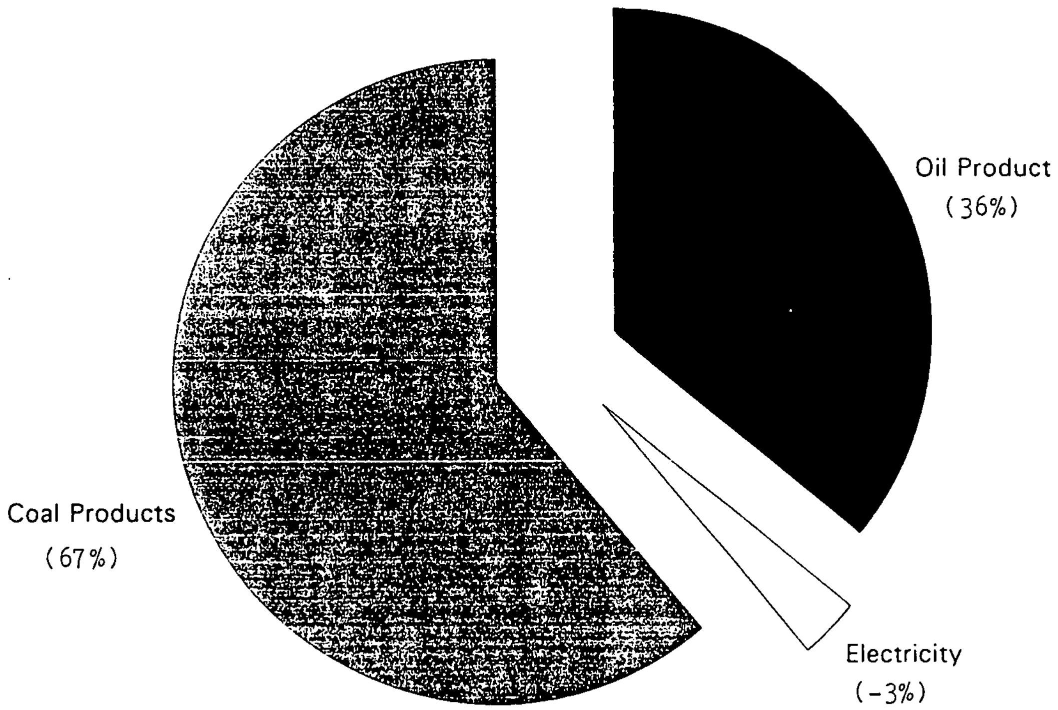

Figure 2 Distribution of FER in 1992

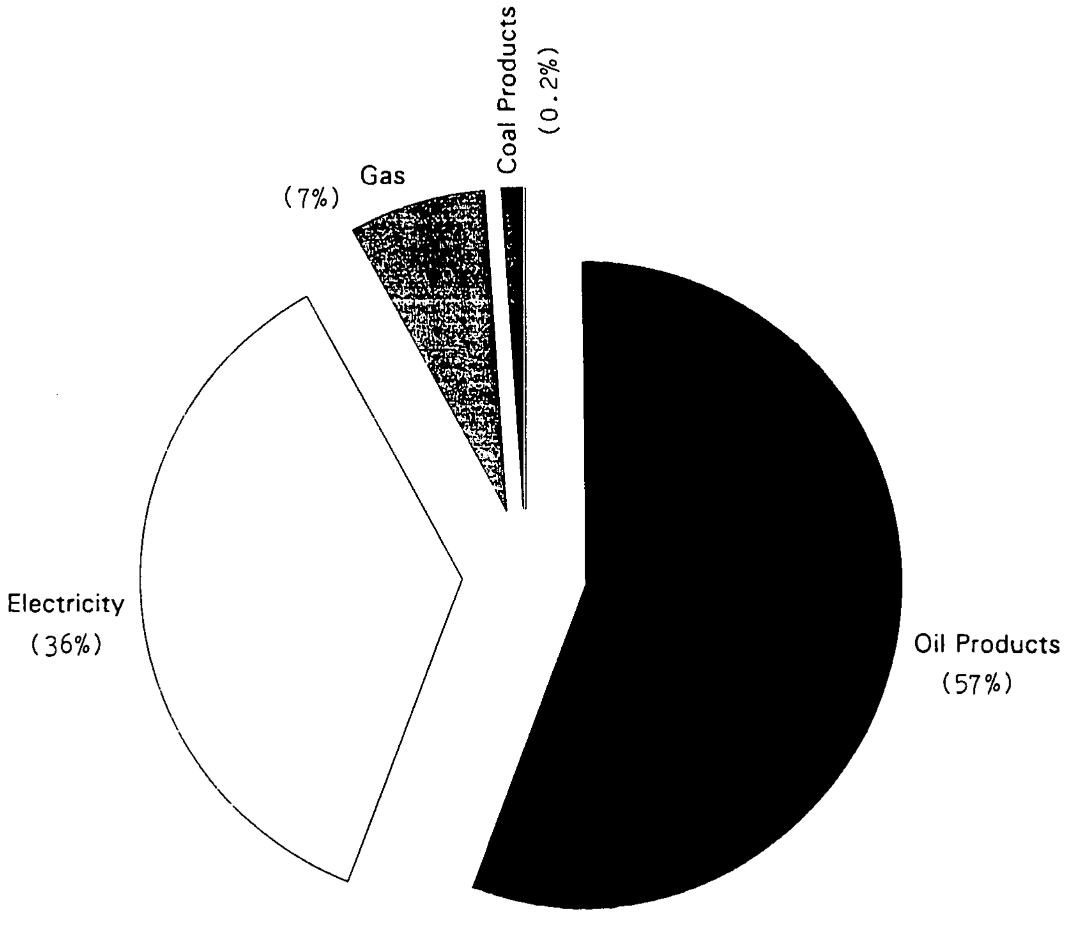

Figure 3 <u>Quantity of retained imports of coal products</u> (1982 - 1992)

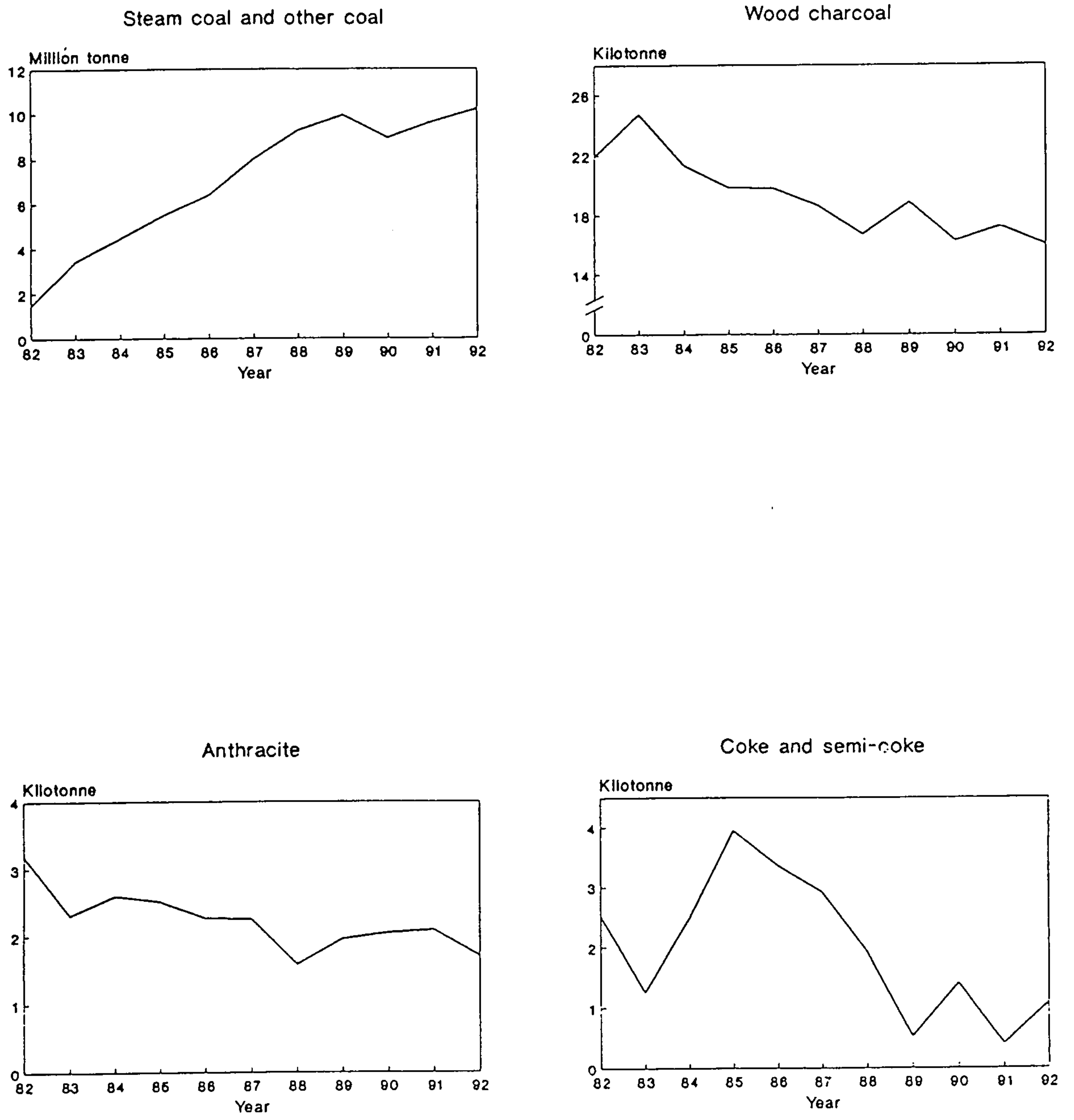

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Figure 4 Local consumption of electricity by type of user (1982 - 1992)

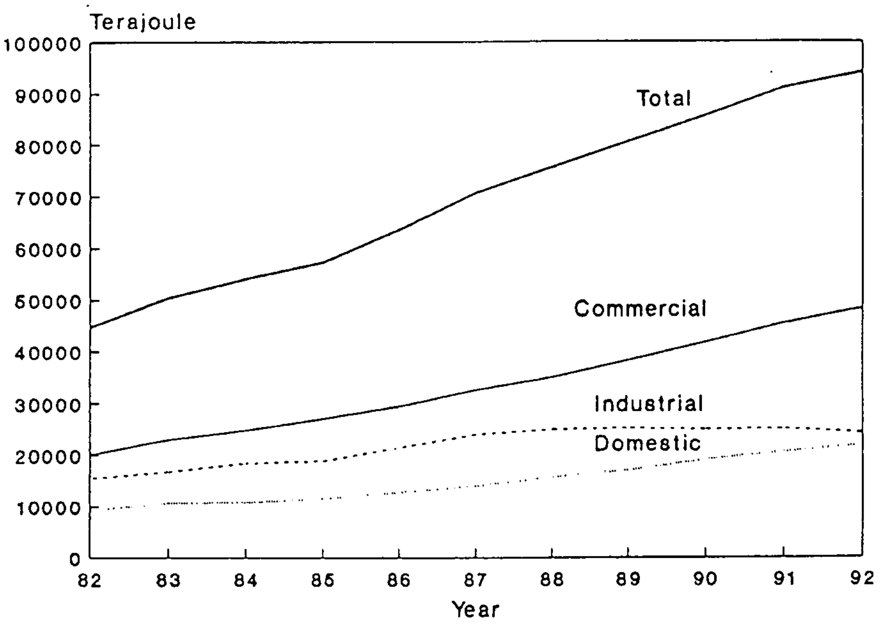


Figure 6 Local consumption of town gas by type of user (1982 - 1992)

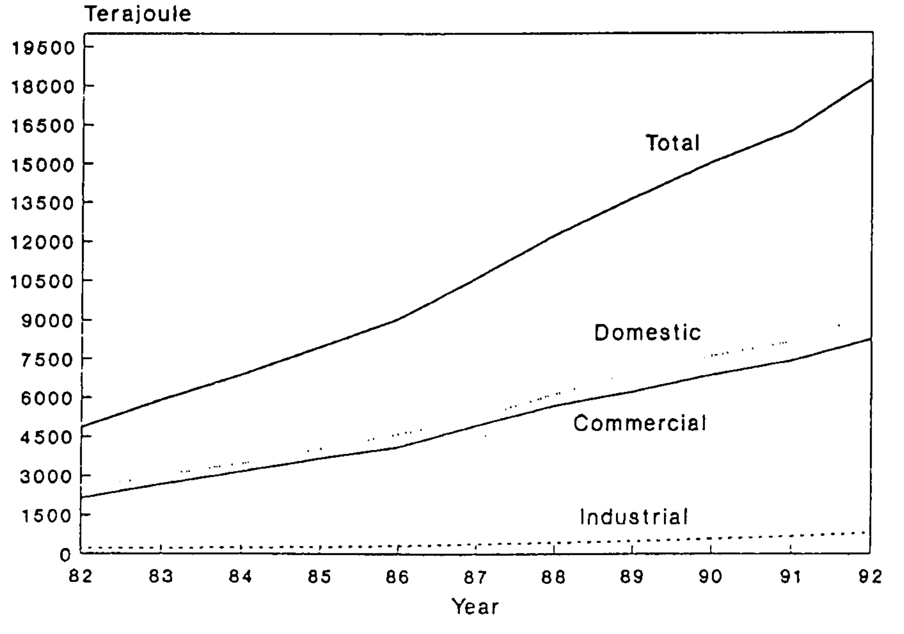


Figure 5 Quantity of retained imports of oil products
(1982 - 1992)

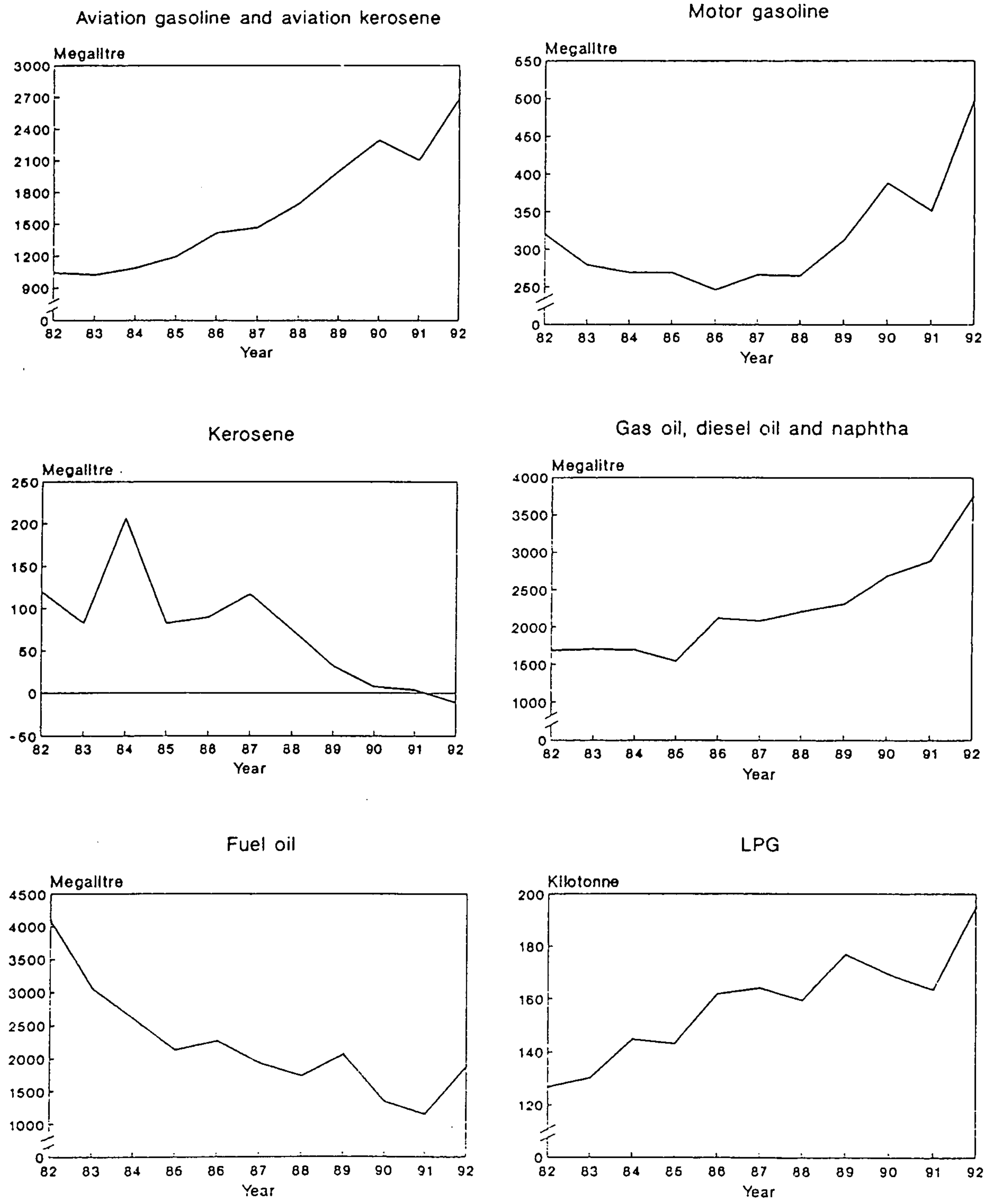


FIGURE 7

COMPARISON OF ENERGY EFFICIENCY BY MODE

(PASSENGER SECTOR:FY1990)

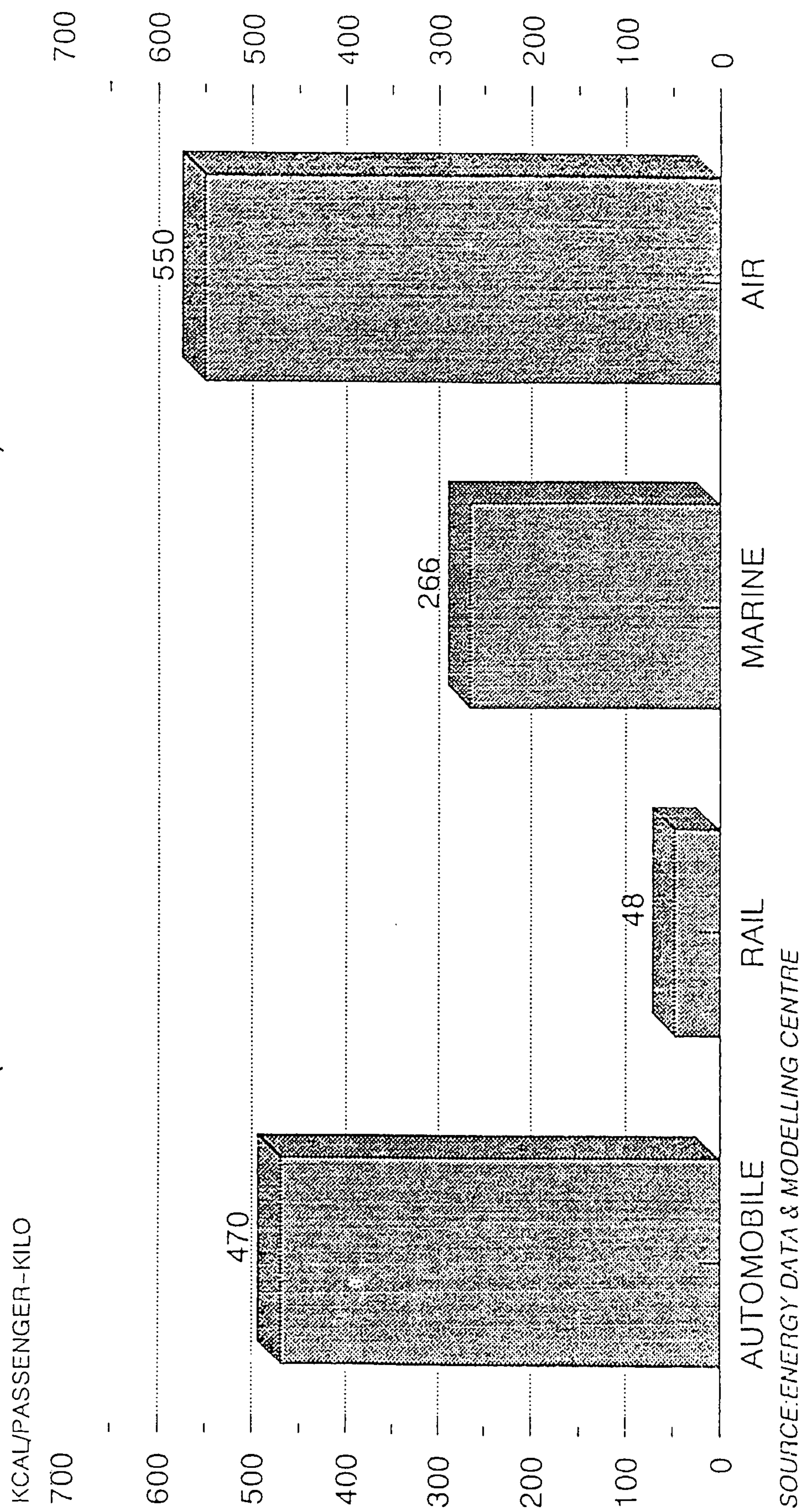
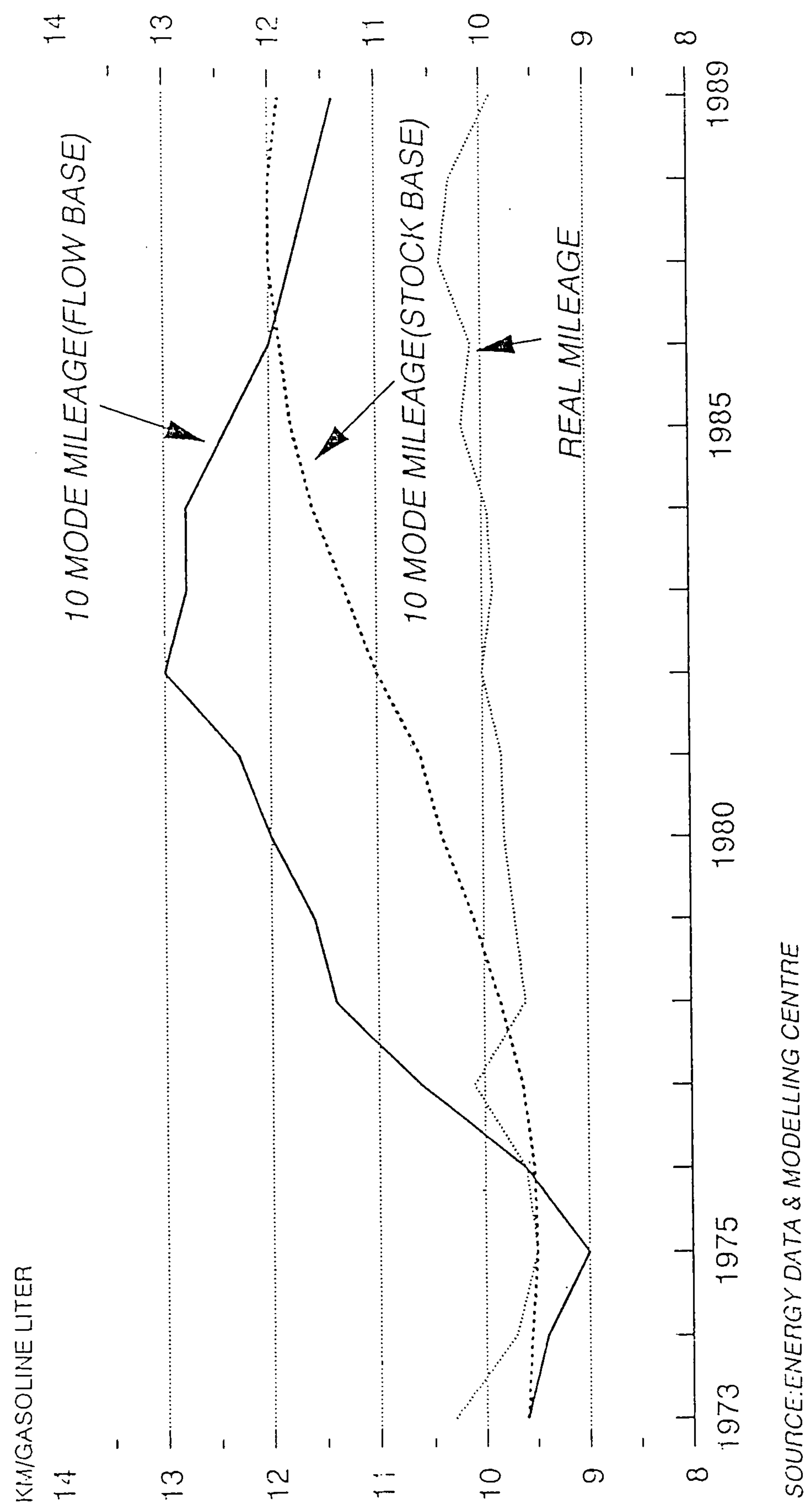


FIGURE 8

MILEAGE CHANGE OF PASSENGER CAR IN JAPAN



SOURCE:ENERGY DATA & MODELLING CENTRE

Table 1 Overall energy balance
(1982 and 1992)

(terajoule)

1982

	Coal products	Oil products	Electricity	Gas	Total
Import	43 498	288 925	0	0	332 423
Export	-159	-9 027	-979	0	-10 165
Bunker	0	-73 100	0	0	-73 100
Stock change	-6 038	3 910	0	0	-2 128
Primary energy requirements	37 301	210 708	-979	0	247 030
Gas manufacture	0	-5 293	0	4 858	-435
Electricity generation	-36 490	-106 933	52 223	0	-91 200
System loss	0	0	-6 475	0	-6 475
Final energy requirements	811	98 482	44 769	4 858	148 920

1992

	Coal products	Oil products	Electricity	Gas	Total
Import	299 881	458 991	0	0	758 872
Export	-85	-136 698	-17 866	0	-154 649
Bunker	0	-152 535	0	0	-152 535
Stock change	40 008	13 887	0	0	53 895
Primary energy requirements	339 804	183 646	-17 866	0	505 584
Gas manufacture	0	-19 369	0	18 207	-1 162
Electricity generation	-339 255	-16 152	125 689	0	-229 718
System loss	0	0	-13 672	0	-13 672
Final energy requirements	549	148 125	94 151	18 207	261 032

Note : 1 terajoule = 10^{12} joules

Compositions of New Energy Balance Table

Table 2 Corresponding sectorial names (row)

	Basic table (43 sectors)		Summary table (34 sectors)	
Primary energy	Domestic energy production	1	Domestic energy production	1
	Imports	2	Imports	2
	Primary energy total supply	3	Primary energy total supply	3
	Exports	4	Exports	4
	Stock change	5	Stock change	5
	Primary energy domestic supply total	6	Primary energy domestic supply total	6
Energy conversion	Public electric generation	7	Public electric generation	7
	Pumping-up hydro generation	8		8
	In-plant power generation	9	In-plant power generation	9
	Heat suppliers	10	Heat suppliers	10
	Town gas production	11	Town gas	11
	Gas coke production	12	Coke by coke producer	12
	Iron and steel coke	13		13
	Coke by coke producer	14		14
	Steelmaking gas	15		
	Oil refining	16	Oil refining	
	Petrochemicals	17	Petrochemicals	
	Others	18	Others	
	Energy conversion sector total	19		
Energy industries own-use and losses	Energy industries own-use	20	Own-use and losses	15
	Transmission/distribution losses	21		
Statistical difference		22	Statistical difference	16
Final energy consumption total		23	Final energy consumption total	17
	Industrial sector total	24	Agricultural sector total	18
	Agriculture/forestry	25	Agriculture/forestry/fishery	19
	Fishery	26		
	Mining	27	Mining	20
	Construction	28	Construction	21
	Manufacturing total	29	Manufacturing total	22
	Foods	30	Foods	23
	Textiles	31	Textiles	24
	Paper/pulp	32	Paper/pulp	25
	Chemicals	33	Chemicals	26
	Ceramics/cement	34	Ceramics/cement	27
	Iron and steel	35	Iron and steel	28
	Non-ferrous metals	36	Non-ferrous metals	29
	Metals/machinery	37	Metals/machinery	30
	Other manufacturing	38	Other manufacturing	31
	Residential/commercial sector total	39	Residential/commercial sector	32
	Residential	40		
	Commercial	41		
	Transportation sector	42	Transportation sector	33
	Non-energy (excl. chemical feedstocks)	43	Non-energy (excl. chemical feedstocks)	34

Paper No. 7

Paper No. 8

PLANNING OF LOAD RESEARCH FOR DEMAND SIDE MANAGEMENT

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PLANNING OF LOAD RESEARCH FOR DEMAND SIDE MANAGEMENT

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1. INTRODUCTION

Demand Side Management (DSM) is the planning and implementation of any activities by a utility that will influence its customers' demand in electricity to achieve a load shape objective most beneficial to the society. There are six load shape objectives in DSM - Peak Clipping, Valley Filling, Load Shifting, Strategic Conservation, Strategic Load Growth, and Flexible Load Shape. Which load shape objective or what combination of these objectives is the most cost effective to pursue will depend very much on how much the utility understands its customers through Load Research. Load Research refers to those utility activities measuring and monitoring customers' load patterns, their stock of electrical appliances, and their general behaviour in consuming electricity. Load Research is a pre-requisite of DSM. The measurement and monitoring techniques developed in Load Research can also be applied later in the post-DSM stages - Evaluation and Monitoring to reveal the actual performance of a DSM program. This paper discusses a plan of load research which, from the authors' point of view, will be able to collect adequate information at reasonable cost for utilities in Hong Kong to devise successful and cost effective DSM programmes.

2. OBJECTIVES OF LOAD RESEARCH

As suppliers of electricity, all electric power utilities must have many years' records of their daily system demand profiles. Depending on the capability of the data acquisition systems employed by individual utilities, accurate system demand profiles with resolution varying from an hour to a few seconds are recorded daily. Load forecasters of utilities usually know the system demand patterns by heart and are able to forecast these patterns for any day types in different seasons with high confidence levels. From Supply Side Management point of view, such in-depth knowledge of the demand profiles is adequate for economic operation and dispatch of available supply resources. However, to go into Demand Side Management, utilities need to understand thoroughly what are the constituents and the driving factors of their system demand.

Figure 1 shows a daily system demand profile in a summer day. The first objective of Load Research is to decompose this total demand profile into demand profiles of the major end-use sectors, i.e., commercial, industrial, and domestic in our case. The demand profile of each end-use sector in turn is composed of demand profiles of various end-use loads such as air-conditioning, lighting, heating, cooking, refrigerators, washing machines and so on.

Figure 1
Decomposition of
System Demand Profile

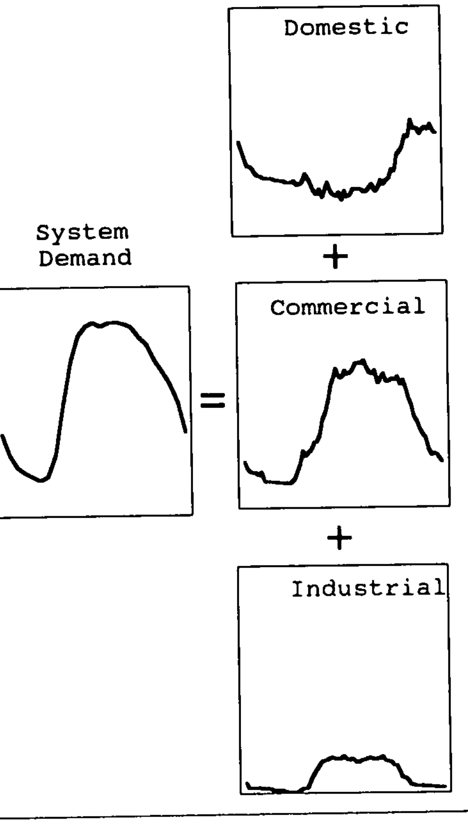

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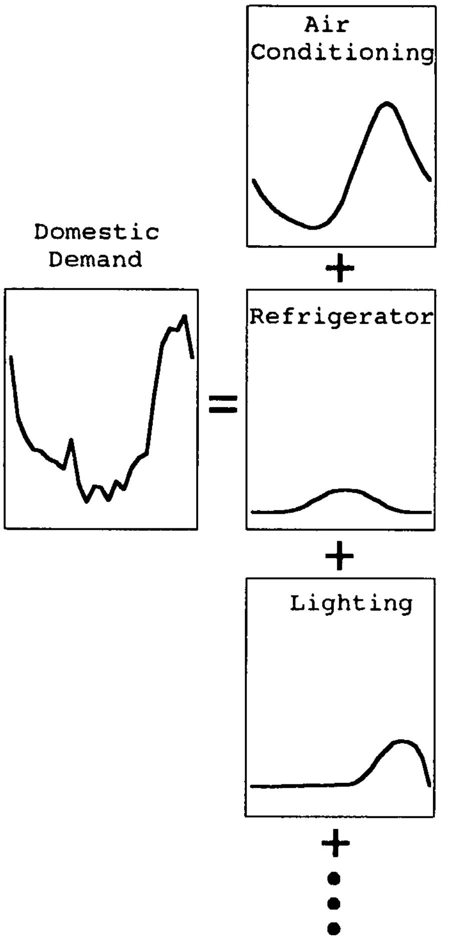
Figure 2 shows the decomposition of a domestic demand profile into load profiles of major end-use appliances, and it is the second objective of Load Research to reveal these end-use load profiles.

Figure 2
Decomposition of
Domestic Demand Profile



3. LOAD RESEARCH METHODOLOGY

In most utilities, small customers are charged monthly or quarterly by the amount of electricity energy (kWh) consumed in that period, and they can have any demand (kW) of electricity at any time within the ratings of their supply circuits. Large customers are usually charged by their maximum demand of electricity in addition to their consumed energy within the metering period.

For both types of customers, utilities do not have measurement data about their demand patterns, though the maximum demand (time of occurrence usually not recorded) of the latter class is measured for billing purpose. For utilities who have time of use rates whereby intelligent electronic meters are being employed to record energy consumed in different time zones of the day, the additional information on how energy is being disposed of in different time zones over a metering period is still far from enough in deducing the demand profile. Hence most utilities will only have their billing history files to start with in Load Research.

Unlike energy meters which must be installed for billing purpose, it is impractical and unjustified to install expensive demand profile recorder at all customer's supply points to record their individual demand profiles. Instead, only small samples of customers of individual major sectors are randomly selected for demand profile measurement, and the measured data will be used to infer the full pictures of these major sectors by means of statistics theory.

Cost of Load Research depends very much on how many customers are selected for demand profile measurement, i.e., the sample size. Not to mention the installation cost and manpower involved in data handling and analysis, just the equipment will cost about HK$30,000 per customer. Hence it is extremely important to optimize the sample size so that no extra money will be spent to collect information that is more than adequate. In statistics theory, sample size to be drawn from a population under study depends on the population parameters such as mean and variance, the confidence level and the precision level of the estimates that can be inferred from that sample size. As population parameters are inherent characteristics of the population under study, it is thus the confidence level and precision level that can be manipulated to give a practical and manageable sample size. Overseas experience shows that a confidence level of 90% and a precision level of 10% error, known as 90/10 criteria, will give a manageable sample size.

In sampling design of Load Research, annual electricity consumption is chosen as the sample design variable and as a proxy for demand which is the object of Load Research. Though not necessarily true a customer's demand of electricity is assumed to be highly correlated to his electricity consumption. For customers under maximum demand tariffs or time of use tariffs, maximum demand or electricity consumption in different time zones can also be used as design variables.

To increase accuracy of Load Research and to reduce the number of samples, logical division of customers into strata is necessary. Utilities will firstly categorize their customers by sectors such as commercial, industrial, and domestic. Each sector is further categorized to subsectors based on the types of business such as retailing, banking, hotels and so on, or based on consumption levels and types of dwelling in the case of domestic. Once all the customers are stratified, sample size is calculated from each stratum based on the 90/10 criteria and the mean and variance of the annual electricity consumption of all customers in that stratum.

To fulfil the two objectives of Load Research, i.e., decomposition of total load profile to major sectorial load profiles and decomposition of sectorial or subsectorial load profile into major end-use load profiles, measurement of loads at customers' supply points as well as end-use loads in customers' premises would be required. Sophisticated electronic data logging equipment that can record electricity consumption (kWh) in regular short time intervals of the day will be employed in load profile measurement. Resolution of these time intervals usually ranges from 5 to 30 minutes, depending on the degree of accuracy required in the survey. Average demand of electricity (kW) within each time interval of the day can be calculated. Depending on the number of measurement points monitored by a logger and the resolution of recording intervals, electronic loggers usually have the capability of storing a few month's demand data. In most Load Research operation, customers' load profiles are usually recorded for a period of at least one year so that load profiles of different day types (week day, week end, public holiday), different seasons, and above all, the system peak day, can be measured. Because of the long logging period required, reliability of the loggers is a key factor for successful Load Research. In the data logging period, it is important to ensure that the electronic loggers on site are functioning properly without extended period of fault. Validation of logged data by comparing the integration of logged energy with metered energy, and reconstruction of data lost in a short period by data patterns of similar day type are common practices in Load Research.

After the extended data logging period is over, all the data collected over that period will be analyzed by proven statistics theory. The full pictures of load profiles of all the major sectors and all the major end-uses are blown up from the logged demand data of the randomly selected customer samples by means of statistical inference.

4. HONGKONG ELECTRIC'S LOAD RESEARCH PLAN

Being a responsible utility, the Hongkong Electric Company Limited (HEC) always puts optimal planning of the electric power system at a high priority in order to supply electricity to customers with maximum security, reliability, and adequacy at low cost. To achieve optimal planning, generation, transmission and distribution subsystems must be closely monitored and their load profiles surveyed to make sure that these assets are best utilized. HEC is able to make use of on-line supervisory control computers and sophisticated electronic data logging equipment to monitor subsystems of all these three levels since late 70s. The gathered load information of generators, transmission and distribution circuits, and transformers has been able to allow HEC to expand its electrical system optimally to meet the fast growing demand at low cost. Such kind of 'Load Research' on the supply side has played a very important role in the development of HEC's system during Hong Kong's fast growth era in the past two decades.

With Demand Side Management being the future direction in resources planning, HEC will fully commit to the kind of Demand Side Load Research as discussed above. HEC believes that only through in-depth understanding of its customers could cost effective DSM programmes be tailor-designed for the special situation of Hong Kong. A Load Research Plan is thus drawn for implementation within the period 1994 to 1996.

The Load Research plan will have three stages - the Sampling Design Stage, the Data Gathering Stage, and the Analysis Stage. The planning of each stage is briefly discussed as follows.

4.1 Sampling Design Stage

Sampling design will follow more or less the concept as mentioned above for the three major classes of HEC customers, namely, Commercial, Industrial, and Domestic. For the first two classes, it is envisaged that further stratification of customers by business types will increase the accuracy of statistical estimates, as customers in the same trade should have less diversified electricity consumption behaviour. On the other hand, there should not be too many strata in the classification as in statistics sampling theory, a minimum sample size of 30 is required from each stratum for the sampling distribution to be normal, and hence too many strata will lead to the survey of too many multiples of 30 customers that may make the Load Research operation not financially affordable. For the domestic customers of HEC, stratification will be based on their consumption levels. Some optimum calculation rules might be employed to calculate stratum boundaries. Again, number of strata thus obtained should be reasonably small.

Customer surveys will be designed to collect additional information for Load Research. For the commercial and industrial customers, a simple survey on their business types will be necessary to support the stratification and sample design as discussed above. At present, HEC has about 77,000 commercial customers and 6,700 industrial customers. A survey of all of them is proposed. The data base of these customers should be updated with the survey results and properly maintained in the future for any deletion or addition of customers. For all customers recruited in sampling design of the Load Research project, a comprehensive survey of their appliance ownership level, demography and housing characteristics should be conducted to identify the major end-use loads to be measured by data logging equipment.

4.2 Data Gathering Stage

Load profile measurement will take place in customers' premises for a long period by means of electronic data logging equipment. In the planning of this stage, it is extremely important to choose the right type of data logging equipment that can perform as required reliably. HEC had some unpleasant experience with loggers using magnetic tapes as storage media which have inherent problems such as high data loss rate and long play back time. With the advance of semiconductor technology whereby many months of data can be stored in a miniature semiconductor memory circuit board, most electronic loggers of this decade have already done away with magnetic tape technology and are extremely handy in size. Most loggers can only accept pulse inputs from energy meters but some can function as a watt meter that can convert current and voltage inputs into electric power. Some loggers have additional channels that can accept temperature and humidity transducer inputs which will be useful in correlating electricity demand of a particular end-use with weather conditions. In the evaluation of the types of loggers for the Load Research operation, not only the reliability of the loggers should be considered, safety of the loggers that will not cause any fire or electric hazards at customers' premises, and installation method that has minimum level of intrusion to customers under survey are important factors to be considered as well.

Other planning activities for this stage include the planning of how customers are to be recruited, how data loggers are to be installed at their premises, and how data is to be collected. Mentality of Hong Kong people on this kind of survey that will require their full co-operation needs to be explored in the planning stage. Overseas experience shows that response of customers to Load Research is usually favourable, especially when the participating customers are given some financial incentives by utilities. In any case, spare samples of customers must be selected to make up the sample size defined by the above sampling design methodology. On the planning of equipment installation, typical electrical systems being employed by various types of customers should be studied, and tailor-designed installation methods of the loggers should be devised. Engineering drawings and installation procedures should be prepared, preferably based on some actual experience in a few pilot sites. On the planning of data collection from the loggers, utilization of dial-up modems and telephone lines to collect data remotely by a central computer can be a good approach that can save a lot of manpower when compared with the manual data collection approach. However, cost of the telecommunication facilities, additional installation and commissioning time required, and the cost and complexity of the central computer system have to be considered before committing such plan. Remote data acquisition can usually be justified in overseas where geographical area covered by Load Research operation is vast. In the Hong Kong situation, manual data collection might be a better approach in HEC's Load Research plan.

4.3 Data Analysis Stage

Analysis methodology to be used for the Data Analysis Stage is at present a big research topic in HEC. Careful planning of this stage is important for accurate estimation of total demand profiles of various classes and various end-uses. Overseas expertise in Load Research, especially that from the United States, should be brought in to reduce the time required for the planning of this stage. Planning activities for this stage include estimation of data volume to be processed in the analysis, evaluation of capabilities of commercially available statistics packages or statistics packages specially designed for load research, and the identification of computer resources and manpower resources required to perform all the desired tasks.

5. UTILIZATION OF DISTRIBUTION SUBSTATION DATA IN LOAD RESEARCH

With the full automation of nearly all the Distribution substations (about 3000) by means of a Distribution Control and Data Acquisition System and the associated Remote Terminal Units installed in those substations, a complete set of load patterns (in kVA) of almost the whole population of distribution transformers in HEC's power distribution network can be easily obtained in any day of the year through on-line data acquisition. In many installations, the distribution transformers are supplying loads to customers of similar classes - domestic, commercial or industrial. Hence by displaying the 24-hour loading history of these transformers stored in the computer, typical load patterns of various classes of customers can be readily seen for any day type - weekday, weekend, summer day, winter day, and the system peak day. Figures 3, 4 and 5 depict the typical demand patterns of three distribution transformers known to be supplying homogeneous classes of customers on the system peak day of 1992.

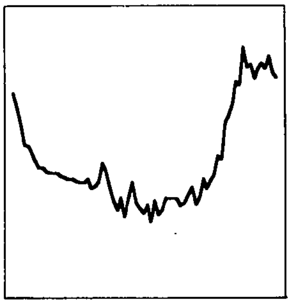


Figure 3
Load Profile of A Distribution Transformer Supplying Domestic Load

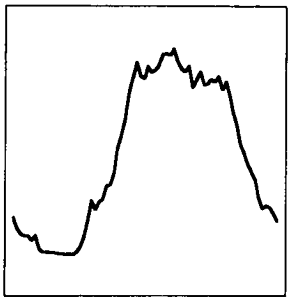


Figure 4
Load Profile of A Distribution Transformer Supplying Commercial Load

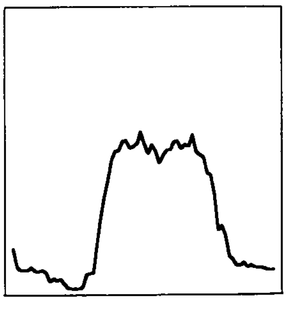


Figure 5
Load Profile of A Distribution Transformer Supplying Industrial Load

Unfortunately, over half of the population of these transformers are supplying mixed classes of customers with unknown proportions. Figure 6 depicts the demand profile of one of these transformers. Segregation of demand profiles of individual classes from the mixed-up demand profile is not a simple task and is now a research item of HEC.

Figure 6
Load Profile of A Distribution Transformer Supplying Mixed Domestic/ Commercial Load

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The possession of such complete information on the demand profiles of all distribution transformers is quite unique among utilities all over the world. It is believed that with some research work such valuable information can be integrated with the above Load Research plan to enhance the plan in several aspects - more optimal sample design, better accuracy, and probably shorter data logging time span.

6. APPLICATION OF LOAD RESEARCH RESULTS

Primarily results obtained from Load Research will be used directly in the planning and programme design of Demand Side Management. From Load Research's estimates of major end-use load profiles, DSM programmes focusing on either demand reduction or energy savings or both can be designed for individual end-uses and their cost effectiveness can be evaluated. For example, if it is revealed from Load Research that commercial air-conditioning load constitutes 50% of the maximum demand while residential air-conditioning load only 5%, obviously more resources and effort should be placed on the commercial customers than on the residential customers for these end-uses in DSM planning, programme design and programme administration. Without Load Research, impacts of major end-uses on the maximum demand can only be guessed intuitively and DSM resources may not be equitably allocated when the guess is far from the actual picture.

Integrating the billing data with the load profiles and energy usage characteristics of the three classes of customers, costs of services of individual classes can be accurately calculated and any unfairness in the tariff system can be assessed. Existing tariff structures can then be reviewed to give a more equitable system.

With clear pictures of customers' demand patterns obtained from Load Research, effective load management programmes supported by new tariff structures can be designed to attract customers to change their demand patterns by longer term capital investment in energy efficient and load shifting equipment. To HEC, time of use tariffs, off-peak tariffs, and seasonal tariffs are new tariff structures that are worth to be studied when supporting data from Load Research is available.

Load Research results can also support Integrated Least Cost Resource Planning, a new approach of utility long term planning in the DSM era. In Integrated Least Cost Resource Planning, the estimated reduction of demand and energy due to a DSM strategy is viewed as a resource option. Costs of various supply side options that can provide the same demand and energy reduced by DSM are then compared with cost of DSM and the least cost option is then chosen. One shortcoming of choosing a DSM option is that it is more risky than any supply side option, as the uncertainty of building a plant on time is usually less than materializing a DSM strategy with desired demand reduction. With more accurate information from Load Research, the real potential of DSM resources can be confidently determined and achievable DSM resources can be planned accordingly.

Information from Load Research can be utilized in Load Forecasting. Load Research data such as appliance ownership level, usage habits of major appliances, demography and housing characteristics, and so on can be useful in setting up a new load forecasting model. Greater degree of accuracy and confidence in the forecast of maximum demand and sales can be achieved by utilizing the additional information.

7. CONCLUSION

Demand Side Management, if carefully planned, will be the most cost effective resource in utility planning. On the other hand, if incorrect estimation on Demand Side Management is made, it would be a waste of fund and resources, and might even lead to electricity shortages, impeding the economic growth of our society and causing inconvenience to our people's daily life. For utilities which have been focusing on Supply Side Management traditionally, Load Research on the demand side is a pre-requisite step before migrating to Demand Side Management and Integrated Resource Planning. HEC considers itself successful in Supply Side Management due to the ongoing comprehensive "Load Research" on all the supply facilities. Likewise, for the success of Demand Side Management in Hong Kong, HEC is planning to conduct a comprehensive Load Research on the demand side. Borrowing experience from overseas, a preliminary plan discussed above has been drawn. However, HEC still has a great effort to make before getting a detailed workable plan that can be implementable. It is thus the purpose of this paper in this Symposium to invite comments or advice from experts in related fields - consultants, data logging equipment suppliers, system suppliers, utilities with Load Research experience and so on.

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DESIGN AND MANAGEMENT FOR ENERGY EFFICIENT BUILDINGS

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DESIGN AND MANAGEMENT FOR DENERGY EFFICIENT BUILDINGS

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ABSTRACT

Energy Costs are a significant component of building operating costs. These costs can, however, be minimized whilst still ensuring that standards of comfort and service are maintained. The first steps towards management of energy usage and the associated costs occur during the design process. A co-ordinated approach is required by all the design team. In particular the input by the E&M engineers, architects, lighting designers and specialist consultants are discussed.

Aspects of the design of buildings for energy management are presented. These will include planning, claimate, nature of buildings, building services and implementation.

Good energy management in existing buildings will have a major impact on operating costs. When this is combined with applicable system retrofits, a previously energy inefficient building can be made to operate much more economically. Recent experience in energy management for a hotel and office building is presented.

INTRODUCTION

In the major industrial countries of the world energy management first became an issue during the energy crisis in the mid seventies. Interest in energy management then tended to follow the worldwide fluctuations in energy fuel costs. Recently the impact of the production of CO_2 with a resulting global warming potential has added increased emphasis on the need for worldwide energy management. It has been estimated that almost forty percent of the current worldwide contribution to CO_2 emissions results from the burning of fuel to provide energy for building lighting, air conditioning and heating. CO_2 is one of the primary gases which are considered to contribute to the greenhouse effect and which may cause the earth's temperature to increase.

Due to Hong Kong's rapid development, less importance has in the past been placed on energy management than in many other parts of the world. This is now changing and pressure is being placed on the government to control energy use within Hong Kong and firms, consultants and individuals have been involved in a variety of projects to control energy use.

In Hong Kong about 50% of the electricity generated is used for commercial buildings. In Hong Kong this is generated by coal fired power plants. The fossil fuels of coal, oil and gas are limited in their quantity. It can be strongly argued that we have a responsibility to conserve this resource for future generations. It can be seen that any steps taken to reduce energy will have an impact on reducing costs, reducing global warming and conserving the earth's resources.

At this point it should be emphasised that energy management should not result in a reduction in the quality or standard of the comfort conditions provided. When areas are occupied adequate air conditioning and lighting must be provided.

Energy costs are a significant component of building operating costs. These costs can, however, be minimised whilst still ensuring that standards of comfort and service are maintained. The first steps towards management of energy usage and the associated costs occur during the design process. A co-ordinated approach is required by all the design team, in particular the E&M engineers, architects, lighting designers and specialists such as laundry and kitchen consultants.

Input is also required from the Client, especially when the design criteria are being established. It is also recommended that the client ensure that energy management is being incorporated into the design by requiring that a suitable reporting system, by all members of the design team, is established. To facilitate this, it is recommended that a member of the design team should act as an Energy Management Co-ordinator.

During the construction stage systems must be properly commissioned and the users fully instructed in the operation of the plant so as to maintain comfort conditions for minimum costs.

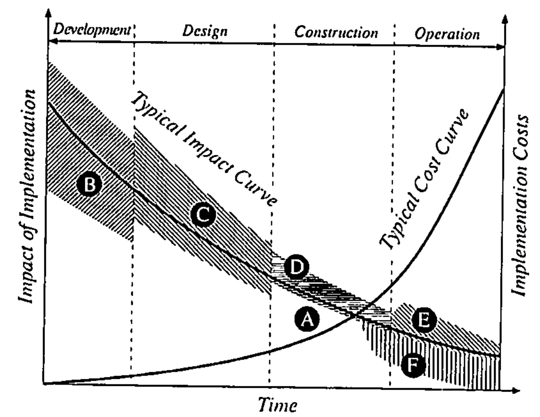
Good energy management in existing buildings will have a major impact on operating costs. When this is combined with applicable system retrofits, a relatively energy inefficient building can be made to operate much more economically.

This paper discusses approaches to energy management in the above areas.

DESIGN CONSULTANT'S ROLE

This section discusses the consultant's role in the design of an energy efficient building. Input is required from the early planning stages through the detailed design to the final commissioning and testing and handing over to the user. At all stages, close co-ordination amongst the project team is required.

FIGURE 1: THE EFFECT OF DECISION MAKING ON TOTAL OWNING AND OPERATING COSTS



A *Break even time*
B *Developers / owners have significant influence over energy costs*
C *Designers can in part compensate for development decisions*
D *Contractors have reduced influence*
E *Well managed buildings should have lower energy costs*
F *Effect of poor commissioning*

Preliminary Planning

The greatest impact on the owning and operating costs can be made during the early planning stages when the implementation cost is a minimum and energy management opportunities may be incorporated into the design with little or no increase in overall building cost, as shown in Figure 1

It is critical, therefore, that all parties in the design team, ideally including the operators, are available during the early stages to establish the basic concepts relating to energy management.

Energy Design Strategy

During the early planning stages of a project I like to prepare an energy strategy report. The report usually comprises the following:

- Fuel and electricity costs and tariffs
- Economic evaluation criteria, confirmed by the client.
- General system concepts
- Alternative systems to be evaluated
- Detailed energy management design guidelines

The design strategy covers all disciplines involved in the project so as to facilitate co-ordination. The design guidelines are also very useful for less experienced engineers working on the project.

Co-ordination

To effectively implement many of the elements of energy management, detailed co-ordination between the various disciplines is required. This may be represented by the typical matrix shown in Figure 2 for lighting design. Similar fully developed matrices may be used as design check lists.

FIGURE 2: LIGHTING ENERGY MANAGEMENT DESIGN CO-ORDINATION

	Daylighting (Windows, Switching Circuits)	*Illuminance (Room Use, Wall Ceiling Reflectance)*	*Lighting Control*	*Air Conditioning Load*	*Lamp and Fitting Type*	*Aesthetic Requirements*
Lighting Consultant	●	●	●		●	●
Electrical Engineer	●	●	●	●	●	
HVAC Engineer				●		
Client						●
Architect	●	●	●	●	●	
User		●		●		●
Electronics Engineer			●			

DESIGN PROCESSES AND STUDIES

Various aspects relating to the design for energy management are detailed below with some of the major considerations which apply in Hong Kong discussed.

The local climate is obviously one of the most significant factors affecting the energy use for air conditioning buildings. The major climate factors which affect Hong Kong are detailed below.

Temperature

Average diurnal temperature ranges during the day are relatively small. Hong Kong is located on latitude 22N and is outside the range where there is little seasonal variation, as occurs in the tropics between latitudes 15S to 15N. Accordingly significant variations between summer and winter occur. Summer temperatures may regularly be 33°C. Winters, however, are still relatively mild and the main energy use consideration is for summer cooling.

Humidity

The mean relative humidity is relatively high for most of the year. Daily variations in a single day, however, may be from 50 to 100% The high humidity levels will significantly affect the cooling load due to ventilation requirements and infiltration of moisture. Perceived comfort conditions are likely to be different from those in a hot dry climate or milder climates.

Solar Radiation

High levels of solar radiation occur during summer and are typically 800 w/m^2 to 1000 w/m^2. This is a major factor in peak cooling requirements. Generally, the high cloud cover and high water vapour content in the air will result in the solar radiation being scattered and reflected. As a result the average diffuse radiation level will be high: a significant factor in the annual energy costs for cooling, associated with glazing and the building fabric. The water content of the air and the high level of cloud cover will reduce heat, in the form of long wave radiation, being effectively radiated from the ground. As a result summer nights tend to be warm.

Thermal comfort in hot and humid climates, such as occurring in Hong Kong will be affected by air temperature, humidity, air movement and ambient radiation. Another factor which will apply in the establishing of criteria for Hong Kong is the possible perceived differences between Asians and Europeans. For this reason existing criteria established overseas must be carefully evaluated.

Architecture and Nature of Hong Kong Buildings

The nature of cities and the type of buildings within those cities may vary considerably from city to city. The design must take into considerations special factors which are applicable to Hong Kong. Some of these factors are as follows:

- a high percentage of buildings are built by developers who are looking for quick returns.
- many buildings are built with prestige as a major consideration, which results in high glazing areas, the use of atriums etc.
- a short term view to profits may exist due to consideration of political changes in 1997
- high land costs
- many high rise buildings
- congested buildings result in localised shading
- air conditioning plant for offices is generally not operated at night
- large areas of water will reflect the solar radiation

Building Envelope

Much of the energy designs for the building envelope will be based on computer modelling. Studies can show the effects of varying the window to wall area ratio, shading coefficient, wind velocities, opaque wall values, orientation, aspect ratio and insulation.

From these studies design guidelines can be developed which will allow designers flexibility in designing an energy efficient building. To balance the computer expertise and theoretical knowledge in each project task team, practical engineers should be included who have been extensively involved in building design for energy management.

Heating, Ventilation and Air Conditioning (HVAC)

Especially in multi-use building complexes there are functional areas, with differing occupancy periods and design criteria. The HVAC system design must be sufficiently flexible to allow easy control of these different areas to satisfy humidity and temperature requirements and also to provide a reduction in energy use when the areas are unoccupied or partly utilised. To assist in achieving these goals it is recommended that a clear design brief be established. Various systems may be used for air conditioning. These include fan coil units, variable air volume systems and constant air volume systems. Experienced designers are required to select the right system for the right area, so as to optimise energy management, and improve

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maintenance aspects and occupant comfort. In Hong Kong most of the building energy costs are due to the production of chilled water for air conditioning. Special attention should therefore be paid to the design, selection, specification and testing and commissioning of the equipment so that it will operate efficiently at both full load and part load.

Additional energy management aspects which may be required to be evaluated during the design include the following:

- Chiller Heat Rejection; Conventional chilled water systems use cooling towers for heat rejection. Due to limitations on water use cooling towers are restricted in Hong Kong. Alternative systems with varying efficiencies are available, including the use of sea water and air cooled equipment. Particular installations should, however, be assessed in detail to determine the most economically viable system.
- Thermal Storage; A system to generate and store cooling energy during periods of low demands when lower electricity tariffs apply. As such energy use is not reduced but capital and operating costs may be reduced. In Hong Kong the electricity tariffs do not make thermal storage cost effective. In Taiwan, however, Tai Power offers high incentives for thermal storage to reduce peak loads.
- Variable Speed Drives; For pumps and fans, with reduced energy requirements during periods of reduced load. Variable speed drives for fans are becoming more common and are effectively implemented. More care is required in designing systems for chilled water pumping, with particular attention to pressure sensor location and co.trol. Otherwise, the variable speed pumping systems will be less effective.
- Heat Recovery; To recover energy from exhausted air from the building. These systems have major applications where all outside air is used, such as hospital operating theatres. They are especially effective in Hong Kong's climate and have been effectively used for many years.
- Outside Air; General practice in Hong Kong is to provide minimum outside air for ventilation, which is below international standards. Even so the outside air can contribute to almost 30% of the typical building energy costs for air conditioning. Increasing outside air rates to those, such as recommended by ASHRAE, would have a major cost implication. Due, however, to considerations such as sick building syndrome the future trend will be to increase outside air. Any measures such as air quality monitoring and improved filtration to reduce outside air requirements and the associated air conditioning costs will become effective energy management strategies.
- Chilled Water Distribution Systems; Should be well planned for efficient systems which not only provide energy cost reductions but better system control and performance. System balancing and commissioning is also of prime importance. For large systems with multiple zones a primary pumping system for chillers with a secondary pumping circuit for distribution to various zones may provide major benefits.
- Direct Digital Control (DDC); Is now common practice for the control of major HVAC plant and air handling units and has provided cost and performance benefits. DDC may also be applied to terminal units such as variable volume air boxes. As a result control is improved and additional energy management strategies may be employed. In the USA a significant proportion of installations have such controls. This is not, however, the current case in Hong Kong, due perhaps to the higher costs, which may be 15% more, or the expertise of maintenance people in the application of the technology.
- Economy Cycles; A free cooling system where the outside air introduced into the building is increased at times when it requires less energy for air conditioning than the return air in the system. The application is most suited to climates with mild spring and autumn conditions. In Hong Kong theoretical savings may be as low a 5% and these can easily be lost by poor control or system set up. As a result systems are not justified with respect to the additional capital costs.
- Control Systems; Advances in control technology now enable strategies for resetting of chilled water temperature during low load cooling periods, to allow chillers to operate more efficiently. Computer based controls also enable chillers to be effectively controlled, with their operating sequence staged for energy efficiency. Practice in Hong Kong is still based on manual control, which is often not energy efficient. At this stage Hong Kong does not appear to be ready for full automatic control of chillers. A computer based system could, however, advise operators of the optimum control strategy.

Plumbing and Drainage

Pumping systems should be designed so that pumping of water during peak electricity use periods can be limited, thus reducing peak demand charges.

Hot water generation is an important consideration for kitchen use and hotel service. Heat pump systems and heat recovery chillers are often used for the economical generation of hot water in hotel applications. For other applications localised generation of hot water against central systems should be considered. Solar hot water systems will reduce energy use but pay back periods are long.

Lighting

The operating hours for lighting, in many areas are long. In other areas lighting may need only be used for defined periods or may be required intermittently. As a result lighting use is often poorly managed and energy costs are higher than they need to be. During the design process the following should be carried out so as to optimise the potential for lighting energy management.

- Wall, floor and ceiling colours and finishes should be carefully selected so as to provide suitable reflectance and to reduce glare.
- Windows should be designed for good daylighting, reduced glare and low air conditioning load.
- Light switching circuits should be selected to suit the functional requirement of the area and should consider daylighting.
- Lamps ballasts and fittings should be selected for high efficiency. It is noted that in many applications in Hong Kong, highly inefficient lighting, which has a short operating life, is used. Alternative systems can reduce cost by as much as 75% and significantly reduce maintenance associated with lamp replacement
- Control features such as dimmers, daylight sensors and time control should be used where appropriate.

To fully incorporate the above into a design a co-ordinated approach is required by the architect, electrical engineer, mechanical engineer, lighting designer and electronics engineer.

Food and Beverage Areas

Many commercial developments in Hong Kong incorporate restaurants and kitchens. Lighting and HVAC control in these areas will have a significant impact on energy use and the comments made above are particularly relevant. Other major considerations include the selection of equipment and the energy source for cooking. Systems should be able to be operated so that energy use is proportional to the number of food covers.

Where steam is required it should be distributed at optimum pressures and condensate should be recovered wherever possible. The energy source used to generate the steam should be thoroughly assessed for energy costs, equipment capital costs, other running costs and impact of flues.

Refrigeration equipment for cool rooms should be carefully specified to ensure low cost, energy efficient systems are provided. Often the trend today is to allow the contractor to provide the lowest cost equipment to meet a general specification. The result is that systems are highly inefficient and may not even achieve the performance of those installed in the 1950s. The location of heat rejection equipment for cool rooms should also be carefully integrated with the HVAC systems so as to reduce air-conditioning costs. As a result a co-ordinated approach is required between the mechanical engineer and the kitchen consultant.

Building and Energy Management Systems

Most large modern buildings in Hong Kong are provided with Building Management Systems (BMS). These can be an effective tool for energy management. All too often, however, systems are either insufficiently specified or not fully commissioned with the result that full energy optimisation cannot be achieved. The Client's requirements must be fully co-ordinated with design requirements for the mechanical and electrical systems. These in turn should be co-ordinated with the BMS design.

IMPLEMENTATION

The effective implementation of the energy management design will occur during the construction stage and during building occupancy. During the construction stage the standard of installation, testing and commissioning will significantly affect the potential for the control of energy use within the building. Adequate supervision must be provided at this stage to ensure that the design intent is achieved. The hand over process to the building users should incorporate training so that the users learn how to operate their building efficiently. On-going energy management should then be part of the building operation.

BUILDING OWNERS INPUT TO DESIGN

The Client or building owner has a significant role to play in co-ordination and in developing an energy efficient building. His main tasks are as follows:

- Appoint all consultants at an early stage.
- Appoint a user's representative at an early stage.

- Agree to economic criteria to be used in system evaluation.
- Establish a system, during the design stage, for reporting on energy management and for the giving of approvals as required.
- Provide a detailed design brief with energy management requirements.
- Make energy management a design requirement

ENERGY MANAGEMENT OF EXISTING BUILDINGS

Unless energy management practices are implemented in existing buildings, even those recently completed, the energy costs are usually higher than in a well managed equivalent building. In many cases savings of 10% to 20% can be achieved, primarily in the area of lighting control and management and operation of the air conditioning system. Savings of ten percent are often extremely feasible, without significant capital expenditure.

It is frequently asked why there is potential for savings in a new building. In many cases the systems are installed by the contractor to satisfy general performance design criteria, for peak load conditions. Very often requirements for partial load or occupancy are not considered in detail. In some cases detailed client requirements are not known till the building is occupied. As a result, the building operator allows the system to run to satisfy the peak load design conditions and takes no steps to reduce energy costs at other times. The occupants are often not told how to reduce energy costs. In the worst cases, buildings may not be commissioned satisfactorily, with resulting increased energy costs and poor comfort performance. By implementing energy management studies, audits and energy programmes, the savings discussed above can be achieved without a reduction in comfort standards.

Typical results for studies carried out in Hong Kong are shown in Figures 3 & 4.

FIGURE 3: MONTHLY ELECTRICITY USE (COMMERCIAL CENTRE)

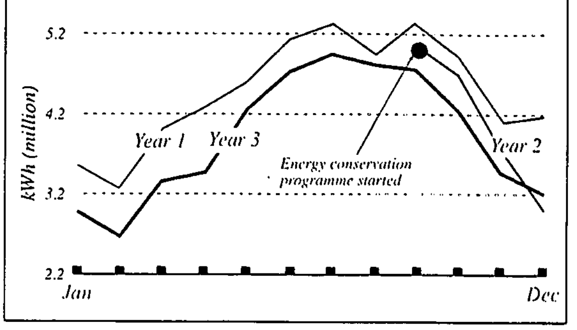
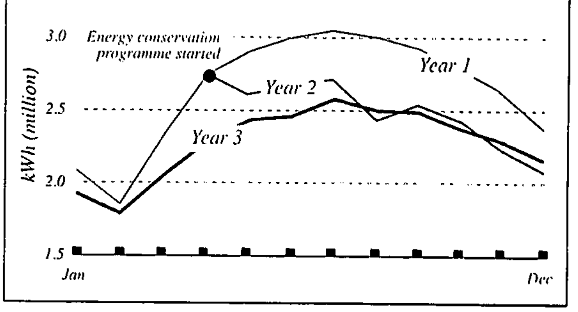


FIGURE 4: MONTHLY ELECTRICITY USE (HOTEL)



Energy Studies

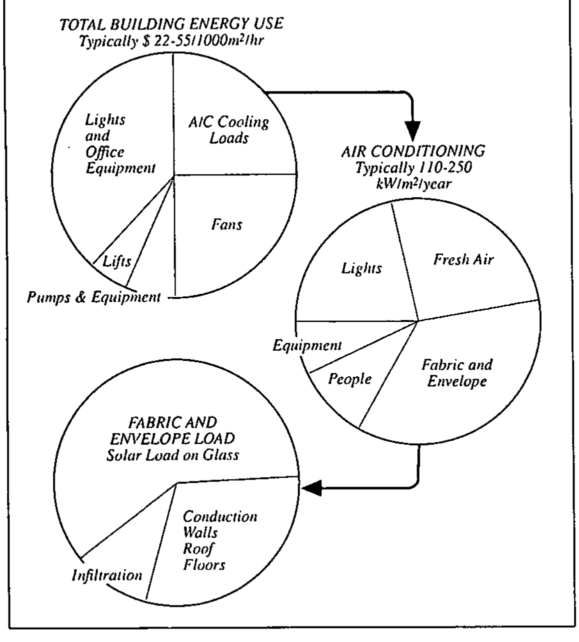
The basic steps in an energy study are as follows:

- Analyse of energy data and review of usage patterns.
- Prepare energy balance for equipment to compare usage with operating hours and equipment ratings.
- Review systems and equipment operations and performance.
- Identify factors relating to high energy use.
- Identify potential areas for savings.
- Evaluate energy management opportunities, using criteria established in conjunction with the owner/occupant.
- Issue interim reports.
- Obtain approvals for energy management implementation.
- Implement energy management measures. It is recommended that Owner/occupants establish an energy management committee, with representation by a Consultant to meet regularly.
- Monitor and review energy management procedures.
- Prepare final implementation report.

Analysis of Existing Energy Use Data for Buildings

The base energy use data for buildings will in many cases be limited to the overall energy use for the building. The overall energy use, however, will be a function of many factors. The major items would include lights, fans, air conditioning, equipment and computers loads. The air conditioning load will comprise people, lights, ventilation, equipment, solar load, conduction load and infiltration. The relative magnitude of the items for a typical office building are shown in Figure 5. The analysis of the data will have to estimate their relative magnitudes. To do this, the use of checklists, energy balances and monitoring will be required.

FIGURE 5: OFFICE BUILDING ENERGY USE - A BREAKDOWN



Checklists

Systems in each building analysed will vary. To assist in the establishment of the relative magnitude of the energy using components, checklists are used so that the building system components and operation can be identified and categorised.

Energy Balance

An energy balance is required for review to equate the total energy use with the estimated energy use for the components. Energy use for major systems and lighting can usually be accurately estimated from specification data and operating and maintenance manuals, and with on site verification as part of the monitoring process in the project.

Monitoring

Monitoring of existing buildings for the energy study may be required to establish typical space conditions in existing buildings and to allow the various components such as air conditioning and lighting component to be separated out of the overall energy costs.

Measurements to be taken would include light switching patterns, overall lighting load, major equipment loads, space temperature and humidity conditions

Typical equipment to be used for the studies could comprise of the following:

- Recording kW meter, with integrator to provide recorded kWh data. Typical equipment would be kW meters, integrator and portable computer for data recording.
- Energy analysers for three phase systems. These units are able to measure voltages, currents, power levels. They measure total and time band power consumption and are complete with a plug in memory pack, which is programmed and analysed off site.
- General air conditioning temperatures can be measured using multi- channel 'squirrels'. These are pre-programmed sensors, suitable for temperature and low voltage input. Data can be unloaded directly to a PC computer for analysis.
- Squirrels can also be used to identity light switching, patterns. (simple uncalibrated thermal detector fitted to light fittings).

Building Management System can also be utilised for data gathering. It is also expected that building engineering staff will be of assistance in taking manual readings of temperatures, humidity and hours of operation.

Economic Analysis

As part of the energy study, the justification for energy use control measures will have to be made using a thorough economic analysis of the alternatives. A similar process would be used in the design of a new project. The evaluation of system alternatives requires that consistent economic criteria be used. To establish these criteria the overall objectives must first be established.

Energy costs will primarily be reflected in tariffs and fuel costs. The current policy of pricing will need to be determined. This is especially important if alternative tariff structures are available. Costs for both demand requirements and usage requirements

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will have to be considered. Various criteria may be used for economic analysis of alternative energy use systems. Some of the criteria to be considered include life cycle costs, simple payback periods, discounted payback periods and internal rates of return

In many building energy related evaluations, where equipment lives are similar and where the relationship between future costs remains constant, simple payback periods are applicable. These will, however, vary for industry, developers, long term building owners and government. Simple payback period analysis may therefore not be appropriate for the energy study and the economic criteria must be agreed upon at an early stage.

The treatment of inflation must also be carefully considered. A good practice is to use discount rates and internal rates of return net of inflation. This is valid if inflation rates for fuels and other recurrent costs are similar. This may, of course, not be true but by using rates net of inflation the dangers associated with long term future predictions are avoided.

Implementation

Implementation of energy management practices requires a combined effort by the Management of the building and the building users. Methods to facilitate this include energy manager, budgetary controls, user participation and energy use reporting. General guidelines for users are included in the Appendix.

CONCLUSION

Energy Management of new and existing buildings is a practical and cost effective exercise. The design approach for new buildings requires a co-ordinated input by the design team and client and should commence as early as possible in the design process. Cost justifiable energy management in existing buildings can result in savings of at least 10%. The full commitment of people involved, however, is required.

APPENDIX

TABLE 1 - GENERAL ENERGY MANAGEMENT GUIDELINES

- Appoint energy manager, with high level of authority.
- Establish energy management committee, which should include representatives from management, engineering and user areas.
- Record and monitor energy use.
- Employ professional consultant for energy audit and specialist advice on implementation.
- Educate and involve staff.
- Explain to customers that energy management is being introduced for their benefit and will not result in reduced standards.
- Set targets.
- Provide incentives.
- Implement a preventative maintenance scheme.
- Ensure that capital cost expenditures are cost justifiable.
- Make areas responsible for their own energy use.

TABLE 2 - AIR CONDITIONING SYSTEM ENERGY MANAGEMENT CHECKLIST

AIR HANDLING UNITS / FAN COIL UNITS / PACKAGED UNITS

- Check thermostat set points and room temperatures
- Review operating hours and prepare on/off schedules or provide timers. Assign staff to be responsible for switching off units.
- Check outside air provisions.
- Regularly clean filters.
- Clean coils.
- Carry out preventative maintenance.
- Check rooms for adequate/correct air circulation.
- Do not obstruct return air grilles.
- Indicate correct thermostat settings.
- Provide timers on intermittently used air conditioners.
- Ensure thermostats are correctly located and have adequate air flow over them.
- Report user complaints to engineering who would keep a record.
- Reset room thermostats in winter.

TABLE 3 - LIGHTING ENERGY MANAGEMENT CHECKLIST

- Replace incandescent lights with fluorescent light.
- Replace low efficiency diffusers.
- Regularly clean lamps.
- Identify staff responsible for controlling light levels.

- Establish lighting strategies and schedules for each area
- Identify strategy on light switch panel showing control prepare standard lighting plans.
- Rewire control light switches to allow partial lighting.
- Take advantage of daylighting and do not provide unnecessary lighting.
- Consider not using decorative lighting at certain times, (chandeliers, wall lights, table lamps).
- Use reduced lighting for setting up bars, dining rooms etc.
- Reduce excessive lighting levels.
- Do not switch on outside lights during daytime.
- Clearly identify dimmer settings and maintain them.
- Where regularly required install high efficiency dimmers.

TABLE 4 - KITCHEN - ENERGY MANAGEMENT CHECKLIST

General
- Switch off all equipment when not in use.
- Regularly maintain and calibrate thermostats.
- Set thermostats appropriately.
- Schedule equipment use for high energy users, to limit peak demand.

Cooking
- Gas flames should not be yellow.
- Correct sized pots and pans should be used (25mm larger than burner), with flat bottoms.
- Flames should be correctly adjusted.
- Pots and pans should be grouped on ranges.
- Covers should be used on pots and pans.
- Griddles and fryers should be cleaned after use, clean grease toughs, drain fryers daily.
- Oil temperatures of fryers should be checked.
- Ovens should be quickly loaded/unloaded and only opened if necessary.
- Limit preheating to 30 minutes.

Water Supply
- Taps should not be left running.
- Flow restrictors should be installed.
- Cold water should be used instead of hot water wherever possible.
- Sinks should be used for washing rather than running water.
- Hot water should not be used for thawing meat.
- Hot water supply temperatures should not exceed 60°C.
- Rather than heating cold water use hot tap water.

Dishwasher
- Full loads should be washed.
- Regular maintenance should be carried out and temperatures, rinse cycles etc. checked.

Refrigeration
- Cool hot food for several minutes before refrigerating.
- Carry out regular maintenance and check thermostats, regularly defrost, check door seals and closing.
- Do not store materials near compressor.
- Do not overload refrigerators, or underload, consolidate food.
- Thaw frozen food in the refrigerator.
- Minimise opening of doors.

Ventilation and Air Conditioning
- Switch off exhaust hoods when not in use.
- Switch off make up air system when exhaust hoods not in use.
- Close doors.

Lights
- Switch off when not in use.

TABLE 5 - SWIMMING POOL
ENERGY MANAGEMENT CHECKLIST
- Do not back wash filters excessively.
- Service filter regularly.
- Clean skimmers and pump strainers.
- Limit debris and leaves entering pool.
- Keep deck areas clean.
- Switch off outside lighting during day time.
- Review heating temperature, period and strategy.
- Carry out preventive maintenance on heating system.
- Review chlorination/disinfection strategy and schedule.
- Investigate potential for thermal blanket for pool.

Paper No. 10

STATUS OF ENERGY SAVING IN CHINA'S INDUSTRY

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ABSTRACT

In the paper, introduction is given to the status of energy saving measures in Chinese Industry, such as the transformation of old production processes and equipment by energy saving new technologies, new processes and new material, the use of energy saving electro-machinery, the recovery of surplus energy (waste heat and residual pressure), utilization of secondary combustible resources, insulation for equipment and piping, co-generation, etc.

1. PREFACE

Being though a big energy country whose reserves of hydropower and coal rank in the first places in the world and whose reserves in oil and natural gas are also abundant, China has a per capita possession of energy resources falling below one half of the world's average. Hence, the Chinese government attaches great importance to energy conservation and pursues the policy of equal importance to exploitation and saving, with priority to saving in near future.

As estimated, Chinese industry consumes 67% of the country's primary energy production, 75% of electricity and 51% of oil, this means that a decisive role on energy saving should be on industrial enterprises. At present, of the cost composition of Chinese industrial products, energy, raw material and other consumables account more than 80% while labour takes only less than 20%. In national energy utilization rate, the figure for China is about 30% as contrast to about 50% for advanced industrial countries. All these explain the great energy saving potential in Chinese industry. According to estimation, if expressed in tons equivalent of standard coal, energy saving potential reaches 50 million for China's 140 thousand kilns, 35 million for her 360 thousand industrial boilers, 30 million for secondary combustible resources recovery in her industry, and 12 million for pumps and ventilators, 4 million for automobiles and tractors. If such potential is fully excavated, the present energy situation will be much alleviated.

Since early 1980s, the country has implemented energy saving in a planned way, and a series of energy saving policies have been set up which are suited to her economic management system, technical and production management level and economic ability. These involve the policies on energy saving technology, energy saving industry, energy saving investment and credit, awarding and punishment, protection of natural resources and environment, and administration system for energy saving. The enforcement and implementation of these policies has brought about a new look to the energy saving situation in Chinese industry : as compared with the early 1980s, increment has been 2 to 3 percentage points in energy utilization, 44% in gross national product per unit energy consumed and 3.73% in average annual rate of energy saving.

2. ENERGY SAVING MEASURES IN INDUSTRY

Since 1980s, Chinese industrial enterprises have steadily carried on their energy saving undertakings firstly enforcing energy management, that is, by setting up energy meteorological system, making the survey of energy balance, stopping leakage from pipings and equipment and pushing along enterprise up-grading drive on energy saving. Measures executed in enterprises may be roughly summed up as follows :-

(1) To push along technological progress - to

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use new technologies, new processes and new material, aiming at energy saving transformation.

Backward technological equipment has long been one of the principal causes of high energy consumption in the country. Of the 400 thousand boilers used in the country, two thirds are small ones and some of them are even the products of 1960s or 1950s with average efficiency as low as 50% to 60%; the average efficiency of the 140 thousand industrial kilns is lower than that of foreign products by 10%; among electric generation equipment, condensation type low-medium pressure small ones take about 20 million kiloWatts at a thermal efficiency of only 25% and the water pumps and ventilators operate at worse than 30% of efficiency. All these indicate that transformation of existing high energy consumption processes and equipment is an important aspect in energy saving.

There are numerous kinds of energy saving technologies and new production processes under popularization, for example, exo-kiln decomposition technology for cement making, continuous casting and rolling for steel making, co-generation, continuous baking technology like roller kiln and tunnel kiln in ceramic industry to replace step-wise baking, infra-red drying and heat pump drying, computerized monitoring of energy consuming equipment, speed regulation by variable frequency of AC motors, hydraulic couplings for pump and ventilator driving, least or chipless machining, etc.

(2) Use of energy saving equipment recommended by the government.

Since 1982, 13 batches of energy saving products totalling 713 kinds have been progressively popularized while at the same time 506 kinds of product were declared high energy consumption and performance-backward ones to be phased out. For example, JO type electric motors are to be replaced by Y type, water pumps and ventilators of previous types are to be replaced by energy saving ones, etc.

(3) Utilization of residual energy (waste heat and residual pressure) from production processes.

This has always been a favoured aspect in enterprises' energy saving. As industrial waste heat especially that contained in fuel gas is large in amount and widely exists, flue gas waste heat recovery technologies have gained rapid development in recent years. For example, waste boilers, arrayed pipe air preheaters, glass tube air preheaters, enameled tube air preheaters, heat resistant cast iron heat exchangers, injection type air preheaters, heat pipe air preheaters, spiral pipe heat exchangers, fluidized bed heat exchangers, etc. Among these, heat pipe air preheaters get rapid development and the research and application of them in China takes a leading position in the world.

For residual pressure utilization, electric generation by pressure difference of gas from blast furnace top and the use of residual steam pressure are also being undertaken and for the latter the ejection type heat pump is developed.

(4) Utilization of secondary combustible resources in industry.

Secondary combustibles in industry means the combustible slag or waste gas from a production process, such as the residue from water gas furnace, screen residue, high carbon content ash, garbage, wood chips, bagasse, etc. or B-gas from metallurgical process or gases discharged from small fertilizer plants. Among these, the relatively high calorie ones may be directly as fuel, and the ones of lower calorie content for example waste gas of a calorie lower than 2400 or 2600 kJ/m^3 or slag of 400 kJ/kg and downwards need some kind of special equipment for their safe complete burning.

(5) Better work on thermal insulation for pipings and equipment.

Since thermal insulation on pipings and equipment at some factories is not good enough, the melioration of it represents a great energy saving potential. In addition to the generally used material like vermiculite, siliceous earth, expanded pearlite, formed asbestos, rock wool, glass wool, porous calcium silicate and aluminum silicate fibre, compound magnesium silicate of coating paste type and other paste type composite insulation material are now available which are featured by wet application, dustlessness, good integrity, better adhesion and low cost. Besides, foam plastic type thermal insulation material of both heat resisting and corrosion preventing can also be found.

(6) Co-generation

For ordinary condensation type fuel-fired electric generation plants, more than 50% of heat is lost to cooling water, resulting in an efficiency of only 30% and less. As an effective way to save energy, co-generation raises heat utilization rate to 60% and more. Today, the Chinese government specifies that for industrial boilers of 10 tons/h and over in capacity and more than 400 hours of operation per year, co-generation must be used.

3. CONCLUSION

For over ten years, China has made great success in energy saving. However, to ensure smooth development of national economy and to protect environment, it is still necessary to push along energy saving. From now on, price of energy should be gradually adjusted so as to urge enterprises to pay more attention to energy saving through economic lever. At the same time, research and development should be intensified on energy saving new technology, new process and new material. Only by all these can energy saving in China be raised to a new level.

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Paper No. 11

DEMAND SIDE MANAGEMENT (DSM) - SELECTED U.S. EXPERIENCE AND POTENTIAL APPLICATIONS TO HONG KONG

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Demand Side Management (DSM) is defined as the planning, implementation, and monitoring of utility activities to encourage utility customers to adopt patterns of energy (electricity) usage that conform as much as possible to the electricity supply pattern both in regard to the timing and the level of electricity demand.

ABSTRACT

As of 1990, there were 360 utilities in the US with DSM programs. This number has been increasing and most major US utilities have now extensive DSM programs.

DSM and other energy efficiency programs have achieved considerable reductions in electric load (3% in 1990) and electric energy use (0.6% in 1990) in the US. These successes point to increasing financial investments by US utilities in DSM and energy efficiency programs (an investment of 0.75% of total utility revenues in 1990). This paper will summarize selected US programs and recommend potential applications to Hong Kong.

The price and thus the competitiveness of the export products of a nation are significantly affected by the amount and cost of energy used in their production. In the case of Hong Kong, which needs to import primary energy sources, energy efficiency and DSM may be taken as an opportunity to demonstrate global leadership and innovation.

1. DSM DEVELOPMENT AND UTILITY PROGRAMS IN THE US

For many decades in the U.S., the utility industry has been practicing Supply Management (i.e., the management of power supply to optimally conform with the customer demand) as a normal course of electric system development and operation. Later, over the last two decades, Load Management (i.e., methods for controlling or altering electric load or demand shapes) became an important aspect of electric system planning and operations. There was considerable debate during that time on whether the benefits derived from Load Management (e.g., higher annual load factors) would be sufficient to offset the costs and side effects from the load management programs (e.g., impact on scheduled outages, higher reserve requirements, etc.)

However, a number of supply management and load management options became institutionalized in utility operations such as:

- Supply Management through bulk energy storage (e.g., pumped hydro) and interconnected system operation (e.g., power pools).

- Load Management through special rate schedules (e.g., interruptible, seasonal or night rates, etc.), supervisory (direct) control of customer equipment (e.g., control of water heaters and air conditioning units), and indirect load control measures (e.g., time-of-day incentive rates).

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In the last decade, DSM has become an increasingly important concept in system planning and utility operations in the U.S. This has been an evolutionary process and many of the original load management concepts mentioned above have become an integral part of DSM.

In general, the following types of DSM programs are currently practiced in the US:

- Direct Load control - this involves setting segments of load (normally residential load) under a supervisory role by the utility with the option of interruptions/alterations in supply with or without notification.

- Special Rate Schedules - this involves setting segments of load (normally industrial and commercial load) under special load agreements (night rates, seasonal rates, etc.) including interruptions/alterations in supply by direct utility action or by the client (per utility request).

- Various DSM Programs - this involves electric or thermal energy storage (including coolness storage) for purposes of load shifting, peak clipping, etc. Also, time-of-use rates (rates reflecting changes in electric production/delivery costs with time of day, season, etc.) designed for various customer sectors and reflecting seasonal changes, and other arrangements between the utilities and rate payers.

DSM opportunities are defined and programs implemented by U.S. utilities through a variety activities (using specific incentives) under the heading of DSM and Energy Efficiency programs such as:

- free analysis of energy use (Analysis Incentives)

- rebates/loans for purchasing efficient appliances and equipment (Equipment Incentives)

- low interest loans for building weatherization and efficiency upgrades (Building Incentives)

- support of liaison with affinity groups

- information/education programs

- innovative rate structure (which applies to the programs mentioned above: direct load control, special rate schedules, etc.)

DSM and Energy Efficiency programs have achieved and promise to achieve significant impacts on U.S. utility operations. In brief the data show:

- Peak demand reduction of 16,700 MW or 3.1% of U.S. summer peak load (538,700 MW) in 1990. This is projected to increase to 7.2% by year 2000 or higher (in the range of 10% according to some projections).

- Energy savings of 17 billion kWh or 0.6% of total U.S. annual sales to ultimate customers (2,838 billion kWh) in 1990. This is projected to increase to 2.2% by year 2000 or higher (in the range of 6% according to some projections).

- DSM expenditures of $1.2 billion or 0.7% of the total electric revenues ($172.3 billion) in 1990 and are projected to increase to 1.5% by the year 2000

Of the $1.2 billion of DSM expenditures in 1990, about 25 utilities accounted for about 68% of program expenditures in that year. East and West coast utilities (plus a few in Mid-West) seemed to have made the greatest DSM investments that year. These 25 utilities (24 investor owned and one public utility) account for 37% of the total US electric revenues for 1990

Exhibit 1 (1a and 1b) presents energy efficiency programs of Large Scale and of Support & Development nature for a major US utility. Noteworthy programs in the context of Hong Kong are those which address cooling, ventilation, lighting, motor/appliance efficiency, etc.

Current developments in the US utility industry point to the following trends:

- Development of improved techniques for evaluation of DSM program effectiveness -- Key indicators include: peak reduction, energy savings, number of participants, less purchase of outside power and energy,etc.

- Development of regulatory incentives for sustained utility commitment to DSM -- Key factors are pricing of electricity (marginal versus average cost) allowing return on investment for DSM options, etc.

- DSM program cost recovery is obtained from increments to rates charged to customers via various procedures. Rate basing is often considered advantageous because it places DSM expenses in similar status as that of investments for capacity.

- Procurement of DSM program and services through competitive bidding is becoming common place.

- Recognition of lost revenues from reduced energy sales resulting from an effective DSM program is of major importance and many states have formally done so through their rulings. To offset this fundamental disincentive, some states require explicit calculation of lost revenues while others permit decoupling the utility recovery of fixed costs from kWh sales.

- Shareholder incentives are needed to offset the perceived negative impact of DSM (i.e., reduced kWh sales, stagnant or declining rate base, etc.). Various approaches are being taken by different states: allowing shareholders to retain a portion of savings from DSM, rewarding/penalizing ROE (Return on Equity) based on the utility's progress in developing DSM effectively, premiums for rate based DSM investments or resource saved above certain pre-set goal, fixed mark upon DSM expenditures, etc.

2. DSM REGULATORY PRACTICES IN US

Exhibit 2 presents a summary of the status of DSM practices in six states in the United States representing various part of the country. The following facts are noteworthy:

- Formal DSM regulations exist in all of the 6 selected states. As of 1992, there were 26 states in the US that had issued formal rulings to guide DSM practices.

- The DSM Total Resource Cost Test (TRC) measures whether a program would increase/decrease the total cost of meeting the utility clients' energy requirements (all customer classes). The DSM Ratepayer Impact Test (RIM) indicates whether average rate levels would change (for a group of participant customers) as a result of a DSM program.

- A formal DSM Resource Plan submitted by the utility is often required for regulatory approval.

3. POTENTIAL APPLICATIONS OF DSM TO HONG KONG

Energy efficiency is gaining in popularity in Hong Kong as the community realizes that its positive contribution is not only confined to the economy and productivity of the Territory but also to enhance environmental protection. Energy efficiency is now recognized as one of the more practical approaches to limit "greenhouse gas" emissions, a requirement which the developed countries will need to comply following the decision of the 'Earth Summit' in 1992 in Rio de Janeiro. Nevertheless, the concept of DSM is relatively new in the local energy industry including power utilities. Positive steps are being taken by the two power companies to formulate DSM strategies and workplans. Although detailed customer base load data has to be established to quantify the maximum technical and economic potential of DSM programs, a review of information concerning macroscopic energy data and the electricity/industrial environments and developments in Hong Kong suggests the following opportunities for DSM programs by the power utilities.

- Domestic Customers - Government expects over the next 10 years the construction of 560,000 new housing units plus the refurbishment of 180,000 private flats (being demolished and redeveloped) for a total of 740,000 units as an aggregate figure between new and refurbished units in Hong Kong.

  These construction plans offer a significant opportunity to introduce energy efficient equipment and/or materials in the domestic sector (light, air conditioners, refrigerators, insulation). In regard to per capita energy use, the Hong Kong domestic client used about 4,800 kWh in 1990 versus 9,500 kWh as the U.S. average and 7,000 kWh for the New Jersey domestic client. Energy efficiency should hold down the increasing rate of energy use resulting from the expected increase level of electrification.

- Manufacturing Customers - In this sector, textiles, clothing and plastic toys represent the principal users of electricity in Hong Kong. Other subsegments include metal processing and electronic instruments. Various energy efficiency measures could likely be considered including energy efficient lighting, more efficient air conditioning, better insulation, energy efficient motors, and improved process efficiency.

- Commercial Customers - This sector includes restaurants, shops, hotels, offices and miscellaneous activities under building management. Opportunities for energy efficiency would likely include improved lighting, more efficient cooling (including thermal storage) and energy efficient motors.

- Miscellaneous Customers - More efficient lighting offers the greatest opportunity in this sector.

- Government and Institutions - Government has a sizeable estate - 1,800 owned buildings and 1,190 leased premises as well as over 100 water and sewage pumping stations. Its annual electricity bill exceeds 500 Million HKD. Various opportunities exist in improved lighting, more efficient cooling and energy efficient motors. The Electrical & Mechanical Services Department is actively supporting the improvement work in this area.

4. POWER COMPANIES LOAD SHAPES AND DSM PROGRAMS

The load shapes (electric demand versus hour on a year-round basis) for the CLP and HEC systems show the typical characteristics that would make four generic types of DSM programs applicable.

I. Peak Clipping - This results in reduced demand during peak periods (non peak demand is generally unaffected).

Benefits: Reduces need for new power plant construction since growth of peak demand is slowed (or eliminate). Increased load factor, reduces tariff. Some reduction in total energy consumption. Reduces operating costs and the use of the more expensive fuels.

Examples: Interruptible power - The power company offers lower tariffs to customers who agree to have their electric equipment (air conditioners, for example) shut off automatically at times of peak demand. The automatic shut-off is accomplished by means of radio-operated switch. At times of peak load the power company broadcasts a signal that switches off the equipment.

Time-of-day billing - The power company implements a means of charging customers for electricity at tariffs that depend on the time of day. Generally, the tariff is high during daylight hours and low at night. Customers normally respond to this by cutting back on electricity usage at times of peak demand.

II. Valley Filling - This results in energy consumption being increased during off-peak periods. Peak demand is generally not affected.

Benefits: Increases load factor, reduces tariff.

Examples Thermal energy storage - The proposed electric water heater schemes of HEC and CLP are valley filling schemes, since hot water heating in Hong Kong is an off-peak load.

Electric cars - Some U.S. utilities are contributing to the development of practical electric cars that use battery storage and can be recharged from a standard domestic outlet. Since most recharging will be done overnight, the increase in electric demand will be primarily off-peak.

III. Load Shifting - This results in load shifting from on-peak to off-peak periods. Energy consumption is essentially unaffected.

Benefits: Reduces need for new power plant construction since growth of peak demand is slowed (or eliminated). Increases load factor, reducing tariff.

Examples: Thermal energy storage - Developers of new commercial buildings can shift daytime demand for heating and cooling by installing ice storage and/or hot water storage systems. With these systems, hot water or ice is produced overnight (depending on whether the need is for heating or cooling) and stored in an insulated vessel. During the day, the stored energy is used for space heating or cooling. The power company can encourage this by providing subsidies to developers or by offering time-of-day tariffs.

IV. Energy Efficiency - This comprises a variety of measures (which are sometimes considered to be outside the strict definition of DSM programs) to reduce energy consumption across the entire load curve.

Benefits: Reduces energy consumption, results in lower total fuel requirements and lower air emissions.

Examples: Energy efficient lighting - The power company subsidizes the cost of high-efficiency lighting equipment, reducing total electric lighting load.

Weatherization assistance - The power company provides free weatherization services (installation of weather stripping around doors and windows, insulation, etc.) to customers with electric heating or air conditioning.

Minimum efficiency standards - Government mandates that certain new products (air conditioners, refrigerators, light bulbs, etc.) must meet minimum energy efficiency standards.

5. ELECTRIC WATER HEATERS

As part of its effort to encourage DSM in Hong Kong, Government has been reviewing proposals on Electric Water Heaters by the power companies. Electric water heating falls into "valley filling" DSM category. Water heater electricity consumption is expected to occur almost entirely off-peak, when low-cost energy is available (typically from coal-fired stations). Since the power companies do not expect electric water heating to contribute to maximum demand, no additional generating capacity is required to supply it; therefore total system electricity cost is increased by the incremental cost of electricity only, and will be distributed over a larger volume of sales. The net result is a reduction in tariff for all consumers.

However, **the review also demonstrated that a small portion of on-peak usage of electric water heater would off-set all the benefit.** To ensure that the proposed programs on electric water heating meet expectations, **it** is being considered that the power companies, (using a random sample of the water heaters), **should** record time-of-day usage and monitor their initial results in their planning for the longer term implementation of such programs.

6. INSTITUTIONAL ISSUES AND FINANCIAL ARRANGEMENTS CONCERNING DSM IMPLEMENTATION

The financial arrangements for implementation of DSM in Hong Kong may follow one or more of the paths being followed in other countries. There are no apparent insurmountable obstacles to DSM application through bidding, cost allocations or other methods. Key regulatory requirements should be :

- Adequate review of the utility DSM Resource Plan which should address a mid to long term horizon (i.e., more than one year). The DSM Resource Plan is a comprehensive presentation of the utility's planned DSM activities over a period of time (e.g. 2 or more years) and is reviewed and updated on an annual basis.

- The DSM Resource Plan should provide all interested parties with an opportunity to bid on specific DSM services or propose innovative applications.

- The avoided cost savings calculations should be consistent and fair to all interested parties.

7. PLANS FOR ACCELERATED GAINS IN ENERGY EFFICIENCY THROUGH DSM IN HONG KONG

The potential advantages that can be gained by Hong Kong from accelerated efforts to improve energy efficiency through DSM applications suggests the development of a Master Plan for Energy Efficiency and DSM.

The development of this document should pool the resources of the Hong Kong electric and gas utilities, other key players in the energy sector, and Government, in a coordinated effort to define opportunities and to chart a course of action in this area. Potential major elements to be considered in the development of such Master Plan are presented in Exhibit 3.

8. CONCLUSION

DSM is increasingly being accepted in the more developed lands as a means to achieve increased efficiencies in electric supply/demand transactions. A Master Plan for energy efficiency through DSM is proposed as a means to coalesce in a single plan the contributions from various sectors in Hong Kong (industry, Universities, Government). A concerted effort on increasing energy efficiency will position Hong Kong advantageously to achieve global leadership in this area in the future.

9. REFERENCES

- US Energy Information Administration - 1990 Data from "Annual Electric Utility Report".
- Edison Electric Institute - Integrated Resource Planning, 1992 Source Book.
- Electric Power Research Institute _ Demand Side Management Utility Options for the Future (1991).

Exhibit 1.a DSM Programs for a Major US Utility 1993-94 Plan

1. Large Scale Programs

C&I (Commercial and Industrial Efficient Lighting Incentives
C&I High Efficiency Electric Space Conditioning Incentives
High Efficiency Motor Rebates
Curtailable Electric Service
Residential Compact Fluorescent Lighting
Residential Submetering
Air Conditioner Dealer Incentives
Refrigerator Dealer Incentives
C&I and Not-For-Profit Energy Survey
Energy Conservation Center
Enlightened Energy in the Workplace
Advertising
Literature
Telephone GuideLine
Enlightened Energy Van
C&I Seminars
C&I Information Program
Direct Access Computers
Energy Efficiency Education
C&I Customer Communications
Residential Customer Communications
Mandatory Residential and Religious TOD (Time of Day) Rates
C&I Customized Energy Efficiency
C&I Customer Lighting Center
C&I New Construction Design Assistance

Exhibit 1.b DSM Programs for a Major US Utitlity
1993-94 Plan

2. Development & Support Programs

DSM Database System
Central A/C Maintenance Assessment
Cool Storage Load Shift Validation
Shared Savings Demonstration
Residential Builder Incentive Pilot
Landlord Incentives for Efficient Appliances
New Construction Lost Opportunity Market Study
Spare Refrigerator Pick-up
Electric Water Heater Timer Demonstration
Cool Storage Retrofit Demonstration
Residential Low Income Market Study
A/C and Pool Pump Direct Load Study
DSM Market Study
Neighborhood Energy Savings
Residential Load Management
CEDMS (Commercial Energy Demand Model Service) - Based Commercial Sector
Adjustable Speed Drive Demonstration
Residential Appliance Saturation Survey
Increase Effectiveness of Existing EMS (Energy Management Systems)
Public Opinion Survey
A/C Load Management Controls
Energy Efficiency Skills Training
Testing & Analysis of Advertising
Commercial & Industrial TOU (Time of Use) Rate
Residential Conditional Demand Rate
Assessment of Renewable Technology
Trade Allies Research
Network Profiling and Marketing

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Exhibit 2 Status of DSM Regulatory Practices in Six States in the US

	Calif.	Fla.	Hawaii	Mass.	N.J.	N.Y.
Regulatory Process in Place						
· Formal Regulations	✓	✓	✓	✓	✓	✓
Cost-Effectiveness Tests Required						
· Total Resource Cost	✓		✓	✓	✓	
· Ratepayer Impact	✓		✓			
Oversight on Cost Recovery Plan						
· Public Hearings	✓	✓	✓			
· Formal PUC Approval	✓	✓	✓	✓	✓	
· Plan Certification Required	✓		✓	✓	✓	
DSM Program Cost Recovery Procedures						
· Deferred to Next Rate Case		✓	✓		✓	✓
· Through Fuel or Similar Adjustment	✓		✓			✓
· As Surcharge or Rider	✓		✓			
· Rate basing of Nontraditional Costs				✓	✓	
Procurement Practices						
· Bidding in Place	✓		✓	✓	✓	✓
Implementation Incentives						
· Recognize/Lost Revenues Resulting from DSM	✓		✓	✓	✓	✓
· Require Explicit Calculation of Lost Revenues			✓	✓		✓
· Permit ":Fixed-Cost Recovery" Decoupling from kWh Sales	✓					✓
Shareholders DSM Incentives						
· Shared Savings	✓		✓		✓	✓
· Allowed ROE Adjustment			✓			
· Premium for Rate Based Investment			✓			✓
· Premium for Performance				✓	✓	
· Mark-Up on Expenditures	✓		✓			

Exhibit 3 Master Plan for Energy Efficiency Through DSM in Hong Kong

Major elements of plan:

- Organization structure - Policy and implementation
- Preliminary list of programs
- Development of priorities within budget
- Development of incentives for DSM analysis and implementation
- Coordinated public education and public relations/information
- Action plans for various sectors

(1) Commercial sector - cooling, ventilation, lighting
(2) Manufacturing sector - motors and processes
(3) Domestic sector - air conditioning, appliances and lighting
(4) Government sector - lighting cooling, ventilation and motors

- Auditing of results - energy savings, cost and environmental benefits
- Special and related issues

(1) Participation by other in energy sector (e.g. Hong Kong & China Gas)
(2) District cooling
(3) Electric vehicles

- Financing of the Plan

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