SELECTION OF HEAT REJECTION METHODS FOR AIR CONDITIONING SYSTEMS IN HONG KONG

P.C. Yip and Sam C.M. Hui
Department of Building Services Engineering, Hong Kong Polytechnic

This paper attempts to analyse and examine the problems and selection of heat rejection methods (HRM's) in Hong Kong and to establish easy-to-follow guidance for design engineers. It also reports on a trial survey to study the performance of Air-conditioning systems in Hong Kong. Results of the survey have demonstrated that direct seawater cooling and direct air-cooled systems are most commonly adopted and the energy utilisation for office buildings in Hong Kong lies between 150 to 200 kWh/sq.m/annum. Recommendations are made on the implementation of extensive studies on building energy analysis. The purpose is to compile useful guide data for design and maintenance.

INTRODUCTION

During the past decade, there was a boom in the building sector in Hong Kong and many fine and prestigious buildings were erected on the territory of Hong Kong. However, there are little research efforts being devoted to the investigation of the performance of their large scale Air-conditioning systems.

This research paper is the first step of an attempt to investigate the performance and limitations of Air-conditioning systems in commercial buildings in Hong Kong. The ultimate aim of the study is to compile useful guide data and to establish recommendations for Air-conditioning systems design and maintenance in Hong Kong.

In this first step of our study, heat rejection system is chosen as the prime focus of attention because its selection will have a significant effect on the capital investment, follow-up maintenance and energy consumption of a building. Important factors affecting selection are examined and a simplified method for decision making at the early design stage is proposed.

Accurate performance comparison cannot be made without understandings of the characteristics of the Air-conditioning systems in real world buildings in that particular area (i.e. in Hong Kong in our case). Therefore, a 'pilot' or trial survey has been conducted to assess the possibility of collecting and analysing performance data on a large scale. The survey results illustrated that large amount of useful information were held about by the owners of individual buildings. By collecting and interpreting data from a number of typical buildings, it is believed that useful performance guides and data can be formulated.

In the coming 90's, there will be a lot of building projects to be developed in Hong Kong [Ref. 1] if the prosperity and stability of Hong Kong can be maintained. It is the right time for the engineers in Hong Kong to review the past activities and to plan for our next generation of buildings. Recommendations are therefore put forward for more in-depth further studies on the subject.

HEAT REJECTION METHODS

Heat rejection system is the primary engineering system in an Air-conditioning plant. It is required by all types of Air-conditioning systems and should therefore be determined prior to the consideration of the design of refrigeration plant and air side system. The basic concept of the heat removal process in an Air-conditioning system is shown on Figure 1.

Heat rejection methods (HRM's) commonly adopted in commercial buildings in Hong Kong are :

- Direct seawater cooling (DSC)
- Indirect seawater cooling(ISC)
- Direct air-cooled (DAC)
- Indirect air-cooled (IAC)
- Evaporative cooling using cooling tower (ECT)

Simple schematic diagrams on Figure 2 show the basic arrangement of these heat rejection methods.

Relevant studies [Ref. 2] show that energy consumed by an Air-conditioning plant may dominate over 60 % of the expenditure on electricity in a commercial building in Hong Kong. Heat rejection equipment and refrigeration plant may consume over half of the total annual energy use for an Air-conditioning system [Ref. 3 & 4]. Thus, selection of HRM will significantly affect the building energy costs in the long run.

FACTORS AFFECTING SELECTION

Major factors affecting the selection of HRM in Hong Kong are summarised in the followings :

Functional

- Site location, site conditions and the availability of heat sink
- Equipment space requirements
- Architectural constraints
- Source of cooling tower make-up water
- Equipment compatibility

Economic and operational

- First cost (capital costs and civil costs)
- Operating cost
- Maintenance cost
- Access provision for installation and maintenance

Environmental

- Environmental acceptability (effects on noise, air and water pollution)
- Local regulations restrictions
- Equipment applicability

Qualitative

- Reliability and flexibility
- Integration with other systems (e.g. heat reclaim using heat exchanger in indirect sea water cooled system)
- Indirect environmental impact (energy conservation and downstream effects on pollution)

COMPARISON OF HRM

Decision Making

The basis for an engineering decision are economics and quality. When time comes for an engineer to make a recommendation to the Client and involve the Client in the final decision process, other factors than pure engineering are involved [Ref. 5]. A method is described here in below for evaluation of heat rejection methods. The purpose is to establish a means of easy-to-follow guidance to determine which system suits best the needs of a particular project. It should be noted that the final answer lies in a balance between quality and economics blended with a judgement of the Client's needs.

Economic Analysis

The life cycle cost method is most commonly used for long time period such as 20 years reflecting the useful economic life of the equipment [Ref. 6 - 10]. The technique employs an economic assessment of design alternative, considering all significant costs of ownership over the economic life of each alternative, expressed in equivalent dollars [Ref. 11].

For the sake of convenience of use by design engineers, a simplified life cycle costing method has been developed here for evaluating design alternatives using a computer spreadsheet program [Ref. 12]. An illustrated example (Example 1) of the method is given in the Appendix and it would be most helpful at the early design stage in a building project.

Qualitative Analysis

Qualitative factors involved in the selection process are not able to be fully recognised in the economic analysis. In order to take into account these system attributes, a simple point scale evaluation method is introduced so as to supplement the life cycle costing evaluation.

The so-called `merit function ranking method' [Ref. 13] allows the system selection to be closely matched to the priorities of the particular building owner. Life cycle costing can be one of its attributes, as can the initial cost, ease of maintenance, noise, floor space, or any number of system attributes. The idea of the method is illustrated in an example (Example 2) given in the Appendix.

The design engineer shall first develop absolute requirements from the Client and then assign values for the weighting factors of each system attribute. The attributes for system selection also change from building owner to building owner. The respective weighting factors can be adjusted accordingly to reflect their preferences and requirements.

Advantages of Merit Function Ranking

This method has the advantage that many qualitative factors e.g. maintainability and reliability which have no numerical ratings can be included in the decision making. Both `hard' numbers like dollar figures and `soft' number judgement factors can be combined into a selection procedure.

The merits of this method of evaluation include :

- Combine both qualitative and quantitative factors in selection
- Encourage the involvement of building owner in decision making
- Simpler for building owners to understand
- Flexibility of adjusting to different preferences and priority

This method is an improvement over simply choosing the system with the lowest life cycle cost or the lowest first cost.

Practical Considerations

One problem being faced by Air-conditioning design and maintenance engineers in Hong Kong is that standard performance data applicable to the local conditions of Hong Kong is not available. When making evaluation of HRM's, Air-conditioning engineers are constantly in need of performance comparison data for Air-conditioning systems. It will be very helpful if useful data can be generated from information collected from local studies and surveys. Therefore, a `pilot' or trial survey has been conducted in our study to assess the possibility of collecting and analysing performance data on a large scale in Hong Kong.

PILOT SURVEY

Methodology

The survey was conducted in three stages. The first stage consisted of collecting existing data from records and archive of buildings developments in Hong Kong. The data collected included floor areas, location, completion year, refrigeration tonnage and general information on their Air-conditioning systems.

In the second stage, a postal survey was conducted to collect information from `users' of Air-conditioning systems in Hong Kong. A questionnaire was sent to relevant organisations such as building owners and maintenance managers. Experience and opinions from `users' of these Air-conditioning systems were also welcomed. The information sought included :

- General building descriptions
- Air-conditioning equipment details

- Records of building energy consumption
- Maintenance practice and costs
- Operators' or users' general comments

In the final stage, technical visits were arranged to plantrooms of some buildings in Hong Kong with large Air-conditioning plants and interviews were made with their maintenance staff. The purpose is to better understand the operation and problems of their Air-conditioning equipment. Ambiguities in returned questionnaires were also clarified in the interviews.

Data Analysis

The pilot survey here concentrated on office and commercial buildings because they constitute a very large sector of air-conditioned buildings in Hong Kong. Summary of the first stage of the survey is shown on Table 1. Results of the survey have shown that direct seawater cooling (31 %) and direct air-cooled systems (31 %) are most commonly adopted for large Air-conditioning plants in Hong Kong.

General description of the postal survey is given in Table 2. The results and findings of the survey are then summarised in Figures 3 to 7. For the sake of confidentiality, the sources of information in the postal survey must remain anonymous and the names of the buildings are represented by capital letters A to P.

Discussion

The collection and interpretation of information in such a survey must be approached with care in order that a reliable and useful conclusion can be produced.

Some general comments on the postal survey are summarized below :

Cost Data. There is reluctance in certain owners to provide detailed figures on building energy use and maintenance cost because of need for commercial confidentiality.

Energy Consumption. Information on energy consumption data supplied by most respondents was not in sufficient details. The reason may be that there is not sufficient attention paid to the keeping of these data at the engineering management level.

Energy Usage Breakdown. Energy usage breakdown on Air-conditioning equipment is not available in most of the time because the electricity supply and sub-metering for these equipment are not properly classified and metered in such a detail. This may impose difficulties to energy audit and analysis for these buildings.

Maintenance Practice. In private sector (Buildings A to I), maintenance works was carried out by either contract maintenance or a combination of contract and direct labour. Whilst in government buildings (Buildings J to P), a large portion of the works was carried out by direct labour (i.e. the H.K. government's maintenance team in the E.M.S.D.). This is not surprising as the H.K. government is the largest building owner in Hong Kong. Plant performance is, in most of the cases, monitored by daily `log sheets'. In some prestigious buildings, periodic operation reports may be required.

Maintenance Costs. Results from our postal survey indicate that the annual maintenance costs in private sector is higher than that in government buildings. The average values as a ratio of refrigeration tonnage are respectively HK$ 301 per TR for private sector and HK$ 63 per TR for government buildings (£ 1 = HK$ 15). The reasons may be that they have hold different assumptions when estimating the maintenance costs. The government's maintenance team has not included all their resources used when arriving at the annual maintenance costs.

Profile of Electricity Use A typical year-round electricity consumption profile for a commercial building in Hong Kong is shown on Figure 7. One factor which cannot be easily taken into account of in the cost analysis is the maximum demand charge in the electricity bill. It was found out that the maximum demand charge may constitute over 10 % of the electrical energy cost for a commercial building in Hong Kong.

User comments

Valuable information was obtained from this exercise, particularly with regard to the operation and maintenance of Air-conditioning plants and heat rejection equipment. Comments were received largely from users of seawater cooling systems. The user comments are summarised in the followings :

Blockage of Seawater Piping and Equipment. Muds, refuse and barnacles cannot be screened effectively. Frequent cleaning and blowdown are required in order to prevent blockage.

'Un-maintainable' Seawater Pipeline Seawater pipelines buried under roads of busy traffic between seafronts and buildings are difficult to be maintained.

Growth of Marine Organisms and Foulings. Marine organisms' growth and fouling are found on condenser tubes, piping and heat exchanger surfaces. Regular inspection and cleaning are required.

Heavy Corrosion of Seawater Pump and Strainers. Casings of seawater pumps and seawater strainers are heavily corroded. Repairs and replacement are required frequently.

Defective Condenser Tubes. Leakage and blockage of condenser tubes are commonly found in all direct seawater cooling systems. Defective tubes are usually plugged and the efficiency of chiller performance is reduced.

Problems with Electro-chlorinators. Precipitation from chlorinators requires periodical chemical cleaning. However, in some systems the chlorinators installed have ceased functioning.

Energy Utilization of Buildings

Energy Utilization Index The building energy utilization index (BEUI) based on the ratio of annual electricity consumption to building area (gross floor area) was computed for five number of the buildings in our survey. The results lies between 150 to 200 kWh/sq.m/annum. However, no definite distinctive relationship can be found between the heat rejection method used and the building energy consumption. Separation of the energy consumption of heat rejection equipment from the total building energy use were not successful because energy consumption data supplied by most respondents was not in sufficient details.

Comparison with Other Countries Studies on building energy use have been carried out in Singapore [Ref. 14 & 15], Japan [Ref. 16 - 21] and other western countries [Ref. 22 & 23]. Attempt was made in our study to compare the building energy utilization index of these countries to those calculated from our pilot survey. The results of the comparison is summarised in Table 3. Buildings in our pilot survey are in general having higher energy utilization indice than those in other countries.

Implications

Large quantities of information are being collected at present by individual buildings but little attempt seems to be made to use them, either for performance comparison or for other management decisions. By collecting data from adequate number of sources, subsequent analysis and interpretation of it should be able to produce the information that individual respondents can use to assess the performance of their own buildings and their associated Air-conditioning plants.

PROSPECT

Seawater Cooling

Hong Kong Development in the 90's. The Port and Airport Development Strategy (PADS) Plan and the Metropolitan Plan announced by the H.K. Government have marked out a bold vision for building development on the territory of Hong Kong in the 90's and at the early 2000 [Ref. 1]. What it has implied to the H.K. Building Industry is that there will be plenty of redevelopment and reclamation on both sides of the Victoria Harbour.

Potential for Seawater Cooling. Existing seawater pumphouses have to be relocated and new pumphouses are to be built for the 'freshly' reclaimed land and new buildings. It is therefore the right time for us to review and reconsider the future of seawater cooling in Hong Kong. More development potentials are provided for using seawater for cooling but at the same time careful planning is required for obtaining the highest benefit and for satisfying the future needs of the society.

Comments. Many of the problems associated with seawater cooling systems, as reported from the respondents in our pilot survey, may be improved if careful strategic planning have been made at early stage. New pumphouse design, tactic selection of their location and seawater pipeline distribution can avoid unnecessary operational and maintenance problems [Ref. 24]. Better maintainability, reliability and correct choice of materials can also improve system efficiency.

Planning. In order to achieve the highest cost effectiveness from the community's point of view, planning should be considered and implemented at strategic level, local level and project level so that the future needs can be met with effectively. Learning of the operational experience from the large number of existing seawater cooling plants in Hong Kong will be a very good reference for design and maintenance engineers.

Air-cooled Systems

General Air-cooled systems (especially direct air-cooled using package chillers) will continue to be popular in small to medium size Air-conditioning plants because of their low first cost and compact equipment size. City fresh water or potable water in Hong Kong is generally prohibited to be used as make-up water for comfort Air-conditioning using evaporative cooling tower system [Ref. 25] (except for hospitals and government buildings). Therefore, for site locations that have great difficulties to gain access to the seafront, air-cooled systems may be the only possible option.

Noise Controls. With the implementation of the Noise Control Ordinance 1988 in Hong Kong [Ref. 26], the use of air-cooled systems is likely to face more restrictions than before because of the problem of excessive noise generation from air-cooled equipment. The effects on their system design may include :

- Location of air-cooled equipment have to considered more carefully.
- Increases in costs are expected for noise control measures.
- Maintenance difficulties are created if acoustic enclosure is installed [Ref. 27].
- System efficiency will be affected if air discharge is restricted [Ref. 28].

Energy Conservation

The energy-conscious people may well know that seawater cooling systems offer higher energy efficiency than air-cooled systems. This is one of the reasons for their popularity along both sides of the Victoria Harbour in Hong Kong [Ref. 24]. However, the generally poor seawater `quality' of the Victoria Harbour has imposed damaging factors to seawater systems and has affected their operational and energy efficiency.

Purely from the economic perspective, we can afford a lot of wastage in energy usage, but from the environmental perspective, no one can. With the rise in the need for energy conservation and environmental protection (the `Big weather'), consideration of energy efficiency of systems will become more and more important in the selection and evaluation of Air-conditioning systems.

RECOMMENDATIONS

It is recommended that in-depth survey and study be carried out on air-conditioned buildings in Hong Kong to collect and compile performance data of their Air-conditioning systems. A system should be set up to gather data on the operating and maintenance costs of Air-conditioning systems. Participating members would be prepared to provide information about their buildings according to a survey questionnaire prepared and distributed effectively, pay an annual fee for the analysis and interpretation service and in return have principal access to the results. The results of the analysis will be used to :

- Enhance the assessment of system performance
- Provide information for the design of new systems
- Ensure operation and maintenance of existing plants at maximum efficiency
- Allow building owners to realise the effectiveness and characteristics of their Air-conditioning systems and equipment

Experiences from other countries have shown that very useful performance guides and data can be formulated by collecting and interpreting survey results from a large number of buildings. For example, studies on building energy performance have been carried out in Japan regularly [Ref. 16 - 21] for quite a long time and the Society of Heating, Air-conditioning and Sanitary Engineers of Japan was the main body responsible for gathering these data. They have made detailed analysis on office buildings, hotels, hospitals and many other building types in their country.

CONCLUSION

The study reported here represents a vital first step towards establishing the strategy which determine the performance in `real world' buildings. This will enable the production of a database of performance data for Air-conditioning systems in Hong Kong.

Results from our pilot survey have demonstrated that direct seawater cooling system is commonly adopted despite that the system are suffering from many operational and maintenance problems. The survey has also suggested that the energy utilisation of office buildings in Hong Kong lies between 150 to 200 kWh/sq.m/annum. Further refinement is required in order to establish a representative figure.

There is a need to maintain and to learn from the past activities so that the next generation of Hong Kong's buildings in the 90's will incorporate some of the better system effectiveness and energy-conserving features.

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APPENDIX

Evaluation of Heat Rejection Methods (Illustrated Example)

22-Apr-90 PROJECT TITLE : Proposed Office Building (Example 1)

JOB : Life Cycle Cost Analysis for Heat Rejection Methods

DESIGNED BY :
SHEET NO. : 1 of 2

Description	< Sea Water Cooling >			< Air Cooled >	
	Direct Sea Water Cooling	Indirect Sea Water Cooling	Evaporative Cooling Tower	Direct Air-cooled Chiller	Indirect Air-cooled (Radiator)
1. CAPITAL COST	[All in HK Dollars; M = million]				
1.1 SYSTEM COSTS	2 x 1250 TR	2 x 1250 TR	2 x 1250 TR	8 x 320 TR	2 x 1250 TR
a) Equipment costs					
- chillers	8 M	6 M	6 M	3.2 M	6 M
- heat exchanger	---	2.5 M	---	---	---
- cooling tower	---	---	1.5 M	---	---
- radiator	---	---	---	---	2 M
- Pumps, pipes & auxil. :					
sea water	0.5 M	0.5 M	---	---	---
condensate water	---	0.2 M	0.2 M	---	0.2 M
make-up water	---	---	0.2 M	---	---
- cond. water treatment	1.5 M	1 M	1 M	---	---
Total Equipment Cost (EC)	10 M	10.2 M	8.9 M	3.2 M	8.2 M
b) Control system costs (assumed 30 % of EC)	3.0 M	3.1 M	2.7 M	1.0 M	2.5 M
c) Installation costs (assumed 50 % of EC)	5.0 M	5.1 M	4.5 M	1.6 M	4.1 M
TOTAL SYSTEM COSTS (SC) ==>	18.0 M	18.4 M	16.0 M	5.8 M	14.8 M
1.2 CIVIL COSTS					
- sea water intake cell & pumphouse (central sea front)	10 M	10 M	---	---	---
- sea water pipeline to the building (underground)	15 M	15 M	---	---	---
- make-up water supply plant costs	---	---	4 M	---	---
1.3 MISCELLANEOUS					
-					
TOTAL CAPITAL COSTS ==>	43.0 M	43.4 M	20.0 M	5.8 M	14.8 M

NOTES :

1. All other costs common to all the above systems are excluded. These costs include air system costs and chilled water system costs.

2. £ 1 = HK $ 15 (approx.)

22-Apr-90 PROJECT TITLE : Proposed Office Building (Example 1)

JOB : Life Cycle Cost Analysis for Heat Rejection Methods

DESIGNED BY :
SHEET NO. : 2 of 2

Description	Direct Sea Water Cooling	Indirect Sea Water Cooling	Evaporative Cooling Tower	Direct Air-cooled Chiller	Indirect Air-cooled (Radiator)
	< Sea Water Cooling >			< Air Cooled >	
2. ENERGY COST	[All the costs are in HK dollars; M = million]				
2.1 Power input (kW per TR)					
- chillers	0.7	0.88	0.88	1.25	1.1
- cooling tower	---	---	0.07	---	---
- radiator	---	---	---	---	0.2
- sea water pumps	0.09	0.09	---	---	---
- condensate water pumps	---	0.08	0.08	---	0.08
- make-up water pumps	---	---	0.02	---	---
Total Power Input (PI) (kW per TR)	0.79 kW/TR	1.05 kW/TR	1.05 kW/TR	1.25 kW/TR	1.38 kW/TR
Energy Input (kW) (= PI x 2500 TR)	1975 kW	2625 kW	2625 kW	3125 kW	3450 kW
2.2 Annual Energy Cost (AEC) ==> (assume : 270 days per year, 12 hours per day HK$ 0.56 per kWh)	3.58 M	4.76 M	4.76 M	5.67 M	6.26 M
3. ANNUAL MAINTENANCE COST (MC) => (assume 2 % of capital costs)	0.86 M	0.87 M	0.40 M	0.12 M	0.30 M
4. REPLACEMENT COST (RC) ==>	---	---	1.5 M	---	---
RESULTS :--					
TOTAL CAPITAL COSTS	43 M	43.4 M	20.0 M	5.8 M	14.8 M
PRESENT WORTH ENERGY COST	59.4 M	79.0 M	79.0 M	94.1 M	103.9 M
PRESENT WORTH MAINTENANCE COST	14.3 M	14.4 M	6.6 M	1.9 M	4.9 M
PRESENT WORTH REPLACEMENT COST	---	---	1.5 M	---	---
{ TOTAL PRESENT WORTH COST }	116.7 M	136.8 M	107.1 M	101.8 M	123.6 M

NOTES :

1. All other costs common to all the above systems are excluded. These costs include air system costs and chilled water system costs.

2. Present Worth Cost = Annual cost x PWF

$$\text{PWF} = \text{present worth factor} = \frac{((1+i)/(1+r))^n - 1}{1 - (1+r)/(1+i)}$$

where i = inflation rate (assumed 8 %)
r = interest rate (assumed 10 %)
n = equipment life (assumed 20 years)

3. £ 1 = HK $ 15 (approx.)

22-Apr-90 PROJECT TITLE : Proposed Office Building (Example 2)

JOB : Comparison of Heat Rejection Methods Using Merit Function Ranking

DESIGNED BY :

SHEET NO. : 1 of 1

				< FUNCTION >				< COST >			
Heat Rejection Methods	Site Condit.	Equip. Space	Arch. Req'	Ease of Install.	Ease of Maint.	Noise	Flexi-bility	First Cost	LCC Cost	Energy Effic.	TOTAL SCORE
Weighting Factor :	10	8	5	2	5	5	3	5	10	5	
1. Direct seawater cooling (DSC)	Good	Poor	Good	Poor	Very Poor	Very Good	Poor	High	High	Very Good	
	6	2	6	2	0	10	2	2	2	10	
>> Scores =	60	16	30	4	0	50	6	10	20	50	246 (2nd)
2. Indirect seawater cooling (ISC)	Good	Very Poor	Good	Poor	Fair	Very Good	Good	High	Very High	Very Good	
	6	0	6	2	4	10	6	2	0	10	
>> Scores =	60	0	30	4	20	50	18	10	0	50	242 (3rd)
3. Direct air-cooled (DAC)	Fair	Good	Very Poor	Good	Good	Poor	Poor	Lowest	Very Low	Poor	
	4	6	0	6	6	2	2	10	8	2	
>> Scores =	40	48	0	12	30	10	6	50	80	10	286 (*1st)
4. Indirect air-cooled (IAC)	Fair	Fair	Poor	Fair	Fair	Good	Fair	Very Low	Averg	Very Poor	
	4	4	2	4	4	6	4	8	4	0	
>> Scores =	40	32	10	8	20	30	12	40	40	0	232
5. Evaporative cooling using cooling tower (ECT)	Poor	Fair	Poor	Fair	Fair	Fair	Fair	Averg	Low	Good	
	2	4	2	4	4	4	4	4	6	6	
>> Scores =	20	32	10	8	20	20	12	20	60	30	232

Numerical weighting to the table above :

Function :-			Cost :-		
Excell.	=	10	Lowest	=	10
Very Good	=	8	Very Low	=	8
Good	=	6	Low	=	6
Fair	=	4	Averg	=	4
Poor	=	2	High	=	2
Very Poor	=	0	Very High	=	0

NOTES :

1. The weighting factors in above can be varied according to the requirements specified by the Client.
2. The weighting on each parametric factor can also be varied according to the respective requirements and perference.

TABLE 1 - First Stage of Survey

Location	DSC	ISC	Number of buildings DAC	IAC	ECT	Total	Average (sq.m/TR)
Central	6	4	3	1	2	16	22.8
Wanchai	2	4	6	1	-	13	20.6
Queensway	-	2	1	2	-	5	20.0
Causeway Bay	2	-	4	-	1	7	23.9
Sheung Wan	2	-	-	-	-	2	26.5
Tsimshatsui	4	2	2	-	-	8	19.9
Total (Percent)	16 (31%)	12 (24%)	16 (31%)	4 (8%)	3 (6%)	51 (100%)	23.6
Total surveyed:	G.F.A. = 2,806,500 sq.m		Refrig. Tonnage = 119,500 TR				

TABLE 2 - General Description of Postal Survey

Total questionnaire posted = 35 (100%)
Total replies received = 10 (29%)
Total number of buildings = 16 nos.

Location	Private Bldgs.	Government Bldgs.
Central	4(A,B,C,D)	1(K)
Wanchai	1(F)	1(O)
Queensway	1(I)	2(L,M)
Sheung Wan	1(E)	2(J.P)
Western	--	1(N)
Tsimshatsui	1(H)	--
Mongkok	1(G)	--
Total	9(A to I)	7(J to P)

Note : For the sake of confidentiality, the sources of the information in the postal survey must remain anonymous and the names of building are represented by capital letters from A to P.

TABLE 3 - Comparison of building energy utilization index (office buildings)

Other Countries :-

Singapore	=	145	kWh/sq.m/annum [Ref. 14 & 15]
Japan	=	157	kWh/sq.m/annum [Ref. 16 - 21]
New Zealand	=	170	kWh/sq.m/annum [Ref. 23]

Hong Kong :- (Data calculated from pilot survey)

Building B	=	182	kWh/sq.m/annum (DSC)
Building C	=	164	kWh/sq.m/annum (DSC)
Building F	=	157	kWh/sq.m/annum (DSC)
Building G	=	191	kWh/sq.m/annum (DAC)
Building H	=	196	kWh/sq.m/annum (DSC)
Average	=	178	kWh/sq.m/annum

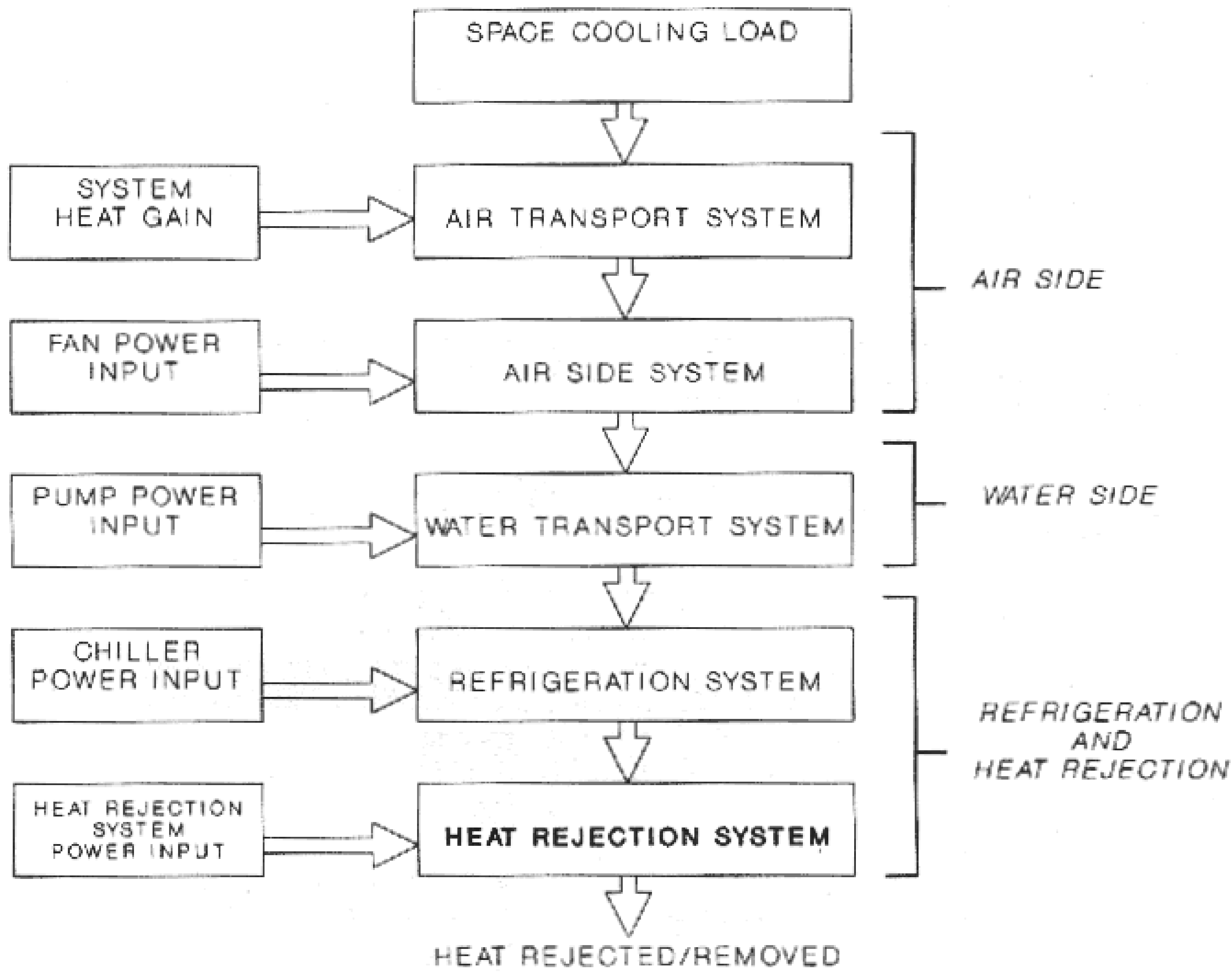


Figure 1 - Heat Removal Process (Cooling System Architecture)

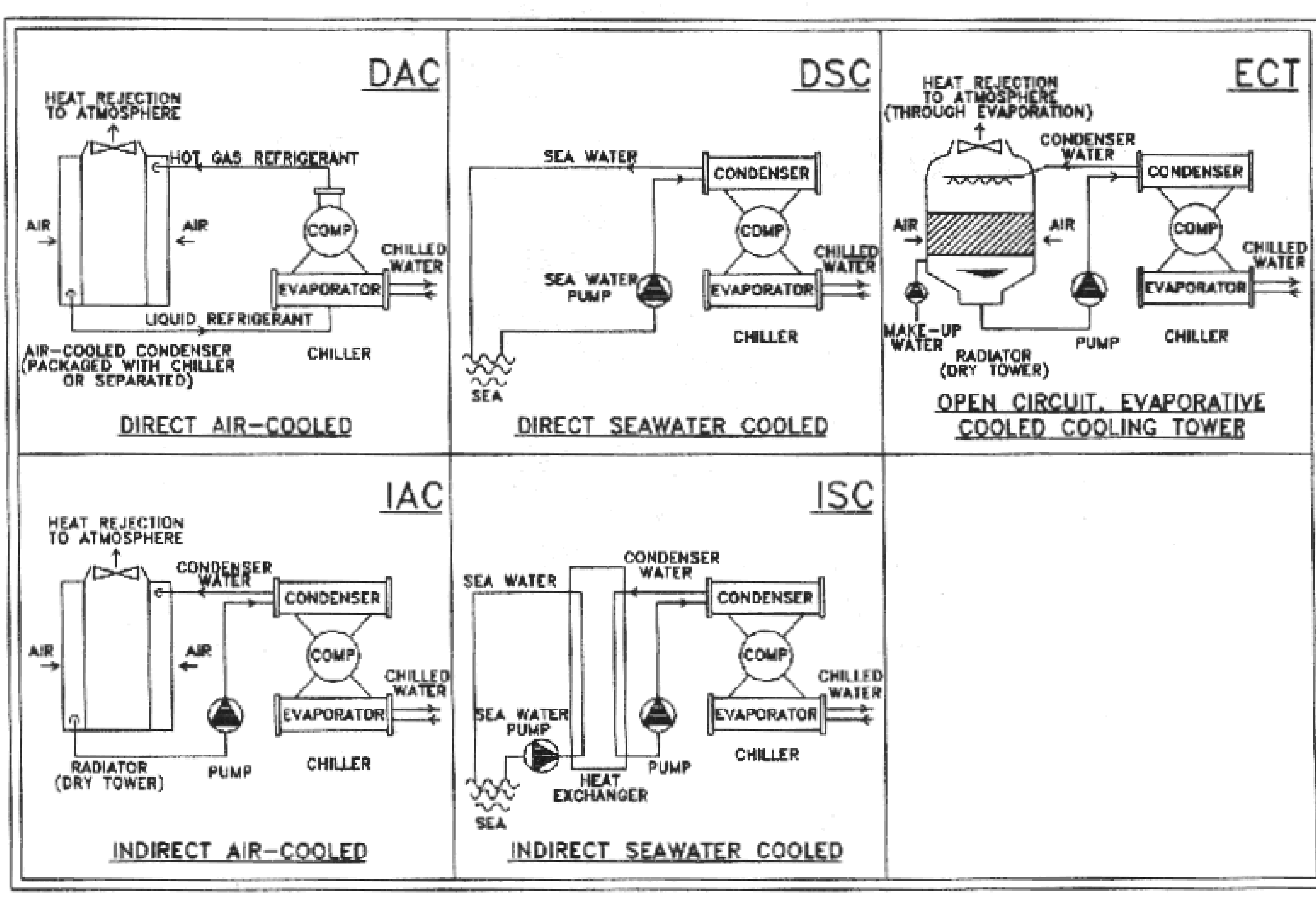


Figure 2 - Heat Rejection Methods for Air Conditioning Systems

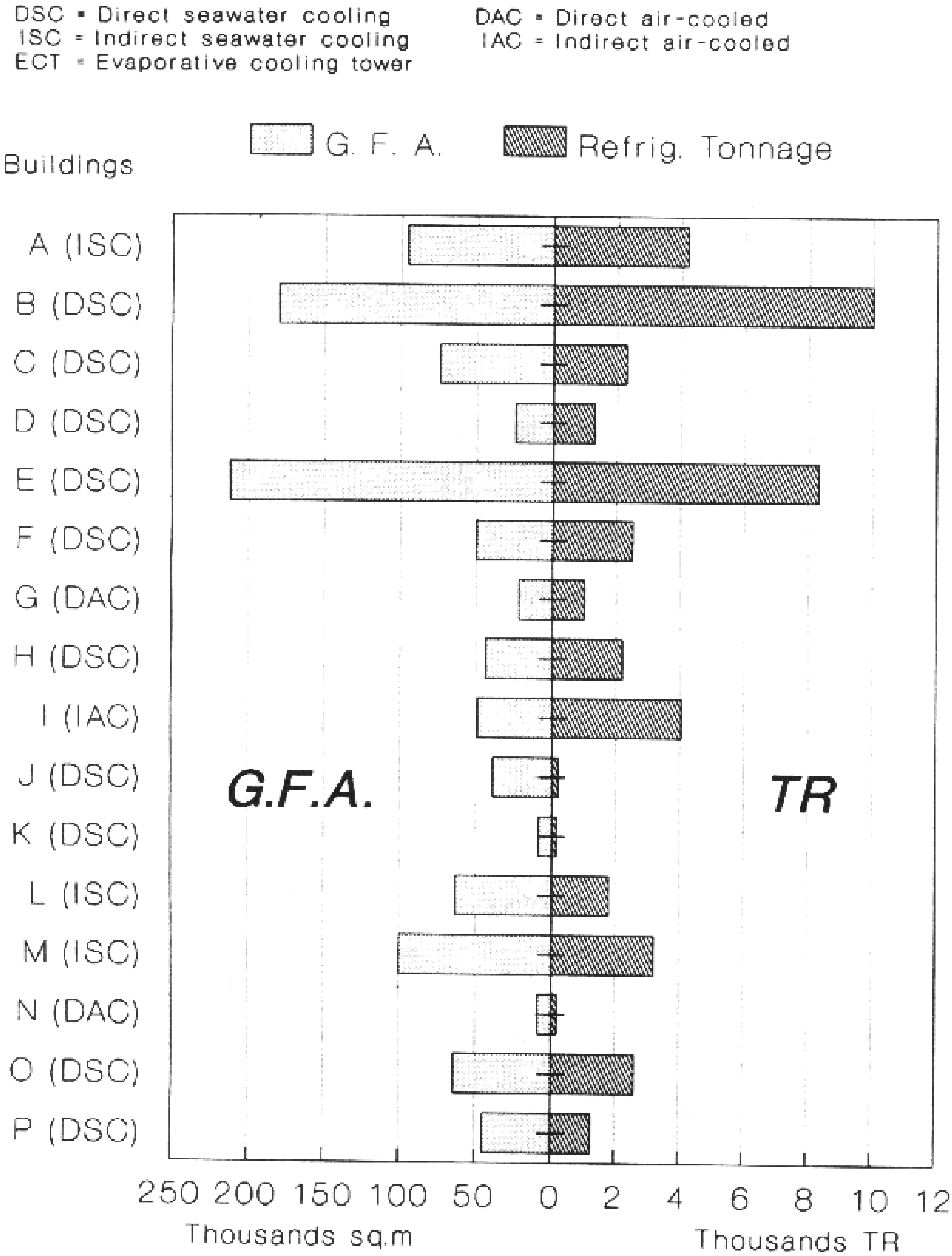


Figure 3 - Range of Buildings in Postal Survey

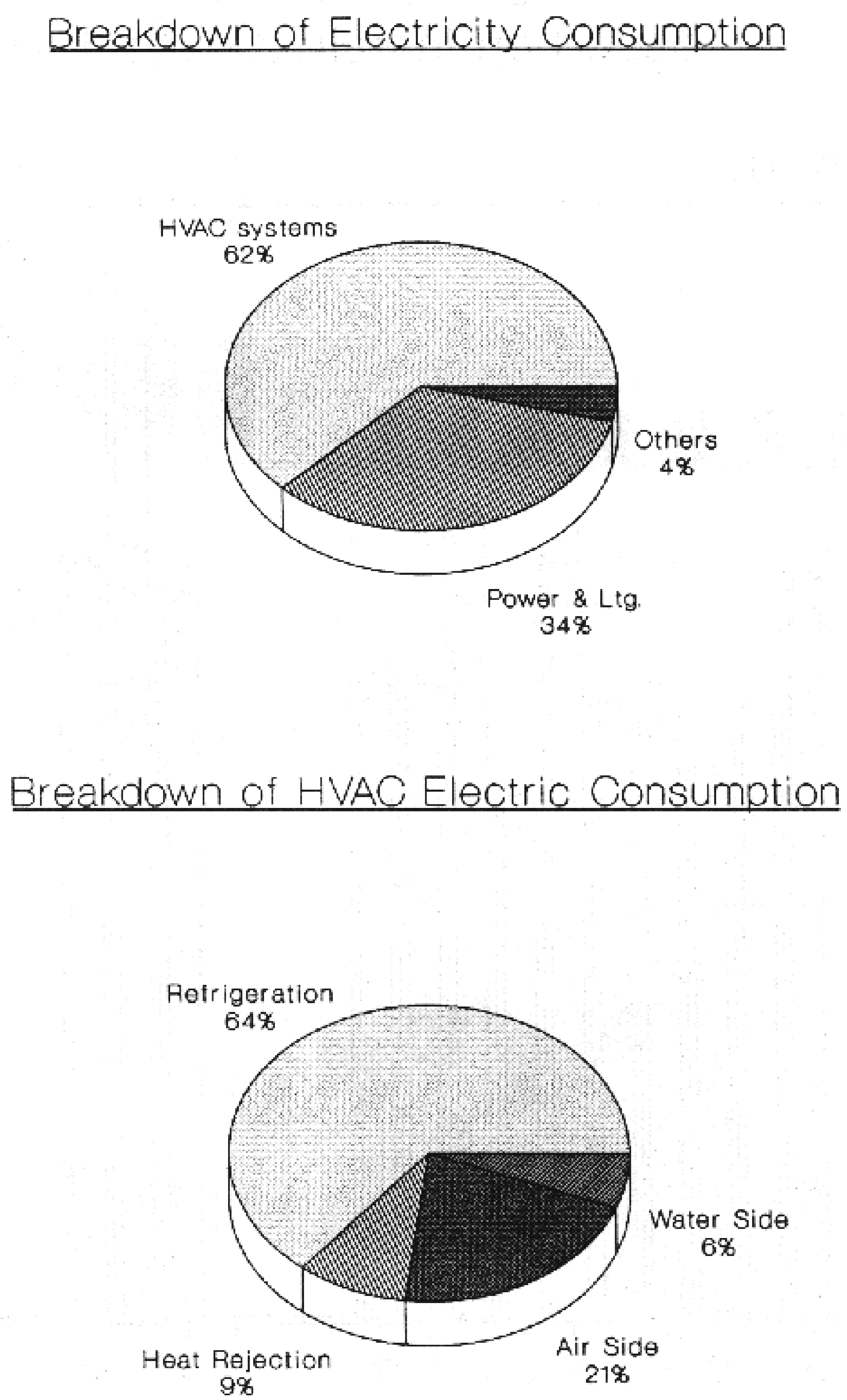


Figure 4 - Breakdown of Electrical Energy Consumption

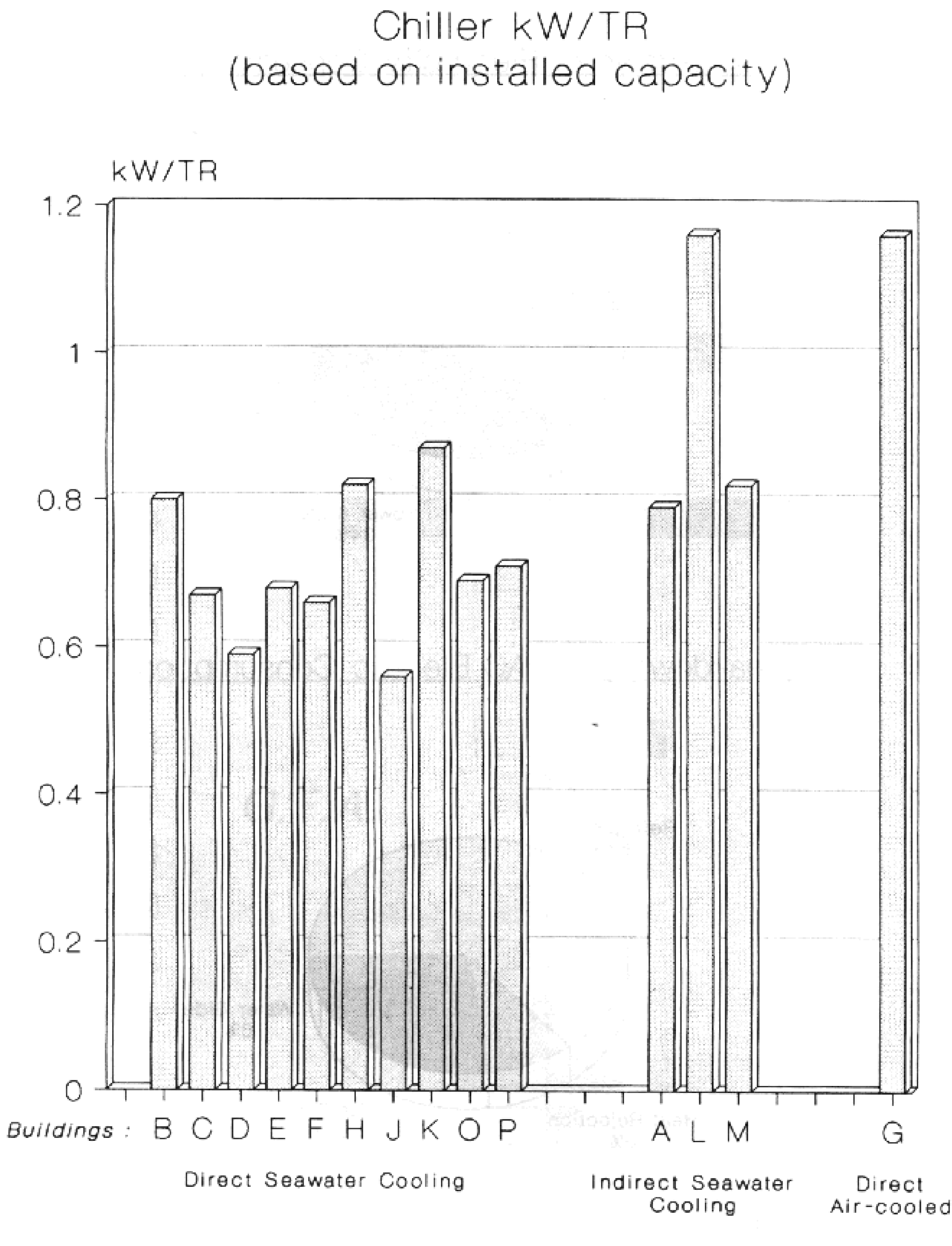
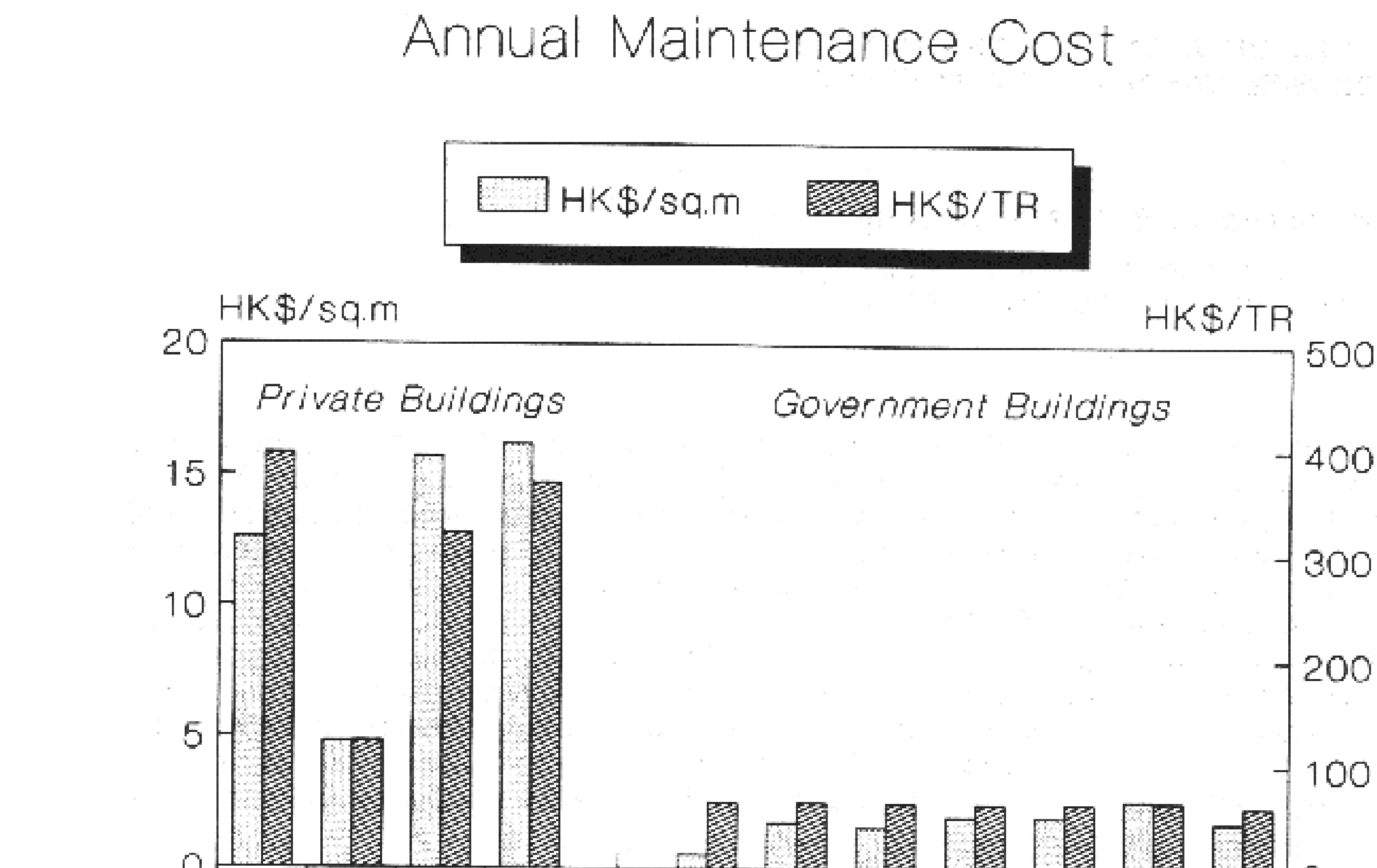


Figure 5 - Ratio of Chiller Input Power to Refrigeration Tonnage (kW/TR)



	C	E	F	G		J	K	L	M	N	O	P
HK$/sq.m	12.6	4.8	15.7	16.2		0.55	1.75	1.6	2	2	2.65	1.81
HK$/TR	395	121	320	368		63	63.6	63.2	62.7	63.2	65.2	60.7

Buildings

Figure 6 - Comparison of Maintenance Costs

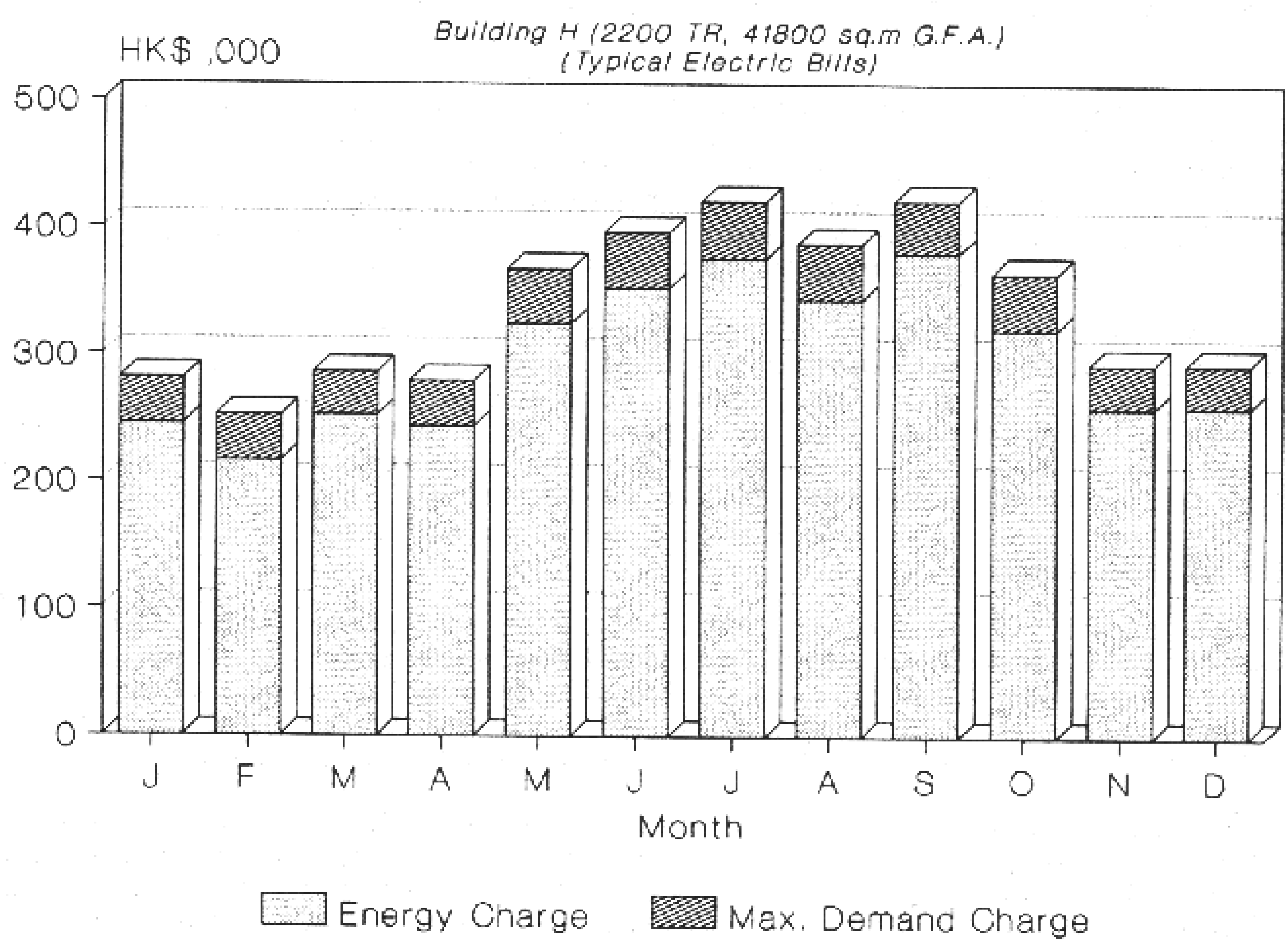


Figure 7 - Profile of Electricity Consumption