GUIDELINES FOR THE DEVELOPMENT OF COMPREHENSIVE MARKETING POLICIES FOR MUNICIPAL ELECTRICITY UNDERTAKINGS, WITH PARTICULAR EMPHASIS ON LOAD MANAGEMENT

BY

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GUIDELINES FOR THE DEVELOPMENT OF COMPREHENSIVE MARKETING MANAGEMENT POLICIES FOR MUNICIPAL ELECTRICITY UNDERTAKINGS

Abstract

It is expected that South Africa will have to construct as much generating capacity in the next five years as has been constructed over the past 50 years. Industrialization and urbanization dictates that the larger portion of this increase will be required in the supply areas under the control of Municipal Electricity Undertakings, which means that these undertakings will have to anticipate rapid growth in their infrastructures. This will put a tremendous strain on their resources of revenue, materials and labour, and it is obvious that comprehensive and co-ordinated policies are required to be developed to enable these undertakings to deliver the electrical energy to the final consumers at the lowest possible cost.

The Electricity Undertaking is a business organization with unusually difficult managerial problems in all its functional areas. Its personnel are adversely affected by the vast area of supply and by the resulting difficulty of direct supervision and control. The capital cost of electrical equipment is high, and there may be a tendency to reduce the initial cost by ignoring the long term costs associated with the selection of equipment. Electricity pricing is very difficult, as electricity is not a uniform product. The consumption patterns of the consumers causes severe peaking of loads to occur, resulting in very low utilization of the capital equipment involved, and which can threaten to overload existing networks. These problems are compounded by the fact that the undertaking is a monopoly and as such is not driven by the free-market motivating forces, such as a profit motive and the constant need to improve to meet competition. There is thus no motive to seek optimum solutions to the many problems.

It is shown that the Load Factor is an indication of the efficient use of scarce resources, and that it is similar to measurements of profitability, such as Return-on-Investment, etc. It is therefore possible to replace the missing drive for profit and product improvement by the need to constantly improve the load factor. By making this the main objective of the undertaking many of the stated problems are put in their correct perspective. Maintenance becomes important, as power failures adversely affect the load factor. More care is exercised in equipment selection, as long term energy losses are taken into account. Electricity pricing and its effect on consumer consumption patterns becomes important. The concerted effort to improve the load factor is referred to as load management.

Due to the tremendous increase in electricity consumption which is expected over the next decade it is certain that load management will play an ever increasing role. Load Management is defined as the sustained attempt at modifying the load curve. Soft load management refers to pricing policies and incentive schemes designed to induce users to shift their loads out of the peak periods. Hard load management physically switches customer loads.

This thesis examines the results obtainable from various methods of load management including off-peak incentive tariffs, on-peak-reduction rebates, the use of current limiters, peak load reduction by means of voltage reduction and remote control of water heater cylinders.

It is shown that whereas Sasolburg saves around R750 000.00 p.a. and Randburg saves over R1,5-million p.a., other towns such as Pretoria and Pietermaritzburg find their geyser control systems ineffective, and are phasing them out. It has hitherto not been possible to determine the actual savings which would result from the installation of a geyser control system, or to determine the optimum number of controlled geysers.

The result was that some undertakings would install a control system at considerable expense which resulted in minimal savings, while other towns forego the opportunity to save hundreds of thousands of rands in reduced demand charges.

In this thesis, the author develops a feasibility study model which permits the system load curve to be analysed and the viability of a geyser control system to be determined. The model was tested against the controlled and uncontrolled load curves of Somerset West, and was found to be accurate. It was shown that a geyser control scheme is a very viable proposition for those undertakings where the feasibility study shows a contribution of more than 0,5 KVA per geyser towards peak load reduction.

This forms the basic guideline for the selection of an appropriate form of load mangement, and guidelines are presented to develop supporting policies in all fields of the undertakings' functions.

In order to facilitate correct decision-making and to assist in the development of comprehensive policies, a database of concepts and models is presented in the various fields and various misconceptions are dicussed.

The guidelines have been applied by several electricity undertakings. By using the Feasibility Study Model it was shown that the proposed installation of 4000 geyser control units at Oudtshoorn, at a cost of over R1-million, was not viable. The Feasibility Study Model permits the savings to be calculated for different numbers of geysers and it was shown that the system saturates at about 1500 controlled geysers. By reducing the number of controlled geysers to around 1500 the installation cost will be reduced by about R500 000.00 and the system will show a net operating savings of R105 540.00 in the first year, increasing as ESCOM increases its tariffs.

The application of these principles conceivably prevented the needless expenditure of R1-million on a system that would have run at an operating loss of over R17 000.00 p.a.

The feasibility study model was applied to the Stanger load curve to determine the correct selection of load management. The results indicate excellent response to geyser control, and showed that a system controlling 2500 geysers, costing R498 500.00 would show a gross savings of R297 000.00 in the first year, rising to R510 000.00 within 5 years if ESCOM increases its tariff by 10% p.a. Based on these results and recommendations the Department of Finance gave ad hoc approval to the Borough of Stanger for the additional expenditure in the current financial year to install the control equipment.

The guidelines indicated a similar result for Tongaat, where the gross savings would be R360 000.00 in the first year, increasing to R637 680.00 within 5 years if ESCOM increases its tariff by 10% p.a. The estimated cost of the control equipment is R493 649.00.

In complete contrast, the feasibility studies for geyser control undertaken on the Ballito load curve showed a contribution of less than 0,5 KVA per geyser, which indicated that the alternative forms of load management should be implemented.

The results are contained in the case studies.

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GUIDELINES FOR THE DEVELOPMENT OF COMPREHENSIVE MARKETING POLICIES FOR MUNICIPAL ELECTRICITY UNDERTAKINGS.

CHAPTER 1

PROBLEM STATEMENT AND RESEARCH METHODOLOGY

1.1 INTRODUCTION [1]

Over the past 50 years the consumption of electricity in South Africa has doubled on average every eight years and has exceeded the growth in the country's total net energy consumption. This growth rate is expected to continue as South Africa's various population groups become more economically active and as electricity replaces more expensive energy sources. In 1961 electricity accounted for 11% of total energy consumption. This had increased to 23% by 1981 and is expected to exceed 40% of the total within the next 15 years.

Present indications are that South Africa will need about 35000 MW of installed generating capacity by 1990 (nearly double the present capacity) and about 70 000 MW by the year 2000. The expected growth over the next 20 years involves a massive expansion programme during which some 20 base-load power-stations (the size of the huge Duvha or Matla power-stations) as well as some five peaking stations, will have to be built by ESCOM at an estimated present day cost of R65 000 000 000.00 (Sixty five thousand million rand).

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1. Information contained in this introduction was obtained from the following:
- Electricity Supply Commission Annual Report 1981 pages 8-13
- ESCOM in Brief (1981 pamphlet)
- Future Electricity Demand and Supply in South Africa - H.B. Norman. Supplement to Municipal Engineer - Sept/Oct 1982 pages 5-11

Municipal electricity undertakings account for some 30% of the total power requirements, and it is expected that urbanization and industrialization will increase this share.

An aspect of these developments which has received little if any attention is the impact this growth is going to have on the municipal electricity undertakings. Their infrastructures will have to be augmented to a considerable degree in order to deliver the electricity to the final consumers. This will require very large financial investments over the next 15 to 20 years.

For various social and technical reasons domestic loads peak at certain periods, and these peaks are increasing rapidly as more labour-saving appliances are introduced.

It is becoming increasingly important for Municipal Electricity Undertakings to set clear policies regarding such matters as load management, capital formation, and supply reliability.

The electricity tariff, to a large degree, represents in financial terms the sum total of all the policies of the electricity department and reflects its efficient use of the scarce resources at its disposal.

1.2 STATEMENT OF THE PROBLEM

Municipal Electricity Undertakings fulfil a vital role in providing a basic energy source to large numbers of consumers, ranging from private home owners to large industrial concerns. The use to which the electricity is put, and the benefit derived therefrom, differs from consumer to consumer, and the need and usefulness of this energy varies as to the time of day, the seasons, and other variables, which suggests that the commodity warrants sophisticated pricing policies.

In addition, the power demands on the electrical infrastructure continually change, increasing as population densities increase, and peak increasingly at certain times as urban lifestyles become more uniform. These changes require early detection and evaluation as improvements to electrical systems require long lead times. Such increases frequently outdate existing electrical reticulation circuits, causing them to be scrapped prematurely, often long before their capital loans have been repaid. The financial implications of consecutive inadequate updating can create an unnecessary burden for the Undertaking. The manner in which the proposals for new capital projects are presented is also somewhat unique, since the Undertaking forms part of the Local Authority, and has to conform to certain statutory requirements. Of increasing interest and concern is the matter of the new political dispensation, and of the effects that the proposed changes will have on local authorities and more importantly, on the electricity undertaking.

Labour relations, and more pertinently, the ability to develop and lead a team of dedicated and reliable key personnel, and to then create such an organizational environment so as to reduce staff turnover to an absolute minimum, is also very important, since a great deal of very important information is built up in the minds of these people over time; for example, the actual position of underground cables throughout the area, the exact position of the underground joints, which sections of overhead lines are more susceptible to storm damage, the exact position of each consumer substation, main switch and electricity meter, etc. The speed with which system faults can be located and cleared, and power restored to the affected consumers will clearly be much better in an Undertaking in which the electricians and their supervisors have the locality knowledge that can only be gained over time.

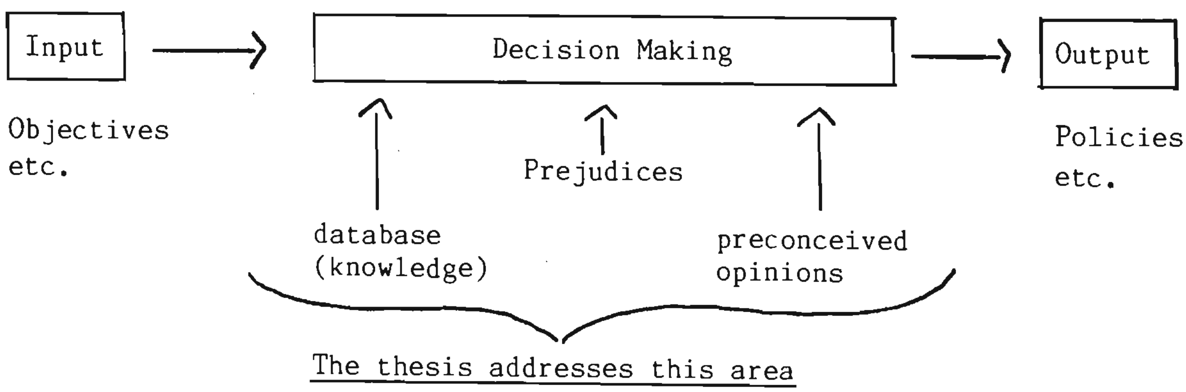
It is evident that, even with only a superficial view of the electricity undertaking, there are heavy demands on the Head of the Department, and to fulfil his role adequately, he needs to be able to set clear policies for his Department, provide technical expertise, advise on the tariff structures, investigate load trends, plan improvements, motivate his staff, prepare financial estimates and take ultimate responsibility for the safety of the consumers in terms of the Factories, Machinery & Building Work Act of 1941, as the Responsible Person.

It is also becoming increasingly necessary to control the shape of the load curve in order to improve the utilization of the very expensive equipment involved in the supply of electricity.

The majority of Town Electrical Engineers are drawn from Industry, and initially have little, if any, knowledge of the wider aspects of their role.

The author has been intimately involved in the activities of a number of municipal electricity undertakings, including Melmoth, Pongola, Port Shepstone, Mooi River, Underberg, Tongaat, Stanger, Ballito, Kokstad, and to a lesser extent Howick, Eshowe, Greytown and several others. The problems handled ranged from fatal accident inquiries, tariff structure design, departmental staffing, and the planning and execution of projects totalling several million rands. As a result of this first hand knowledge gained by direct involvement with these undertakings the author identified several fundamental areas in common with all the undertakings, in which their lack of correct information, prejudice and incorrect preconceived opinions was adversely influencing decision making.

The effect that an insufficient database and incorrect opinions and prejudices have on the resulting policy formulation can be illustrated as follows :



There is therefore a distinct need to clarify many issues in this field. This thesis sets out to correct several misconceptions on various issues, to widen the relevant database and to create guidelines for the development of comprehensive marketing policies for Electrical Undertakings. This could reduce the learning period and prevent needless and costly repetitions of sub-optimum tariff structures and management systems.

1.3 THE MARKETING CONCEPT AND ITS APPLICATION TO LOCAL GOVERNMENT

Kotler [2.] defines Marketing as "a human activity directed at satisfying needs and wants through exchange processes." He further defines the Societal Marketing Concept [3.] as "a management orientation that holds that the key task of the organization is to determine the needs and wants of target markets and to adapt the organization to delivering the desired satisfactions more effectively and efficiently than its competitors in a way that preserves or enhances the consumers' and society's well being."

Professor J.A. Lombard [4.] points out that "Local Authorities are extensions of the market mechanism. Their very existence stems from the need people have for goods and services which for one reason and another cannot be supplied through private demand and supply. Local authorities are to a much lesser extent extensions of the sovereign central organs of the State which are concerned with the maintenance of the general order of the state and related matters. For this reason it is also logical that as far as possible, public service should be decentralised to the local authorities, if these functions cannot be completely decentralised to private enterprise. It is therefore logical that the local authorities should use their powers like economic entrepreneurs and not like political strategists."

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2. KOTLER, Philip, Marketing Management, Fourth Edition, p.18.
3. KOTLER, Ibid, p. 35.
4. LOMBARD, Professor J.A., "Correct, Efficient and Effective Spending by Local Authorities in a changing South Africa", The Institute of Municipal Treasurers and Accountants, S.A. 1978, p. 102

It is thus reasonable to then accept that Local Authorities, and their trading undertakings in particular, fall well inside the Marketing Concept as stated by Kotler, and hence many of the principles of Comprehensive Marketing Management will apply to the Municipal Electrical Undertaking.

1.4 COMPREHENSIVE MARKETING MANAGEMENT DEFINED

According to Kotler[5.] "Marketing Management is the analysis, planning, implementation, and control of programmes designed to create, build, and maintain mutually beneficial exchanges and relationships with target markets for the purpose of achieving organizational objectives. It relies on a disciplined analysis of the needs, wants, perceptions, and preferences of target and intermediary markets as the basis for effective product design, pricing, communication and distribution."

Somewhat closely related to Marketing Management is Strategic Management, which is defined by Schendel and Hatten[6.] "as the process of determining and maintaining the relationship of the organization to its environment expressed through the use of selected objectives and of attempting to achieve the desired status of relationships through resource allocations which allow efficient and effective action programmes by the organization and its subparts."

The principal difference between these definitions, in the context of this thesis, is Kotlers' "mutually beneficial exchanges and relationships with target markets," and Schendel's "maintaining the relationship of the organization to its environment." This is largely a choice of words, rather than a difference of meaning, since in the one case employees

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5. KOTLER, Ibid, p. 22.

6. As quoted by STEINER, G.A., and MINER, J.B., Management Policy and Strategy, 1977, p.7.

form part of the Labour Market, whereas in the second case these employees form part of the Organizational Environment.

Kotler reconciles any differences in terminology by defining an organization's performance in the market place as a matter of the degree of alignment between the organization's environmental opportunities, objectives, marketing strategy, organizational structure, and management systems.[7] In the ideal case we have

Environment - Objectives - Strategy - Structure - Systems

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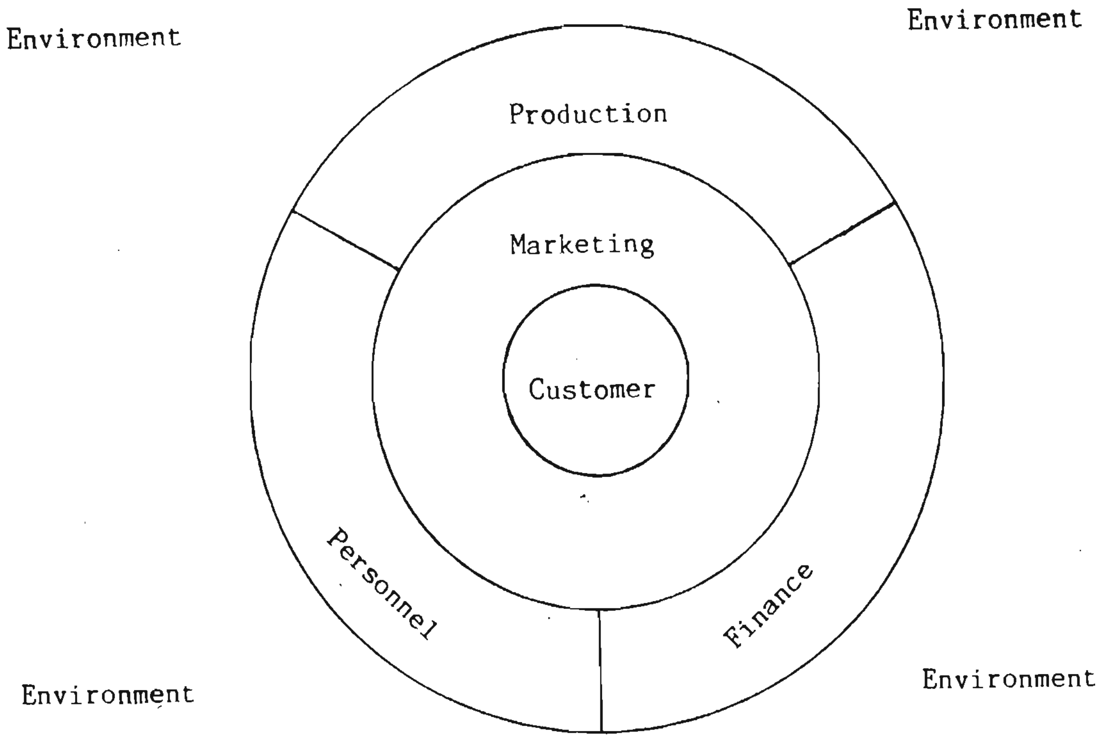
7. KOTLER, Ibid, p. 96.

1.5 PLAN OF THIS THESIS

The plan of this work is based on the conceptual model of an organization in its environment as seen by Kotler.[8.]



MODEL OF AN ORGANIZATION IN ITS ENVIRONMENT

FIGURE 1.1

This is a customer orientated model in which all functions work together to sense, serve, and satisfy the customer. Marketing needs to command a central position to ensure that the customers' needs are correctly interpreted and efficiently satisfied.

The "production" function in the above model will in this case represent the electricity reticulation networks which are installed and maintained for the efficient distribution

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8. KOTLER, Ibid, p. 10.

of electricity.

This thesis will then examine various policies in the following fields :

a) Customers - The customers of the Undertaking, market segmentation, consumer behaviour and load management, and load forecasting. (Chapter 2)

b) Finance - Financial matters affecting the Undertaking, the development of tariffs, welfare economic foundations, theory of peak load pricing and practical tariff determination. (Chapters 3 and 4)

c) Production - The "production" of efficient and easily managed reticulation networks, methods of establishing secure supplies, and financial comparisons of different systems. (Chapter 5)

d) Personnel - The personnel making up the staff of the Undertaking, the need for setting objectives, motivation and control. (Chapter 6)

e) Environment - The environment in which the Electricity Undertaking operates, the decision making processes, and the anticipated environmental changes. (Chapter 7)

The objective of this thesis is to indicate how the cost of electricity to consumers can be influenced by the policies set by the Electricity Undertaking, and how the resultant electricity tariff is, to a large degree, determined by the policies adopted. A summary and recommendations is presented in Chapter 8.

1.6 LITERATURE SURVEY, INFORMATION SOURCES AND RESEARCH METHODOLOGY.

The above discussion showed that the electrical undertaking can be thought of as a total organization comprising the following parts : Environment, Customers, Finance, Personnel and Production. Supplier/s. ?

Representing each of these parts are groups of people, dedicated to identifying and solving problems in their fields.

Wherever possible, this author has attempted to use the perception of these workers by quoting from their papers and making reference to their conclusions.

In the fields of local government environment, and finance as it pertains to South African towns, reference is made to several papers presented to the Institute of Town Treasurers and Accountants. In the technical fields of customers, production and distribution, and load management, work done in the United States of America and England is used, as it is considered that technical aspects will not be influenced unduly by locality.

In the field of electricity tariffs, there is extensive literature representing varying opinions on the relative importance to be attached to short run and long run marginal costs in the determination of price, and these are critically examined with indications as to how they may be suitable for practical application in the design of electricity tariffs.

Various load management techniques are examined and the effectiveness of load control by voltage reduction, and by current limiters, was experimentally determined for Stanger and Tongaat. The intention here is not to solve specific problems of these towns, but rather to indicate by the way of guidelines how these problems can be resolved.

All the above results and conclusions are presented in a total framework to form the guidelines for the development of comprehensive marketing management policies for Electricity Undertakings.

DEFINITIONS

Some of the more frequently used terms and words are defined below. The electricity utility industry has a complex technological background, and it is inevitable that terms and expressions will be used that are not necessarily familiar to the reader. The wording used in the definitions is intended essentially to provide an understanding of the text which may at times result in a loss of scientific precision or accuracy. The definitions used here are adapted from the set used by G.F.K. Herrmann[9.] which was derived from the following sources: The Association of Edison Illuminating Companies Load Research Committee, British Standards Institute, Edison Electric Institute Statistical Committee and the Federal Power Commission.

Ampere (Amp or A) : The unit of measurement of electric current, analogous to volume of water flow. It may for convenience be defined as the current produced by one volt acting through a resistance of one ohm.

British Termal Unit (B.th.U. or BTU) : The amount of heat required to raise the temperature of 1 lb. of water through 1° F, used to express the latent heating value of fuel, and consequently used in fuel adjustment clauses in tariffs. 1 BTU = 0,252 kcal = 0,293 watt-hour.

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9. Herrmann, G.F.K., "Electricity Tariffs : The principles underlying their design and structure with some reference to conditions in South Africa." pages 1.1 - 1.3.

Capacity : The rated output of equipment or plant expressed in kW or kVA.

Capacity Costs or capacity Related Costs : Those costs that depend primarily on the capacity of the equipment required to meet the "demand".

Coincidence Factor : The ratio of the total maximum demand (Ps) of a group, class or system as a whole, to the sum of the individual maximum demands (Σ Pi) of the several components of the group, class or system. As defined, coincidence factor is always less than unity. Coincidence Factor : $\frac{Ps}{\Sigma Pi}$

Consumer Class : A sub-division of a utility's electricity consumers according to the similarity of their consumption patterns. A typical classification is into 'domestic', 'commercial' and 'industrial' consumers.

Consumer Group : A number of consumers of the same consumer Class.

"Demand" : is shown in inverted commas to indicate the engineering sense of the term where there may be doubt as to the meaning intended. It is the average rate at which energy is delivered (i.e. the rate of consumption) during a specified continuous interval of time, such as 15, 30 or 60 minutes. It may be expressed in kW or kVA, or other suitable units.

Demand Charge : usual abbreviation for Maximum Demand Charge.

Demand Integration Period : The duration of successive equal intervals of time (such as 15, 30 or 60 minutes) during which the "demand" is averaged by integration for the purposes of determining the maximum demand.

Demand Related Tariffs : Tariffs in which some or all of the charge is determined by the consumer's maximum "demand" or (generally confined to smaller consumers) by installed plant capacity.

Diversity Factor : The reciprocal of coincidence factor, and hence always greater than unity. Diversity factor $= \frac{\Sigma Pi}{Ps}$ (cf. coincidence factor)

Kilocalories : (kcal) The amount of heat required to raise the temperature of 1000 g of water through 1°C. Used in the metric system, as BTU is in the f.p.s. system, to express the heating value of fuel and used in fuel adjustment clauses.

Kilovolt-Ampere (kVA) : Certain types of electrical circuits and apparatus have a characteristic which causes them to take additional current with no increase in the amount of usable energy supplied. The unit of this "apparent" electric power is in the kVA.

Kilowatt (kW) : Equals 1000 watts. The watt is the unit of electric power and corresponds in principle to the term 'horsepower' (1 HP = 746 watts or 0,746 kW).

Kilowatt-hour (kWh) : This is the unit of electrical energy or consumption, and is the product of power or "demand" in kW and time in hours.

Load : The amount of power delivered or received at a given point at any instant. It may be applied to a generating plant, a transmission or distribution system, a whole power system, or a consumer's requirements. Note the distinction between load and "demand" although the terms are often used interchangeably.

Load Factor : The ratio of the number of kWh supplied during a given period to the number of kWh that would have been supplied, had the maximum "demand" been maintained throughout that period : usually expressed as a percentage. The load factor is usually related to monthly or annual periods, but may also be related to daily or weekly periods, and may apply to a system, a consumer group, an individual consumer or an appliance. In many European countries it is expressed in hours of use (of the maximum demand) per annum i.e. $\frac{\text{Annual consumption in kWh}}{\text{Annual maximum demand in kW}}$; since there are 8760 hours per annum, the percentage load factor may be obtained from the hours of use : Load factor in percent = $\frac{\text{hours of use per annum}}{8760} \times 100$.

Maximum Demand (MD) : The highest indicted "demand" during a metering period, usually expressed in kW or kVA, but may also be expressed in terms of current (amps), particularly when thermal type demand meters are used.

Megawatt (MW) : 1 000 000 watts. Frequently used as a unit for expressing the capacity of generating plant.

Power : The rate of consumption or the rate of doing work, and usually expressed in kW. Often used interchangeably with "demand" and load.

Power Factor (also referred to as Cos ϕ) : The ratio of $\frac{kW}{kVA}$ and an indication of the amount of current that is not producing useful energy. May be expressed as a decimal fraction or as a percentage.

Thermal Efficiency : In relation to generating plant, the ratio (usually expressed in percent, but also often expressed in terms of kcal per kWh) of the electrical energy generated or sent out from a power station, to the latent energy in the fuel used to produce this amount of electrical energy. As 1 kWh = 864 kcal, Thermal efficiency (%) = $\frac{864}{\text{kcal per kWh}} \times 100$.

Reactive Kilovolt-Amperes (kVAr) : The inactive or non-energy producing component of kVA.

Voltage (V) : The voltage of a circuit in an electric system is the measure of electric pressure of the circuit, which is analogous to water pressure in a water system.

APPENDIX 1.

A new uniform electricity tariff for South Africa

Data

CONSUMER INFORMATION

NUMBER

1 AUGUST 1985

ESCOM INTRODUCES A NEW TARIFF STRUCTURE

THE ELECTRICITY ACT

Escom's operations have always been regulated by the Electricity Act and its subsequent revisions. For several years, there has been a gradual equalisation in the costs of supplying Escom's consumers in South Africa. The Electricity Act No 50 of 1985, introduced subsequent to the recommendations of the Commission of Inquiry into Electricity Supply in the Republic of South Africa, dispensed with the need to identify the costs of supplying individual groups of consumers in distinct geographical areas. This has enabled Escom to accelerate the evolutionary merging of these individual groups. A single uniform tariff structure can now be universally applied to all Escom consumers.
Five major changes are now being introduced earlier than would have been possible with the evolutionary process.

MAJOR CHANGES

1. The concept of undertakings. Undertakings refer to the five areas where Escom has been licensed by the Electricity Control Board to supply electricity in South Africa. Before 1960 the undertakings were not only legally but also physically separate entities.

   The national network is now sufficiently extended to allow the merging of these undertakings. This development has resulted in a gradual reduction in the number of the undertakings from a total of eight to the present five. Given the impetus of the new Electricity Act however, the merging of the remaining undertakings can be accelerated.

   This enables Escom to introduce a national equalisation of tariffs regardless of the geographical location of the consumer. The resultant administrative uniformity allows the pooling of costs for consumers in the same categories.

2. Differentiating between demand costs and energy charges. Energy charges are applied to the amount of electricity actually used. Demand charges are related to the capital expenditure Escom must invest in order to ensure that it has the generation and transmission plant to guarantee that the energy needs of all consumers can be met at any given time.

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Tariff A consumers (large power users) pay for both energy and demand. No demand charges are presently paid by tariff B, C and D consumers (small power, domestic and rural users). Demand-related charges will also be introduced for Tariff B and D consumers This will encourage an economic and efficient use of electricity.

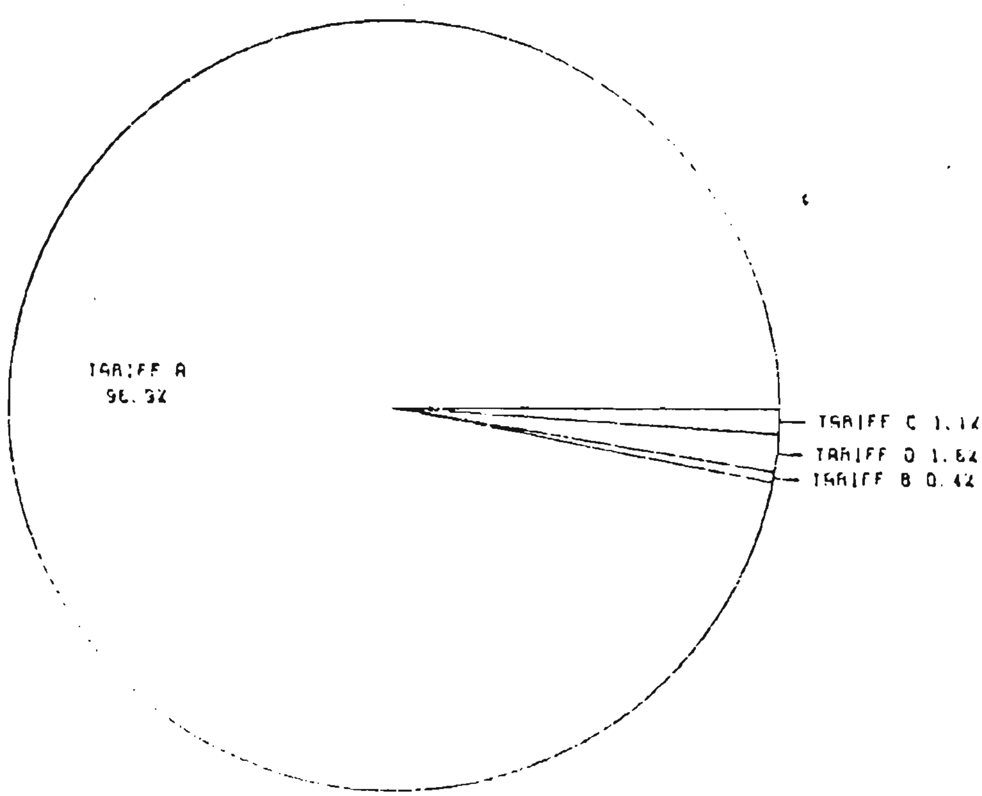
3. Fixed transmission costs to agreed reference points. Transmission costs reflect the loss of energy involved when electricity is transmitted over long distances from the major generating areas on the coalfields. These costs will now be fixed in increasing percentages from 0% - 3% according to four distinct zones, each with a radius of 300 km departing from the central reference point of Johannesburg.

4. Pooling of costs. Costs for like groups of consumers will be pooled throughout the country, enabling Escom to recover the costs of supply in a more equitable manner.

5. Introduction of a tariff structure to satisfy load management requirements. Tariff A consumers (large power users) may opt for a new tariff designed to encourage off-peak use of power. This makes the existing load management incentive available not only to consumers who operate on a 24-hour basis but also to those who can alter part of their activities to operate during off-peak periods. By introducing a more efficient pattern of use, consumers can gain financially while reducing their demand during Escom's peak period of load.

SALES TO DIFFERENT TARIFF GROUPS

This pie chart of sales shows that tariff A users occupy first place at 97%



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NUMBER 4 AUGUST 1985

ESCOM'S NEW TARIFF STRUCTURE AUGUST 1985

TARIFF A - LARGE POWER USERS

Large power users are those whose demand generally exceeds 100 kV.A. This tariff is optional for non-domestic consumers with demands exceeding 25 kV.A.

MAIN CHANGES

The demand charge will vary according to the voltage of supply. Certain tariff A users will benefit by the introduction of additonal voltage-related demand charges. This is intended to avoid the situation where consumers at high voltage pay for losses and capital charges for consumers on lower voltages.

A greater flexibility is introduced, including the option of selecting the off-peak tariff, thus providing the consumer with more options than under the previous structure.

PROPOSED TARIFF STRUCTURE

TARIFF -	PROPOSED
ALL	a) UNIFORM THROUGHOUT THE REPUBLIC
TARIFF A Large Power Users	b) DEMAND CHARGES DIFFERENTIATING BY VOLTAGE AS FOLLOWS: i) 380 ~~400~~ V ii) ABOVE 380 ~~400~~ V AND BELOW 66 kV iii) 66 kV TO 132 kV iv) ABOVE 132 kV c) TARIFF SURCHARGE FOR TRANSMISSION
TARIFF C Domestic Users	d) NO STRUCTURAL CHANGE
TARIFF E Off-peak Large Power Users	e) OFF-PEAK TARIFF
TARIFF B Urban Small Power Users and	f) BASIC CHARGES DIFFERENTIATING BY DEMAND AS FOLLOWS: i) 25 kVA ii) 50 kVA iii) 100 kVA
TARIFF D Rural Small Power Users	g) 1 000 kW.h AT HIGH kW.h RATE IN TARIFF D h) NO EXTENSION CHARGES. A FIXED CAPITAL CHARGE IS TO BE APPLIED IN THE CASE WHERE THE LENGTH OF DISTRIBUTION LINE PER POINT OF SUPPLY EXCEEDS 2.0 km
ALL	i) NO QUARTERLY COAL PRICE ADJUSTMENT j) NATIONAL GENERAL SURCHARGE

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TARIFF E

Tariff A consumers (large power users) may opt for a new tariff designed to encourage off-peak use of power. This makes the existing load management incentive available not only to consumers who operate on a 24-hour basis but also to those who can alter part of their activities to operate during off-peak periods. By introducing a more efficient pattern of use, consumers can gain financially while reducing their demand during Escom's peak period of load.

1. The kV.A demand recorded during off-peak periods will not be charged. Demand recorded during peak periods will be charged at the appropriate tariff A demand charge.

2. The kW.h charge will be applied according to tariff A parameters.

3. If extension charges apply, the rebate will be applied on the basis of the demand chargeable.

4. An average minimum kW.h price will be applied to the total kW.h consumption. This will be compared with the total of the amounts calculated for demand and kW.h, and the actual amount charged will be the greater of the two.

Immediate results expected from the introduction of this new tariff are the provision of a cheaper supply of electricity to large power users and economic benefits for both consumers and the country as a whole. Escom will benefit by capital savings on generating and transmitting plant.

TARIFF PARAMETERS

PARAMETERS	TARIFF A	
Basic Charge	R45 per point of supply	
Demand Charges		
380 ~~400~~ V	R10,15/kVA	R10,90/kW
380 ~~400~~ V < 66 kV	R9,75/kVA	R10,50/kW
66 kV to 132 kV	R9,35/kVA	R10,10/kW
>132 kV	R8,95/kVA	R9,70/kW
Energy Charge	1,87c/kW.h	
Rebate Rate for monthly Extension Charges	R2,00 / kW or kVA	

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TARIFF A MONTHLY CHARGE

The monthly account will be made up as follows:

	Basic Charge	
		Above 132 kV
		66 kV - 132 kV
+	Demand Charge (kVA)	~~400~~ 380 V - 66 kV
		~~400~~ 380 V
+	Energy Charge (kW.h)	
+	Transmission Percentage Charge	
+	Extension Charge	
-	Rebate/kVA	
	(Surcharge)	

TRANSMISSION CHARGE

Transmission costs reflect the loss of energy involved when electricity is transmitted over long distances from the major generating areas on the coalfields. These costs will now be fixed in increasing percentages from [illegible] according to four distinct zones, each with a radius of 300 km departing from the central reference point of Johannesburg.

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[illegible] AUGUST 1985

[illegible]

The tariff structure is divided into five categories:

Tariff A	Large power users
Tariff B	Urban small power users
Tariff C	Domestic users
Tariff D	Rural small power users
Tariff E	Off-peak large power users

These tariffs will be nationally applicable with a single set of parameters. Geographic location of the consumer will no longer determine the tariff parameters. In the case of Tariff A consumers an additional transmission charge will be added. This will reflect transmission losses incurred in supplying consumers situated far from major generating centres. Tariffs A to D are counterparts of existing tariffs, whereas Tariff E is an addition to the structure and is designed to encourage a more efficient use of electricity by large power consumers.

PROPOSED TARIFF STRUCTURE

TARIFF	PROPOSED
ALL	a) UNIFORM THROUGHOUT THE REPUBLIC
TARIFF A Large Power Users	b) DEMAND CHARGES DIFFERENTIATING BY VOLTAGE AS FOLLOWS: i) ~~400~~ 380 V ii) ABOVE ~~400~~ 380 V AND BELOW 66 kV iii) 66 kV TO 132 kV iv) ABOVE 132 kV
	c) TARIFF SURCHARGE FOR TRANSMISSION
TARIFF C Domestic Users	d) NO STRUCTURAL CHANGE
TARIFF E Off-peak [illegible] Power Users	e) OFF-PEAK TARIFF
TARIFF B Urban Small Power Users and	f) BASIC CHARGES DIFFERENTIATING BY DEMAND AS FOLLOWS: i) 25 kVA ii) 50 kVA iii) 100 kVA
TARIFF D Rural Small Power Users	g) 1 000 kW.h AT HIGH kW.h RATE IN TARIFF D
	h) NO EXTENSION CHARGES. A FIXED CAPITAL CHARGE IS TO BE APPLIED IN THE CASE WHERE THE LENGTH OF DISTRIBUTION LINE PER POINT OF SUPPLY EXCEEDS 2.0 km
ALL	i) NO QUARTERLY COAL PRICE ADJUSTMENT
	j) NATIONAL GENERAL SURCHARGE

MONTHLY EXTENSION CHARGE

The standard tariff is designed to cover the "average consumer". If the cost of supplying a particular consumer, or group of consumers, is greater than the average, it is necessary to levy a charge in addition to the tariff in order to cover the additional costs, this additonal charge is called the "monthly extension charge". The monthly extension charge will be reduced by R2 for every kV.A of demand charged to the point where it is eliminated.

TARIFF E

MONTHLY CHARGE

This tariff applies only to consumers who qualify for the Tariff A group.

The monthly account will be made up as follows:

1. Demand recorded during off-peak periods is not charged.

2. A basic charge higher than that of Tariff A.

3. Demand charges as per Tariff A voltage category.

4. kW.h Charge as for Tariff A.

5. An average minimum kW.h price will apply to the total kW.h consumption. This will be compared to the total amount under 3 and 4 and the amount charged will be the greater of the two.

6. Extension charge less rebate.

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TRANSMISSION CHARGES

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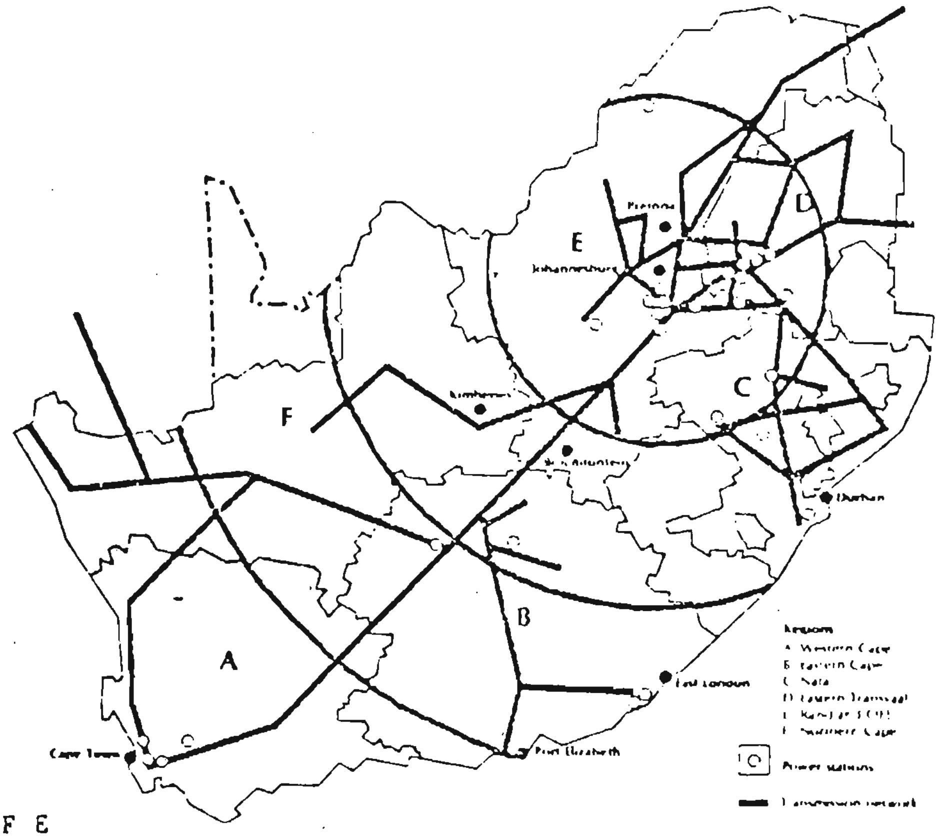

TARIFF E

Tariff A consumers (large power users) may opt for a new tariff designed to encourage off-peak use of power. This makes the existing load management incentive available not only to consumers who operate on a 24-hour basis but also to those who can alter part of their activities to operate during off-peak periods. By introducing a more efficient pattern of use, consumers can gain financially while reducing their demand during Escom's peak period of load.

1 The kV.A demand recorded during off-peak periods will not be charged. Demand recorded during peak periods will be charged at the appropriate tariff A demand charge.

2 The kW.h charge will be applied according to tariff A parameters.

3 If extension charges apply, the rebate will be applied on the basis of the demand chargeable.

4 An average minimum kW.h price will be applied to the total kW.h consumption. This will be compared with the total of the amounts calculated for demand and kW.h, and the actual amount charged will be the greater of the two.

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ESCOM NATIONAL LICENCE, 1986,

granted to

E S C O M

by the

ELECTRICITY CONTROL BOARD

under the

ELECTRICITY ACT, 1958 (ACT NO. 40 OF 1958)

ON ______________

This licence consolidates the following six licences:

Rand and Orange Free State Licence, 1983, granted on 11 October 1983.

Eastern Transvaal Licence, 1925, as amended; originally granted on 6 April 1925.

Natal Central Licence, 1927, as amended; originally granted on 29 June 1927.

Natal Southern Licence, 1927, as amended; originally granted on 29 June 1927.

Eastern Cape Licence, 1985, granted on 3 September 1984.

Northern and Western Cape Licence, 1985, granted on 8 October 1984.

LICENCE GRANTED BY THE ELECTRICITY CONTROL BOARD
UNDER THE ELECTRICITY ACT, 1958,

for the

SUPPLY OF ELECTRICITY IN THE REPUBLIC OF SOUTH AFRICA

LICENCE SUBJECT TO THE ELECTRICITY ACT, 1958

1. This licence, which may be cited as the "Escom National Licence, 1986" is issued under and subject to the provisions of the Electricity Act, 1958, and the Regulations in force thereunder, and any modification or amendment of the said Act or Regulations.

DEFINITIONS

2. The expressions used in this licence shall, unless inconsistent with the context, have the following meanings:

"Act"

means the Electricity Act, No. 40 of 1958, as amended, and includes the Regulations in force thereunder.

"Electricity Control Board"

means the Electricity Control Board constituted under Section 22 of the Act.

"Licensee"

means Escom constituted under Section 2 of the Act.

All other expressions used in this licence shall have the same meanings as those assigned to them in the Act.

LICENSEE AND HEAD OFFICE

3. The licensee is a body corporate with its Head Office at Megawatt Park, Maxwell Drive, Sunninghill Extension 3, Sandton, 2199, charged with the function of generation, supply and distribution of electricity throughout South Africa under the authority of this licence and of the Permit of the Central Generating Undertaking granted to it by the Electricity Control Board on 26 January 1972.

CONDITIONS OF LICENCE

4.1 Grant of licence

This licence replaces the licences previously held by the licensee which were known as "Rand and Orange Free State Licence, 1983", "Eastern Transvaal Licence, 1925", "Natal Central Licence, 1927", "Natal Southern Licence, 1927", "Eastern Cape Licence, 1985", and "Northern and Western Cape Licence, 1985", and shall come into effect from 1 January 1986 or such other date as may be approved by the Electricity Control Board.

4.2 Authority of licensee

The licensee is licensed to undertake the supply of electricity under the Act within the area described in Clause 5 hereof and for that purpose to construct and/or instal, use, maintain, remove, alter, deviate, repair, renew or duplicate such transmission and distribution lines, cables, substations and other equipment and such buildings, or other works incidental thereto as may be required from time to time for supplying electricity in the area of supply.

AREA OF SUPPLY

5. The area within which the licensee may supply electricity shall be the entire territory of the Republic of South Africa, including such territories outside the Republic as may be approved in terms of Section 4A of the Act.

CONSUMERS TO WHOM SUPPLY MAY BE GIVEN

6. Subject to the provisions of the Act the licensee is authorised to supply electricity to any consumer in the area referred to in Clause 5 hereof, provided that:

(a) The licensee may not supply electricity to any person, except the South African Transport Services for power purposes, within the area of jurisdiction of an urban local authority as existing at the time of granting of this licence, except in so far as the licensee already has the right of supply within such area in accordance with Section 38 of the Act, or except with the consent provided for in Section 41 of the Act; provided however, that if the area of jurisdiction of an urban local authority is extended thereafter into the area of supply of the licensee or if a new urban local authority is established within the area of

FIRST SCHEDULE

SCHEDULE OF STANDARD PRICES

DEFINITIONS

1. For the purpose of this Schedule the following words and phrases shall have the meanings herein assigned to them:

"Month"

shall mean the period between successive monthly meter readings made in terms of the contract of supply, irrespective of whether such readings are taken on the last day of the calendar month: provided that if, in terms of the contract of supply, meter readings are made at three-monthly intervals, "month" shall mean one-third of the period between successive meter readings, and the monthly consumption in kW.h shall be deemed to be one-third of kW.h taken in the period.

"Maximum demand"

when specified in kilowatts shall mean the highest load in kilowatts supplied or to be supplied by the licensee to the consumer during any period of 60 (sixty) consecutive minutes in the month; and, when specified in kilovolt amperes, shall mean the highest load in kilovolt amperes supplied or to be supplied by the licensee to the consumer during any period of 30 (thirty) consecutive minutes in the month.

Where electricity is supplied or made available at more than one point of supply to a mine or works or installation, in terms of a single contract of supply, then the maximum demand shall be the maximum simultaneous demand supplied or to be supplied at the several points of supply agreed to under the contract.

"Notified maximum demand"

shall mean:

(i) The maximum demand notified in writing by the consumer and accepted by the licensee as the maximum demand which the consumer requires the licensee to be in a position to supply on demand; plus

(ii) any increase in the notified maximum demand referred to in (i) above, notified in writing by the consumer giving reasonable notice thereof, and accepted by the licensee; provided that such increase shall not form part of the notified maximum demand until the date on which the licensee is required in terms of the notification to meet such increased maximum demand, or the date on which the licensee is in a position to meet the requirements of the consumer in this respect, whichever is the later date; plus

(iii) any increase in the maximum demand taken by and supplied to the consumer above the notified maximum demand for the time being in force, provided that in each instance where notice of the increase in the notified maximum demand is not given and the licensee notifies the consumer that such increase or any portion thereof cannot be regarded as available to the consumer on demand until a future date, such increase or portion shall not, until such future date, form part of the notified maximum demand;

(iv) provided that, subject to the provisions of the Act and this licence, the notified maximum demand may be temporarily increased for a period of not less than one month on such terms and conditions as may be agreed between the licensee and the consumer.

"Point of supply"

shall mean a point or position on the property of the consumer or elsewhere, at which electricity is or is to be supplied as agreed between the licensee and the consumer.

"Transmission percentage charge"

shall mean an extra percentage charge applied as a contribution to transmission costs.

"General surcharge"

shall mean the percentage surcharge applied from time to time adjusted by the licensee in terms of Section 14 of the Act.

"Dwelling unit"

shall mean a residence for an individual household, whether electricity is taken or not.

"Group of dwelling units"

shall mean any two or more dwelling units fed from a single point of supply.

"Legally constituted township"

shall mean, in the Transvaal, an approved township as defined in Section 1 of the Town Planning and Townships Ordinance (Ordinance 25 of 1965) and, in the other Provinces, shall mean townships which are proclaimed in the prescribed manner.

"Peak hours"

shall mean the hours which in the opinion of Escom coincide with the period of peak demand on the Escom system.

STANDARD PRICES

2. The standard prices chargeable by the licensee for electricity supplied or made available shall, subject to the provisions of the Act and of this licence, be as set out hereunder.

TARIFF (A) : LARGE POWER USERS: GENERAL

For electricity supplied to a consumer whose notified maximum demand is 25 (twenty-five) kilowatts/kilovolt amperes or over, in the form of three-phase alternating current at a frequency of 50 (fifty) hertz and at an agreed voltage which is available in the vicinity, excepting supplies provided under Tariff (E), the following charges shall apply:

(a) A basic charge for each point of supply of R45,00 (forty-five rands) per month, which charge shall be payable whether any electricity is taken or not.

(b) A demand charge for each kilovolt ampere of the maximum demand supplied in the month of:

(i) R10,15 (ten rands fifteen cents) when the supply is furnished at the nominal voltage of 380 volts between phases and 220 volts between phase and neutral;

(ii) R9,75 (nine rands seventy-five cents) when the supply is furnished at a nominal phase-to-phase voltage between 380 volts and 66 000 volts;

(iii) R9,35 (nine rands thirty-five cents) when the supply is furnished at a nominal phase-to-phase voltage from 66 000 volts up to and including 132 000 volts;

(iv) R8,95 (eight rands ninety-five cents) when the supply is furnished at a nominal phase-to-phase voltage above 132 000 volts;

provided that consumers previously supplied in terms of Escom's Rand and Orange Free State Licence, 1983, with supply contracts originally concluded before 1 January 1984, shall have the right to have their maximum demand measured in kilowatts. Unless and until such consumers have requested their maximum demand to be measured in kilovolt amperes, the demand charge for each kilowatt of the maximum demand supplied in the month shall be:

(v) R10,90 (ten rands ninety cents) when the supply is furnished at the nominal voltage of 380 volts between phases and 220 volts between phase and neutral;

(vi) R10,50 (ten rands fifty cents) when the supply is furnished at a nominal phase-to-phase voltage between 380 volts and 66 000 volts;

(vii) R10,10 (ten rands ten cents) when the supply is furnished at a nominal phase-to-phase voltage from 66 000 volts up to and including 132 000 volts;

(viii) R9,70 (nine rands seventy cents) when the supply is furnished at a nominal phase-to-phase voltage above 132 000 volts.

(c) An energy charge of 1,87c (one comma eight seven cents) per kW.h supplied in the month.

(d) The sum of the amounts determined under paragraphs (a), (b) and (c) hereof shall be subject to a transmission percentage charge as follows:

(i) Nil for points of supply within a linear distance of 300 kilometres from Johannesburg;

(ii) 1% (one per cent) for points of supply within a linear distance between 300 and 600 kilometres from Johannesburg;

(iii) 2% (two per cent) for points of supply within a linear distance between 600 and 900 kilometres from Johannesburg;

(iv) 3% (three per cent) for points of supply with linear distance from Johannesburg exceeding 900 kilometres.

(e) The amount determined under paragraph (d) hereof shall be subject to the general surcharge ruling at the time.

TARIFF (B) : SMALL POWER USERS

For a supply to a consumer whose maximum demand at no time exceeds 100 (one hundred) kV.A, made available at a nominal voltage of 380 volts between phases and 220 volts between phase and neutral or as otherwise agreed, excepting supplies provided under Tariffs (C) and (D), the following charges shall apply:

(a) A basic monthly charge for each point of supply, payable whether electricity is taken or not, graded according to the consumer's notified maximum demand as follows:

Charge, rands per month	Notified maximum demand, kV.A
13,00	25
21,00	50
36,00	100

(b) In respect of each point of supply, a kW.h charge of 8,65c (eight comma six five cents) per kW.h for 500 (five hundred) kW.h of the monthly consumption, or the monthly consumption, whichever is the lesser number.

(c) A kW.h charge of 5,00c (five comma nought nought cents) per kW.h for kW.h taken in excess of the kW.h referred to in (b) above.

(d) The sum of the amounts determined under paragraphs (a), (b) and (c) hereof shall be subject to the general surcharge ruling at the time.

TARIFF (C) : URBAN DOMESTIC CONSUMERS

For a supply of electricity for domestic purposes for a dwelling unit or a group of dwelling units, or for a church, hall, old age home or the like premises, within a legally constituted township or within an area considered by the licensee to be similar to a legally constituted township, the following charges shall apply:

(a) A basic charge of R6,00 (six rands) per month in respect of each point of supply, which charge shall be payable whether electricity is taken or not.

(b) In respect of each point of supply, a kW.h charge of 8,65c (eight comma six five cents) per kW.h for 300 (three hundred) kW.h of the monthly consumption, or the monthly consumption, whichever is the lesser number; provided that, for a supply to a group of dwelling units this charge shall be calculated on 300 (three hundred) kW.h or the average monthly consumption per dwelling unit.

(c) A kW.h charge of 5,00c (five comma nought nought cents) per kW.h for kW.h taken in excess of the kW.h referred to in (b) above.

(d) The sum of the amounts determined under paragraphs (a), (b) and (c) hereof shall be subject to the general surcharge ruling at the time.

TARIFF (D) : RURAL SMALL USERS

For a supply to a consumer whose maximum demand at no time exceeds 100 (one hundred) kV.A, made available at a nominal voltage of 380 volts between phases and 220 volts between phase and neutral or as otherwise agreed, and whose point of supply is situated within an area defined as "agricultural land" in terms of the Sub-division of Agricultural Land Act (Act No. 70 of 1970), or is situated within an area deemed by the licensee to be similar to such a defined area, the following charges shall apply:

(a) A basic monthly charge for each point of supply, payable whether electricity is taken or not, graded according to the consumer's notified maximum demand as follows:

Charge, rands per month	Notified maximum demand, kV.A
22,00	25
30,00	50
45,00	100

(b) In respect of each point of supply, a kW.h charge of 8,65c (eight comma six five cents) per kW.h for 1 000 (one thousand) kW.h of the monthly consumption, or the monthly consumption, whichever is the lesser number.

(c) A kW.h charge of 5,00c (five comma nought nought cents) per kW.h for kW.h taken in excess of the kW.h referred to in (b) above.

(d) The sum of the amounts determined under paragraphs (a), (b) and (c) hereof shall be subject to the general surcharge ruling at the time.

TARIFF (E) : LARGE POWER USERS: OFF-PEAK

For electricity supplied to a consumer whose notified maximum demand is 25 (twenty-five) kilowatts/kilovolt amperes or over, and who elects to be charged for demand on the basis of the maximum demand measured during peak hours, in the form of three-phase alternating current at a frequency of 50 (fifty) hertz and at an agreed voltage which is available in the vicinity, the following charges shall apply:

(a) A basic charge for each point of supply of R100 (one hundred rands) per month, which charge shall be payable whether any electricity is taken or not.

(b) A demand charge for each kilovolt ampere of the maximum demand supplied during peak hours in the month of:

(i) R10,15 (ten rands fifteen cents) when the supply is furnished at the nominal voltage of 380 volts between phases and 220 volts between phase and neutral;

(ii) R9,75 (nine rands seventy-five cents) when the supply is furnished at a nominal phase-to-phase voltage between 380 volts and 66 000 volts;

(iii) R9,35 (nine rands thirty-five cents) when the supply is furnished at a nominal phase-to-phase voltage from 66 000 volts up to and including 132 000 volts;

(iv) R8,95 (eight rands ninety-five cents) when the supply is furnished at a nominal phase-to-phase voltage above 132 000 volts;

provided that consumers previously supplied in terms of Escom's Rand and Orange Free State Licence, 1983, with supply contracts originally concluded before 1 January 1984, shall have the right to have their maximum demand measured in kilowatts. Unless and until such consumers have requested their maximum demand to be measured in kilovolt amperes, the demand charge for each kilowatt of the maximum demand supplied during peak hours in the month shall be:

PRELIMINARY PARAMETERS FOR TARIFF (E) LARGE POWER USERS: OFF-PEAK

OFF - PEAK PERIODS

Monday	23h00	to	Tuesday	07h00
Tuesday	23h00	to	Wednesday	07h00
Wednesday	23h00	to	Thursday	07h00
Thursday	23h00	to	Friday	07h00
Friday	23h00	to	Monday	07h00

Public Holidays to be negotiated.

Minimum agreement period of one year.

DEFINITION OF LOAD FACTOR

$$\text{Load Factor} = \frac{\text{Average demand}}{\text{Peak demand}}$$

$$\text{Monthly Load Factor} = \frac{\text{kW.h}}{\text{kW} \times 730}$$

(v) R10,90 (ten rands ninety cents) when the supply is furnished at the nominal voltage of 380 volts between phases and 220 volts between phase and neutral;

(vi) R10,50 (ten rands fifty cents) when the supply is furnished at a nominal phase-to-phase voltage between 380 volts and 66 000 volts;

(vii) R10,10 (ten rands ten cents) when the supply is furnished at a nominal phase-to-phase voltage from 66 000 volts up to and including 132 000 volts;

(viii) R9,70 (nine rands seventy cents) when the supply is furnished at a nominal phase-to-phase voltage above 132 000 volts.

(c) An energy charge of 1,87c (one comma eight seven cents) per kW.h supplied in the month.

(d) A minimum overall charge of 3,3c (three comma three cents) per kW.h supplied in the month.

(e) The sum of the amounts determined under paragraphs (a), (b) and (c) above shall be compared with the sum of the amounts determined under paragraphs (a) and (d) above; and the larger of the two amounts so compared shall be the amount payable, subject to a transmission percentage charge as follows:

(i) Nil for points of supply within a linear distance of 300 kilometres from Johannesburg;

(ii) 1% (one per cent) for points of supply within a linear distance between 300 and 600 kilometres from Johannesburg;

(iii) 2% (two per cent) for points of supply within a linear distance between 600 and 900 kilometres from Johannesburg;

(iv) 3% (three per cent) for points of supply with linear distance from Johannesburg exceeding 900 kilometres.

(f) The amount determined under paragraph (e) hereof shall be subject to the general surcharge ruling at the time.

STREET LIGHTING

3. Where the licensee provides a supply for, and maintains, any street lighting or similar public lighting, the charge for such supply and service shall be fixed by special arrangements between the licensee and the consumer.

CHARGES PAYABLE MONTHLY

4. All accounts payable by a consumer in terms of this schedule shall be rendered and shall be payable monthly. If, in terms of the contract of supply, meter readings are made at three-monthly intervals, the licensee shall render provisional accounts for the months in which no meter reading is made, based upon the monthly consumption in the previous three-monthly period or upon an estimated amount, and a final account, incorporating an adjustment of the provisional accounts, based upon the actual consumption for the period.

If the commencing date or the termination date of any supply be such that the supply was available for portion of a month, the monthly charges payable in terms of the schedule shall be calculated pro rata to the portion of a month of 30 days during which the supply was available.

SPECIAL CHARGES FOR SERVICES RENDERED

5. The licensee may make special charges for services rendered to the consumer e.g. the provision of service mains, the installation of equipment in the consumer's substation, for the taking of any special meter readings, for reconnection of the supply after disconnection (i) either at the request of the consumer or (ii) for failure by the consumer to carry out his obligations, and for special work done for the consumer by the licensee.

VARIATION OF STANDARD PRICES

6. Where a consumer, at his request, is supplied with electricity at a nominal voltage which is not the voltage generally available to consumers in the area, or where any of the other circumstances provided for in Section 29 of the Act apply, the licensee may vary the prices prescribed by this schedule or may impose additional charges or both, in accordance with the Act.

SECOND SCHEDULE

GENERAL CONDITIONS GOVERNING THE INSTALLATION, EQUIPMENT AND USE OF CONSUMERS' PLANT

1. The apparatus of the consumer shall be of good design and construction properly installed and maintained by the consumer, and shall in all respects comply with any statutory or other regulations or by-laws in force from time to time governing the use of electricity. The wiring of the consumer's premises shall be carried out in accordance with the standard regulations in force from time to time for the wiring of premises.

2. The consumer shall, if and when required to do so by the licensee, provide and maintain at the point of supply a substation of a design and in a position to the reasonable approval of the licensee. Subject to the consent of the consumer, which shall not be unreasonably withheld, the substation and the apparatus of the licensee herein may be used by the licensee in conjunction with the general supply.

3. The consumer shall provide efficient switchgear and apparatus to the approval of the licensee at the point of supply for the protection of the apparatus of the licensee and the installation of the consumer against overload, faults and lightning on the consumer's installation.

4. The consumer shall so use the supply as not to interfere with an efficient and economical supply to other consumers.

5. The licensee may call upon the consumer to install such power factor correction apparatus as may be necessary to ensure a power factor not lower than 0,85 lagging at normal maximum load, in which event the consumer shall take the necessary action to procure and install the required apparatus within a reasonable time.

6. In the event of a consumer not complying with any of the foregoing conditions, the licensee may discontinue the supply, but the supply shall be restored as soon as the cause for discontinuance has been remedied.

APPENDIX 2

SUMMARY OF SURVEY OF

OBJECTIVES AND POLICIES OF MUNICIPAL ELECTRICITY UNDERTAKINGS

The following responses to the attached questionaire were obtained in the telephonic interviews with senior personnel of the electricity undertakings of Cape Town, Johannesburg, Pietermaritzburg, Durban, Port Elizabeth, Mooi River, Stanger, Tongaat and Bloemfontein.

Written Objectives & Policies (page 1)

Question 1 :	9 No.	0 Yes
Question 2 :	9 No.	0 Yes
Question 3 :	9 No	0 Yes

Statement of Objectives (page 2)

	1	2	3	4	5
Question 1 : Responses : Towns					9
Question 2 : Responses : Towns				2	7
Question 3 : Responses : Towns				3	6
Question 4: Responses : Towns			2	2	5
Question 5 : Responses : Towns	1	2	3	3	0

<u>Finance</u> (Page 3)

Question 1:	9 Yes	0 No
Question 2:	2 Yes	7 No

<u>Load Management</u> (Page 3)

Question 1 :	9 Yes	0 No
Question 2 :	2 Yes	7 No
Question 3 :	3 Yes	6 No
Question 4 :	3 Yes	6 No

UNIVERSITY OF DURBAN WESTVILLE

GRADUATE SCHOOL OF BUSINESS

SURVEY OF OBJECTIVES AND POLICIES OF MUNICIPAL ELECTRICITY UNDERTAKINGS

MUNICIPALITY : ....

PERSON INTERVIEWED : ....

POSITION : ....

OBJECTIVES. Please ring the applicable answer

1. Does this Undertaking have a written statement of its mission, purpose and objectives?

   Yes/No

2. Is this main objective supported by written sub-objectives in the fields of its Customers, Finance and the environment?

   Yes/No

3. Are there written policies which have been developed to ensure that the various functions of the Undertaking strive towards the stated objectives?

   Yes/No

OBJECTIVES

Please place a cross in your rating of the following statements. One represents low importance, and 5 represents high importance.

1. The undertaking must deliver electricity safely. 1 2 3 4 5

2. Electricity distribution must be efficient. 1 2 3 4 5

3. System design must be constantly improved to reduce future outages to a minimum. 1 2 3 4 5

4. Tariffs must be improved to reduce load peaking. 1 2 3 4 5

5. Tariffs must be revised to ensure that each consumer group contributes fairly to actual costs. 1 2 3 4 5

FINANCE. Please ring the applicable answer.

1. Is your present tariff structure based mainly on a historic tariff structure which is updated annually primarily to derive the necessary income?

   Yes/No

2. Is a very careful consideration given to the precise actual cost of electricity for every consumer group to ensure that tariffs are perfectly equitable?

   Yes/No

LOAD MANAGEMENT Please ring the applicable answer

1. Does your tariff structure segment your customer market into Domestic and Non-domestic users?

   Yes/No

2. Does your tariff structure further segment your customers into those who contrbute to the peak load?

   Yes/No

3. Are any of your tariffs designed to attempt to shift load out of the peak period?

   Yes/No

4. Does your system use remotely switched water-heater load control in an effort to reduce the peak-load?

   Yes/No

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5. "Komitees-Koodinerende Raad vir Plaaslike Owerheidswese - het belangrik taak, maar moet waak teen persoonlike waardes wat tot nadeel kan strek", Munisipale en Openbare Dienste, April 1984.

6. Professor VOSLOO, W.B., "The Regional Approach to Local Government Re-organization in South Africa". The Institute of Municipal Treasurers and Accountants S.A., 1979, p. 330.

7. Professor VOSLOO, Ibid, p. 335.

8. "Natal Could Lose Control : Martin", The Daily News, Saturday, May 26 1984.

9 & 10. "Big Blueprint for all races to run Durban", The Daily News Saturday August 24 1985, p. 7.

11. "P.F.P. warns on danger to future Natal", The Daily News, October 19 1985, p. 4.

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13. WISEMAN, J., "The Theory of Public Utility Price - An Empty Box" OEP V9 (1957) p. 61.

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CHAPTER 8 : POLICY FORMULATION AND RECOMMENDATIONS

1. STEINER, George A., and MINER, John B., Management Policy and Strategy , Macmillan Publishing Co., Inc. New York 1977, pages 24, 25.

2. STEINER, G.A. and MINER, B.M., Ibid, p. 99.

CHAPTER 8 : POLICY FORMULATION AND RECOMMENDATIONS

1. STEINER, George A., and MINER, John B., Management Policy and Strategy , Macmillan Publishing Co., Inc. New York 1977, pages 24, 25.

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CHAPTER 2

THE CUSTOMERS OF THE ELECTRICITY UNDERTAKING

As stated in Chapter 1 (page 1.10) marketing needs to command a central position to ensure that the customers' needs are correctly interpreted and efficiently satisfied.

It is therefore important that as a starting point we need to identify the customers and to classify them into groups or categories according to their needs.

2.1 The Customers

Strictly speaking, all persons working or living in the municipal area of supply are direct or indirect customers of the undertaking. The cost of electricity used for general lighting in an office block, for example, must be recovered from the tenants and is included in their rent. Similarly the cost of electricity used for lighting and airconditioning of a large store must be recovered in the price structure of the goods sold, hence every shopper is an indirect customer of the undertaking.

The direct customers of the undertaking are its "consumers".

The most common classification of consumers is by consumer type and the self explanatory classification normally used is :-

a) Domestic Consumers

b) Commercial Consumers

c) Industrial Consumers

There is no clear boundary between these consumer types. For example, domestic consumers are generally thought of as individual households living either in houses or flats, while boarding houses, hotels and the like are normally considered to be commercial consumers. Similarly a small printing works may be considered to be a commercial consumer, while a large printing press may be deemed to be an industrial consumer.

An alternative classification of consumer types is by way of power consumption, and the typical classification used is :-

a) Single phase consumers

b) Three phase small power user (s.p.u)

c) Three phase large power user (l.p.u)

In either of the above methods of classifying consumers it is helpful to further subdivide the consumers into those who contribute towards creating the system peak demand from those whose peak demand periods do not coincide with the system peak period. A yet further subdivision can be made by identifying those consumers who can shift some of their load out of the peak period.

The resulting classification of consumer types based on power demand is shown in Fig 2.1.

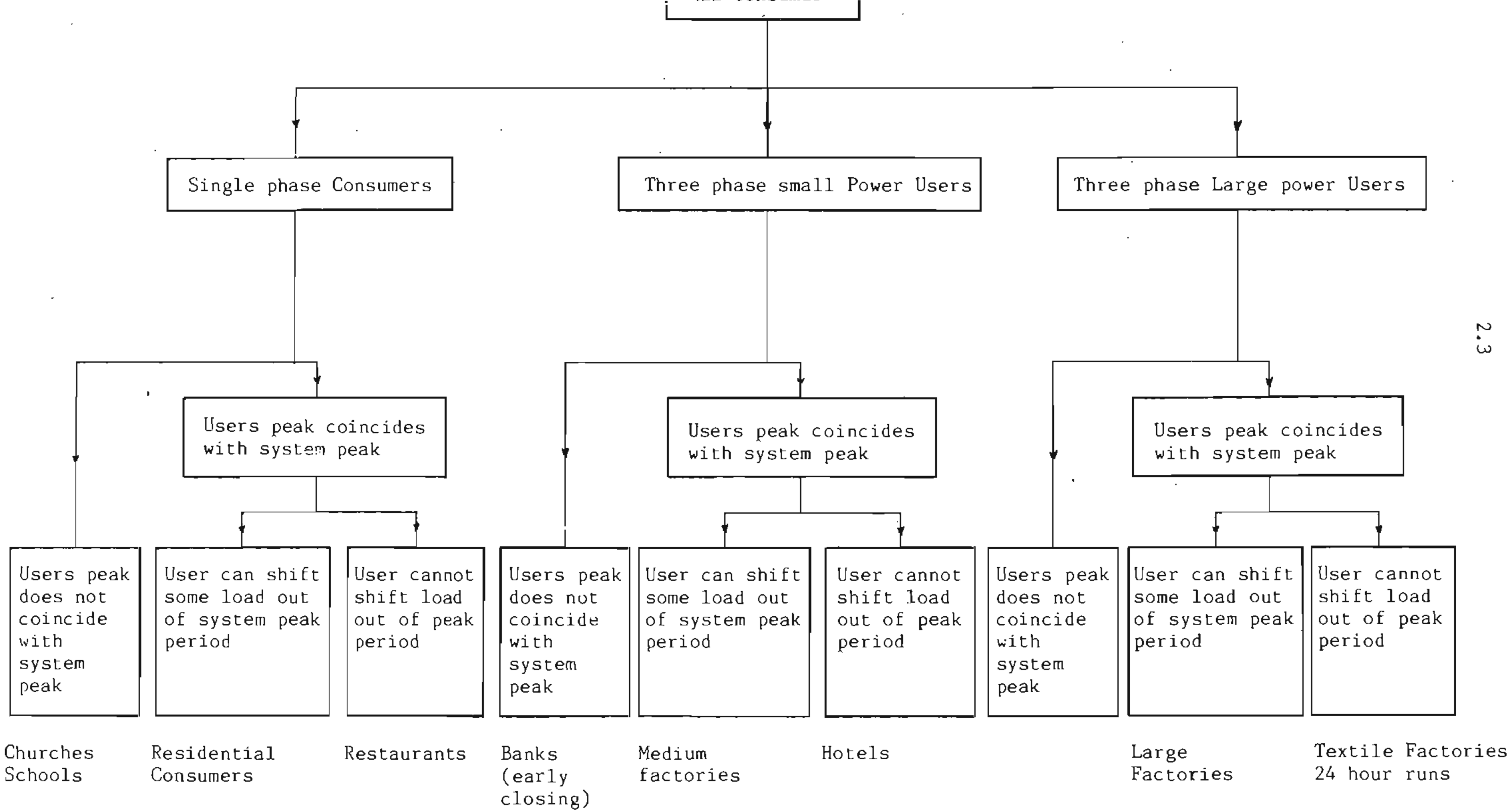


FIG 2.1

DIAGRAM ILLUSTRATING MARKET SEGMENTATION AND EXAMPLES OF TYPICAL CONSUMERS

From Fig 2.1 it can be seen that at least nine different categories of consumers can be identified and it will require at least nine different tariffs if correct cost allocation amongst the different consumer categories is to be achieved. Since the system reticulation network must be designed to meet the peak load it follows that a lower tariff could and should be available to those consumers whose peak load does not coincide with the system peak, while a heavier tariff should be imposed on those consumers whose peaks are the cause for further system augmentation, and incentive tariffs should be available to those consumers who can shift some of their load out of the peak period.

2.2 CUSTOMER CONSUMPTION PATTERNS :

THE SYSTEM LOAD CURVE

The system load curve represents the sum of all the individual loads acting in the system. The highly organized lifestyles of the community dictates that at certain times load peaking will occur. It is obvious that domestic loads will peak in the late afternoon as workers return home, meals are cooked, people use hot water for washing up and baths, etc. Similarly domestic loads and many commercial loads drop to near zero late at night.

Such periods of high power usage requires the installation of adequately sized cables and transformers which are typically fully utilized for only a few hours during a few specific days in the year. For the rest of the year this equipment is under-utilized, representing large sums of capital needlessly tied up. Of even greater concern is the fact that an ever increasing number of energy-intensive appliances are being developed for domestic use, such as high speed kettles, microwave ovens, etc. This means that the present supply networks, which are under utilized most of the time, may become overloaded for short periods on particular days in the future. Many towns and cities are therefore faced with the choice of either continually uprating supply networks, or to attempt to control the load-peaking. Such attempts to control the load peaking is refered to as load management, and worldwide, has met with considerable success.

The system load curve can be determined in a number of ways, and the following methods of data capture yield satisfactory results :

2.2.1 DATA CAPTURE : MANUAL RECORDING METHOD

This is the simplest method, which can be applied at very short notice with quick results. It simply requires a meter-reader to note down the maximum demand reading at 15 minute intervals over the period in question. Table 2.1 shows the actual readings taken manually at 15 minute intervals at the main intake substation at Stanger on the 31st August 1983. Fig 2.2 is a graphically representation of these readings and clearly illustrates the peaking which takes place at the later afternoon.

2.2.2 DATA CAPTURE : PHOTOGRAPHIC RECORDING

Most substations are equipped with non-recording instruments, normally used for instantaneous readings for protection purposes. A satisfactory method of determining the load curve is to use an electrically operated cine-camera, which has been fitted with suitable timers. By positioning and focusing such a camera onto the relevent meters, the cine-camera can photograph the position of the indicators on the meters for

STANGER

LOAD READING TAKEN ON WEDNESDAY, 31ST AUGUST, 1983 : CHAKAS KRAAL SUBSTATION

TIME	k V A METER	CHECK
08h15	25920	25440
08h30	25440	24960
08h45	25440	24960
09h00	25440	24960
09h15	24960	24720
09h30	24960	24480
08h45	24960	24960
10h00	24960	24480
10h15	24960	24480
10h30	24480	24000
10h45	24480	24000
11h00	24480	24000
11h15	24480	24000
11h30	24000	23520
11h45	22560	22080
12h00	22560	22080
12h15	25560	22080
12h30	23520	23040
12h45	24000	23520
13h00	24000	23520
13h15	24000	23520
13h30	23520	23040
13h45	23520	23040
14h00	24000	23520
14h15	23520	23040
14.30	23520	23040
14h45	24480	24000
15.00	24480	24000
15h15	24480	24000
15h30	24960	24400
15h45	24960	24400
16h00	24960	24400
16h15	25920	25920
16h30	26400	25920
16h45	25920	25920
17h00	26920	25920
17h15	25920	25920
17h30	26880	26400
17h45	27840	27360
18h00	29280	28800
18h15	30720	30240
18h30	30240	29760
18h45	29760	29280
19h00	29280	28800

MANUAL RECORDINGS OF LOAD READINGS : STANGER.

TABLE 2.1

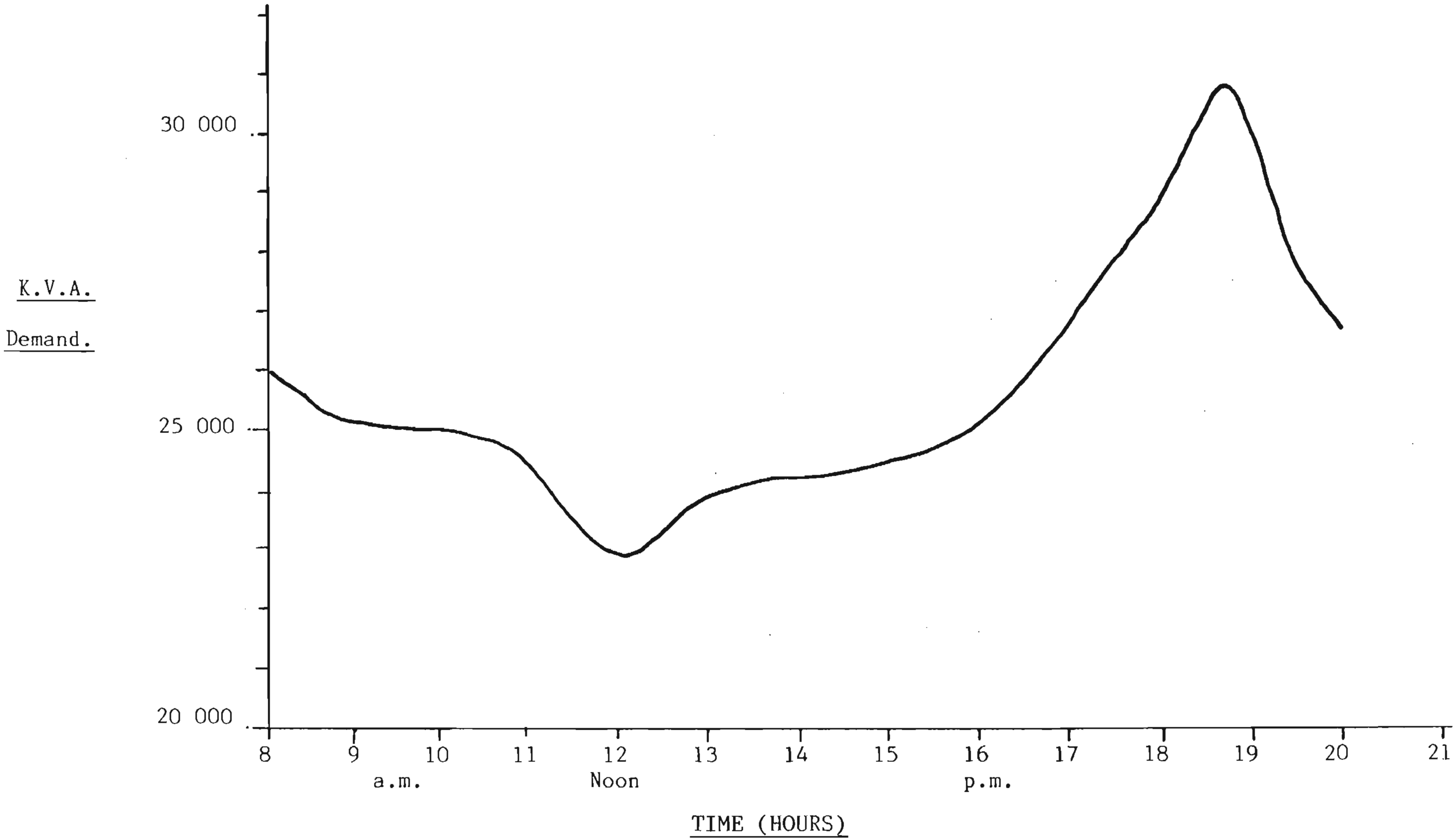


FIGURE 2.2

GRAPHICAL REPRESENTATION OF LOAD DEMAND FOR STANGER. BASED ON MANUAL READINGS.

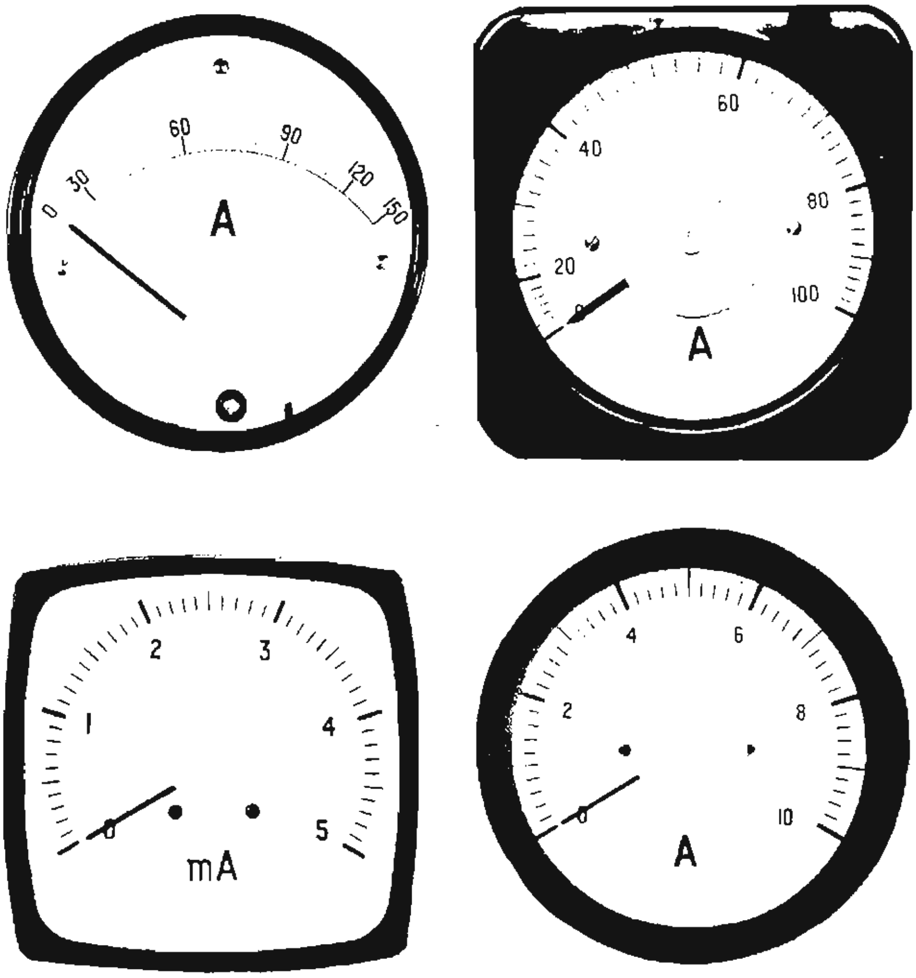
one second intervals every 10 mintues. The typical 8mm film is 15 metres long (50 ft) and runs through the camera at 18 frames per second, and has a continuous running time of about 15 minutes. An exposure of 1 second every 10 minutes allows such a film to record the events over a period of 150 hours, or about 6 days.

An interesting feature of timed photographic recording is that numerous simple (and inexpensive) instruments, such as clocks, thermometers, humidity meters, barometers, voltmeters, ammeters, etc can be placed in the field of view of the camera, allowing simultaneous recording of numerous variables.

Fig 2.3 shows the clarity of readings that can be obtained from photographic recordings and Fig 2.4 is a graphical representation of the load curve as determined for Tongaat-Maidstone using photographic recording.

FIGURE 2.3

PHOTOGRAPHIC RECORDING OF TYPICAL METERS



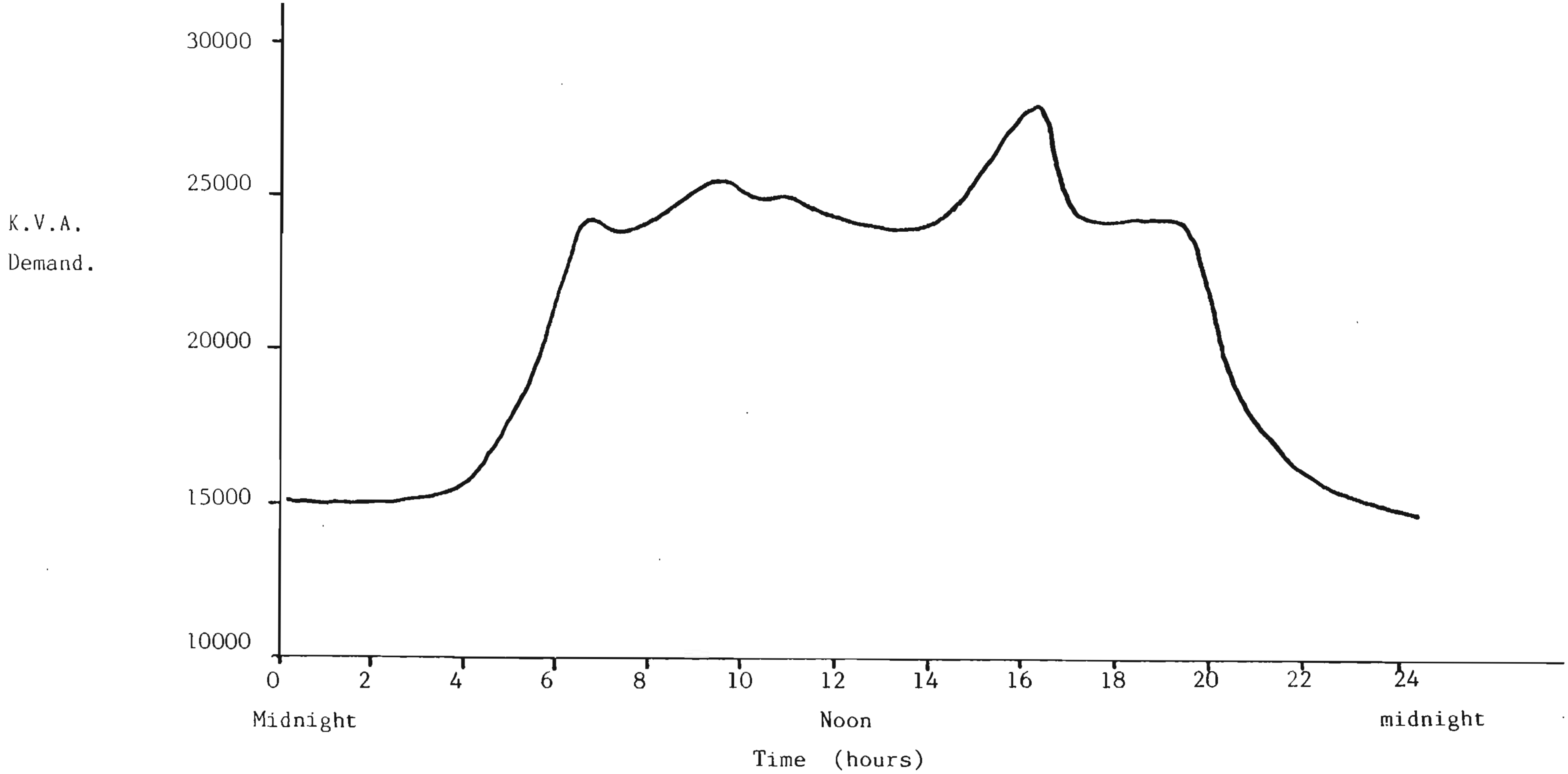


FIGURE 2.4

GRAPHICAL REPRESENTATION OF LOAD DEMAND FOR MAIDSTONE SUBSTATION : TONGAAT. BASED ON PHOTOGRAPHIC RECORDINGS.

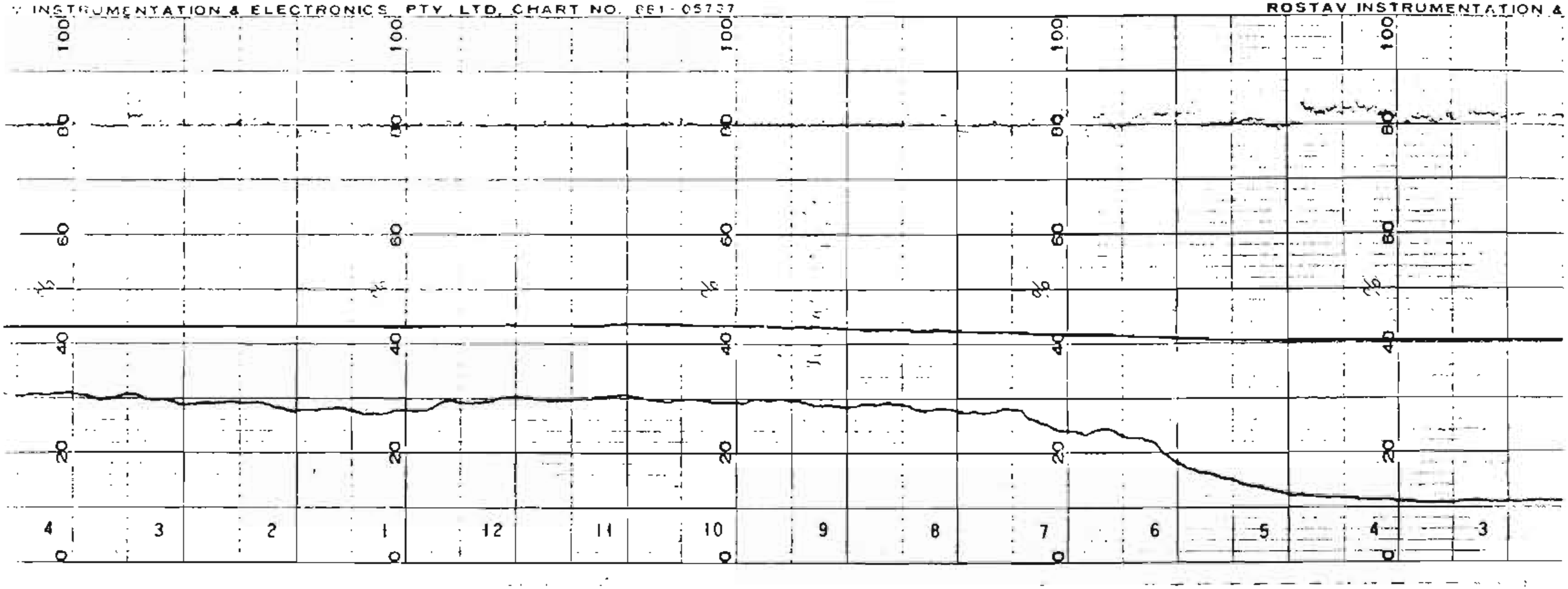
2.2.3 DATA CAPTURE : MULTIPLE-CHANNEL CHART RECORDERS

Multiple-channel chart recorders are frequently used for recording changes in load demand and weather-related variables. The results are accurate and easy to comprehend but requires expensive equipment and necessitates the installation of current transformers and transducer in the system network, which may require total shutdown for such installation. Normally, four, six or eight channel chart recorders are used and these channels will record KVA demand, voltage, current, temperature, humidity, air pressure, wind speed, wind direction etc. depending on the number of channels available.

Fig 2.5 shows the chart of a multi-channel recording taken at Tongaat Substation and Fig 2.6 is a graphical representation of the load curve determined from the chart recording.

2.2.4 DATA CAPTURE : COMPUTER RECORDING

The advent of micro-processors, and the accuracy obtainable from analogue-to-digital convertors has significantly improved the techniques of data/capture. Although it also requires the installation of current transformers and various transducers in the system, it allows for the simultaneous capture of data from a very large number of inputs, as for example 32 inputs for the microcomputer based recorder shown in Figure 2.7.



TOP TRACE : System Voltage

MIDDLE TRACE : Ambient Temperature

LOWER TRACE : System Load demand

FIGURE 2.5

PHOTOCOPY OF MULTI CHANNEL CHART RECORDING

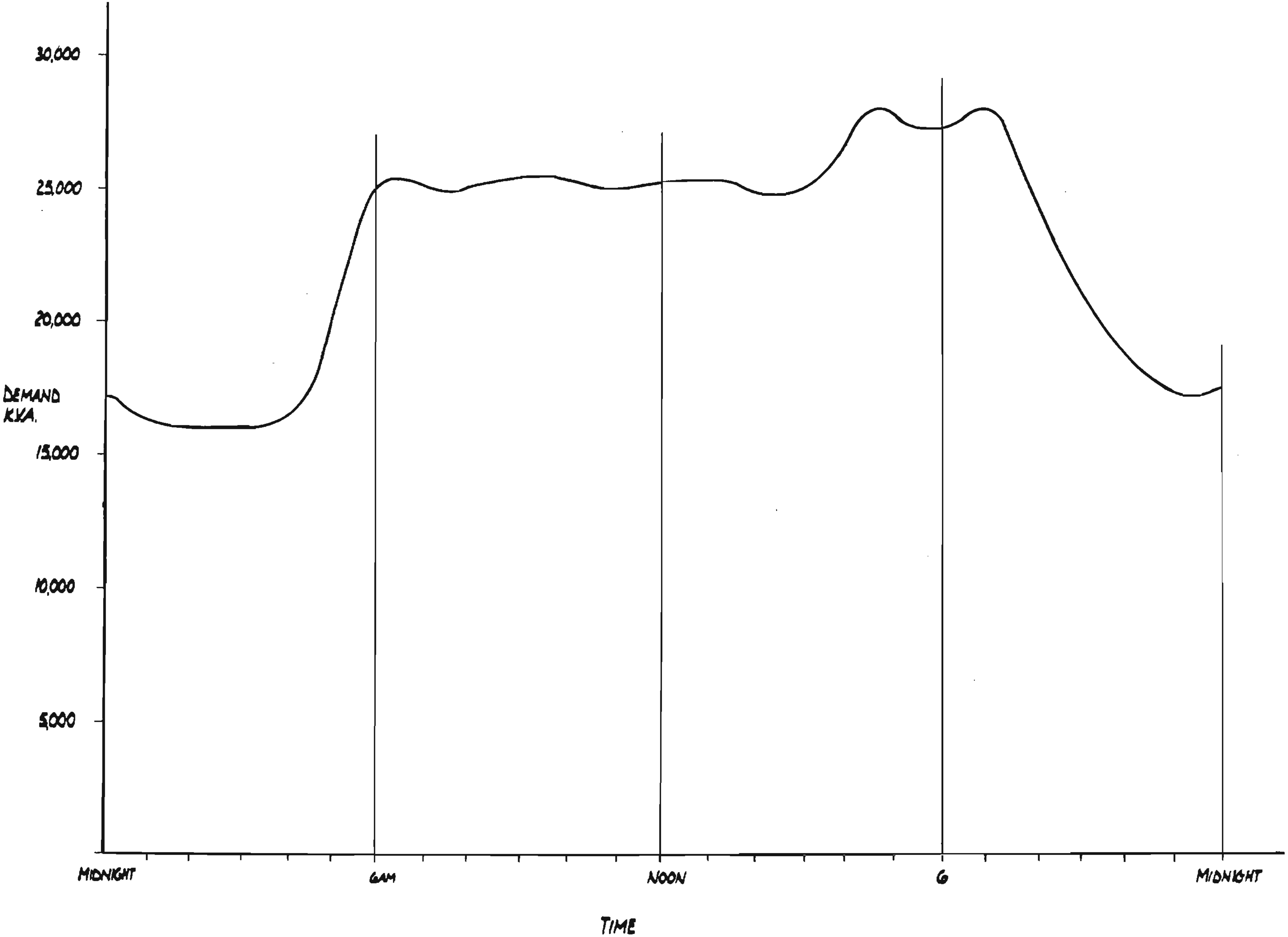
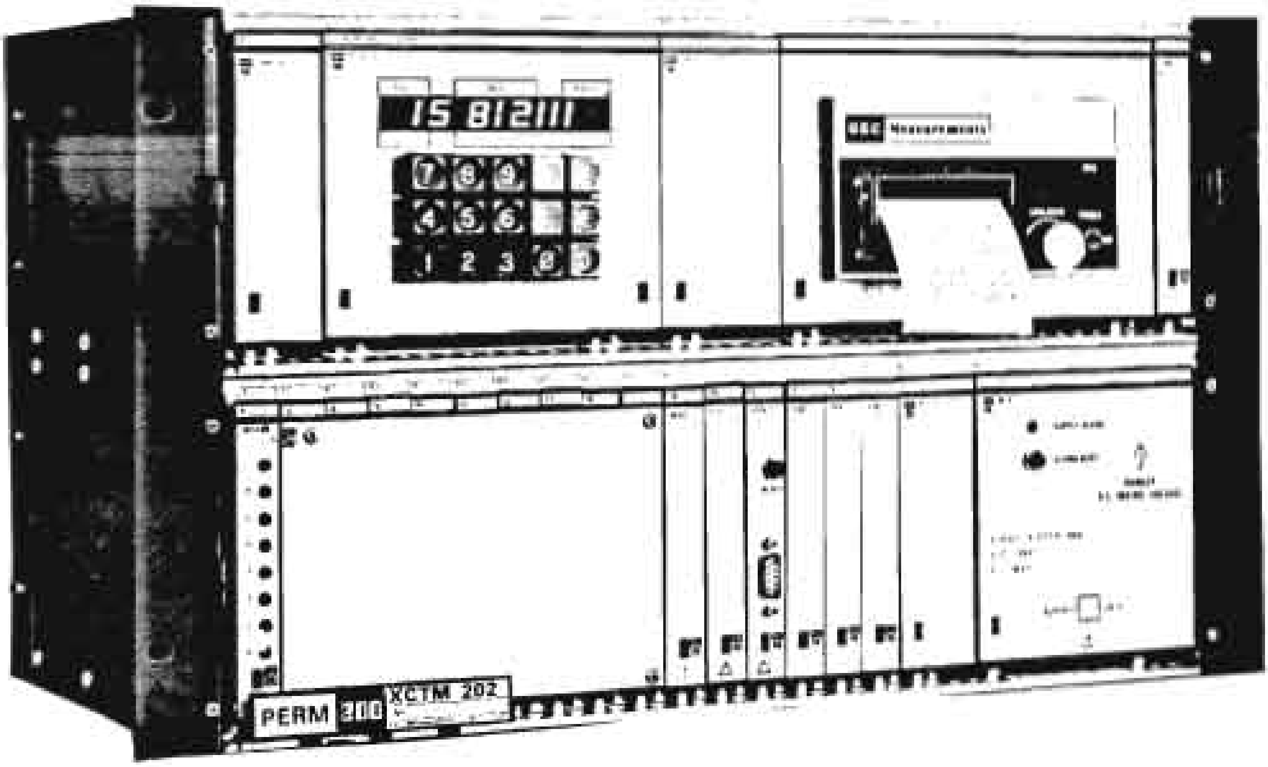


FIG 2.6 LOAD CURVE FOR TONGAAT SUBSTATION



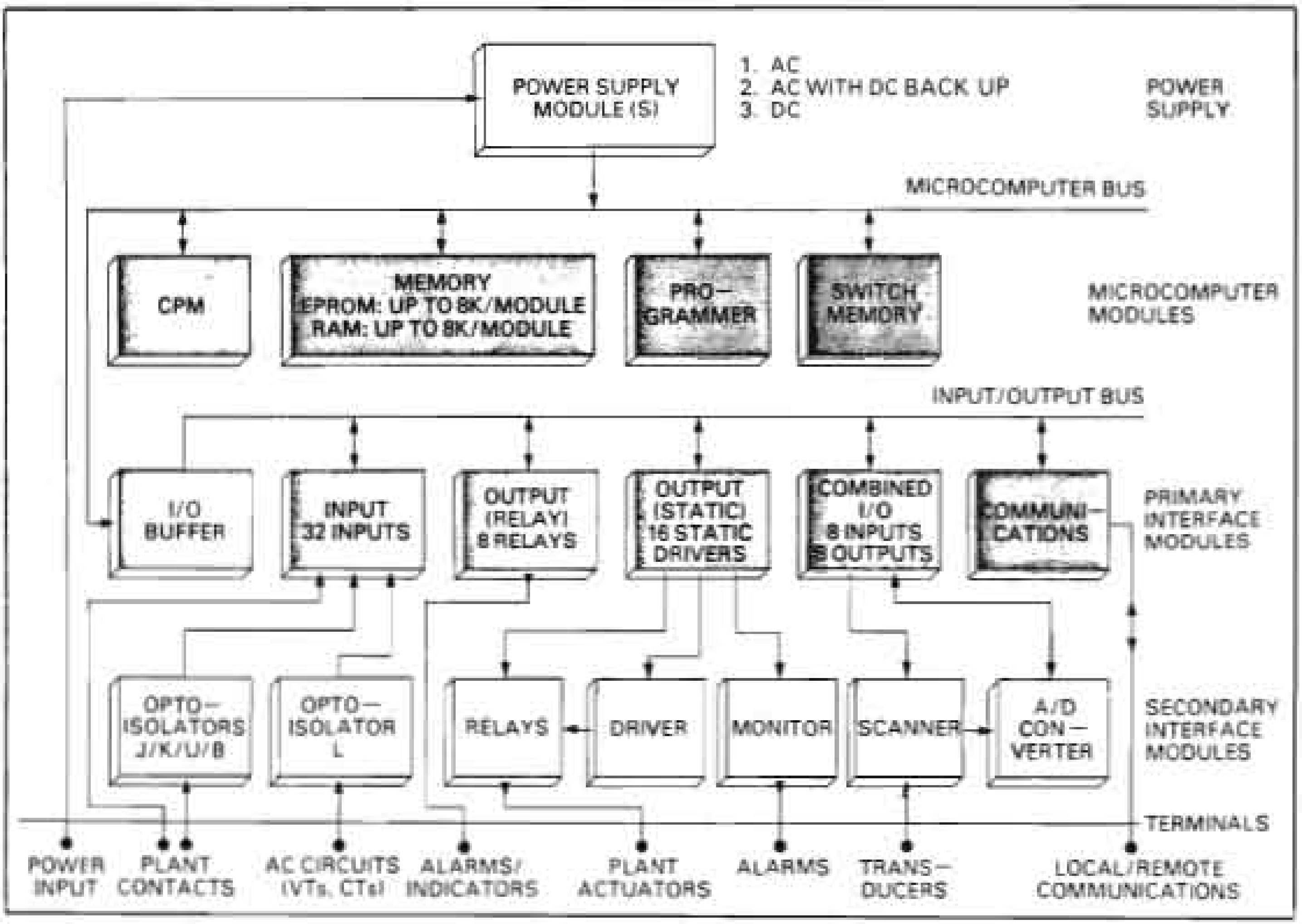


FIG. 2.7

MICROCOMPUTER - BASED RECORDING INSTRUMENT
COURTESY : G.E.C. MEASUREMENTS

2.3 ANALYSIS OF THE LOAD CURVE

The load curve is a graphical representation of the demand for power of the system over the relevant time period. Thus the daily load curve indicates the demand for power over the twenty-four hour period.

The daily load curve for Stanger is shown in Fig 2.2 ESCOM will charge the Municipality for the highest Demand recorded for any half hour period in the month. The extent to which this peak demand exceeds the average demand is of considerable concern to electricity planners, and represents a great waste of money, since the entire electrical reticulation network must be designed to carry this load, yet it is used only over relatively short periods. Also ESCOM charges R9.75 per KVA demand, irrespective of whether it is used for only half an hour or for the entire 720 hours in the month.

The "Load Factor" is one of the most commonly used ratios, and it is a clear indication of the under-utilization of the capital equipment installed to supply power at peak demand periods.

The load factor can be defined as the ratio of the average demand to the actual maximum demand. Under conditions of unity power factor, one KVA per hour equals one kWhr. The average demand is $\frac{\text{Energy Consumed}}{\text{Time}}$

Hence we have

$$\text{Load Factor} = \frac{\text{Actual energy consumed}}{24 \times 30} \times \frac{1}{\text{maximum demand}} \times 100\%$$

The load factor can also be defined as the ratio of the actual power consumed to the amount of power available at the maximum demand level over the relevant period.

Hence we have :

$$\text{Monthly Load Factor} = \frac{\text{Actual Energy consumed in month}}{\text{Maximum demand} \times 24 \times 30} \times 100\%$$

which is the same as previously derived.

$$\text{Annual Load Factor} = \frac{\text{Actual Energy consumed in year}}{\text{Highest Maximum Demand} \times 24 \times 365} \times 100\%$$

The annual load factors for various municipalities is shown in Table 2.2.

TABLE 2.2

ANNUAL LOAD FACTORS FOR VARIOUS MUNICIPALITIES

Town	Number of Consumers	Annual Load Factor
Alberton	13 221	45,5%
Bethlehem	3 438	42,5%
Bloemfontein	26 255	47,7%
Brandfort	681	26,0%
Carltonville	5 515	44,5%
Carolina	693	37,9%
Dewetsdorp	328	35,6%
Eshowe	1 636	47,7%
Johannesburg	106 374	48,8%
Kimberley	15 667	48,9%
Krugersdorp	17 987	50,6%
Louis Trichardt	1 350	49,2%
Pietermaritzburg	34 076	51,9%
Sasolburg	6 320	37,8%
Springs	16 497	66,9%
Warmbad	1 077	58,9%
Germiston	24 300	49,0%
Pretoria	107 765	54,6%

EXTRACTED FROM TABLE B : SOUTH AFRICAN MUNICIPAL YEAR BOOK, 1981-82, PAGE 198.

It is primarily the low level of activity at night that causes the low load factors indicated above. If domestic activity starts at 6.00 a.m. and ends at 9.00 p.m., then if power was used at a constant rate over this period the load factor cannot be greater than 15 ÷ 24 = 0,625 or 62,5%. Since meal preparation and evening bathing causes power to be used unevenly during the day it follows that the load factor will be somewhat less than 62,5% for a residential area.

Similarly, a large factory which works day-shifts only of 9 hours, for five days a week, will have a load factor at best of (9x5) ÷ (7x24) = 0,268 or 26,8%

These figures are important to tariff-designers since they indicate to what extent capital equipment is utilized. Towns with low load factors must have slightly higher tariffs to recover the capital outlay, and conversely, towns with high load factors can reduce their tariffs since less capital equipment is required to meet the energy requirement.

2.4 SEGMENTING THE CUSTOMER MARKET

Ideally, each commodity should have only one selling price. In many countries this ideal is set in legislation. For example, in the United States of America, under the Robinson-Patman Act the seller cannot charge different prices to comparable customers unless the price differences are based strictly on cost differences.[1.]

The sale of electricity is in fact a very complex matter. What is the customer paying for? Is it the actual energy consumed? Or is it the convenience of being able to switch any appliance on without any other consideration? Or is it to be based on the number of appliances which may be turned on at the same time? Should richer and poorer consumers have the same tariff structures? If the capital costs are averaged out and recovered on the average units sold, then should excess units be sold cheaper since fixed costs have already been recovered? This will mean that richer consumers who use more electricity, get the additional units cheaper making their average cost per unit cheaper than that for their less fortunate fellows.

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1. KOTLER, Ibid, p. 389.

Is this discrimination acceptable? If industry is in business to make money should it be called upon to pay higher charges for electricity than those sections of the community which are not able to benefit financially from its use? To what extent should consumers living outside the municipal area have to contribute towards the operating surplus which will be used only to the benefit of the municipal ratepayers?

It can be seen from the above that many of the choices which the pricing authorities have to face are mutually exclusive, but are not unique. Therefore there is no concensus as to what constitutes the ideal tariff structure. It also follows that the optimum selection of numerous pricing alternatives may suit one category of customer, but may not be the best arrangement of alternatives for another category of customer. It is therefore widely accepted that the best solution is to segment the customer market into groups (or categories) which have similar needs and which exhibit similar load patterns. Each category or consumer group can then be viewed separately and tariffs can then be designed to cater for the specific needs, and more importantly, specific tariff categories can allow the supply authority to encourage selected groups to reduce load at system peak periods with incentive-based tariffs, which if applied universally, would result in other groups being penalized needlessly.

By segmenting the consumers a lower tariff can be made available to those consumers who do not add to the peak, and incentive rebates can be made available to those consumers who can reduce load during peak periods.

The consumers can be successfully segmented by presenting them with numerous alternative tariffs, many of which will contain time-based information, and the individual consumers will study their own load requirements and by selecting the appropriate tariff they automatically join other similar consumers, to form the segmented sub-group.

It is evident that the system used to segment this customer market has to relate the demand curves of the customer to the daily, weekly, monthly and yearly demand curves of the system, and so to identify those consumers whose load peaks coincide with the system peaks, those whose load peaks are displaced off the system peaks, and those who have flat load curves. Each of these major sub groups is further segmented into those consumers who can shift load at system peak periods, and those whose loads are fixed at peak periods.

Durban Corporation Electricity Department has a very sophisticated segmented tariff system comprising some twelve major tariff structures of which four are time-based. The present tariffs are shown in Table 2.3 (page 2.23) and it can be seen that whereas the usual Business & General consumer is charged 5,75 cents per kWhr unit, a consumer who arranges to do industrial heating during off-peak periods is charged only 2,3 cents per kWhr unit, which is a savings of 60%.

TABLE 2.3

SW/5342E

DURBAN CITY COUNCIL - ELECTRICITY UNDERTAKING

SCHEDULE OF ELECTRICITY CHARGES

BYLAWS TARIFFS

Tariff	Voltage	Charge per kWhr.	Monthly Minimum Charge Equivalent to	Monthly Service Charge	Regional Surcharges
Business & General	220/380 6 600 & 11 000	5,75 cents	-	R7,50	Durban City - Nil 'A' Areas - 5% 'B' Areas - 10%
Residential	220/380	Single Phase First 100 @ 6,00 cents Next 500 @ 3,00 cents Remainder @ 2,70 cents	First 100 kWhr	-	Durban City - Nil 'A' Areas - 7,5% 'B' Areas - 15%
		Three Phase First 100 @ 8,50 cents Next 500 @ 4,50 cents Remainder @ 2,70 cents	First 100 kWhr		
Business Cooking		3,20 cents	-	R6,00	Durban City - Nil 'A' Areas - 5% 'B' Areas - 10%
Industrial Heating Water Heating & Pumping		Supply restricted for 3 hours per day - 2,80 cents Supply restricted for 6 hours per day - 2,30 cents	R3,00 per kW of installed capacity but not less than R10,00	Time switch rental R6,00	Durban City - Nil 'A' Areas - 5% 'B' Areas - 10%

NOTE: All energy charges subject to coal cost adjustment

Industrial Heating, Water heating and Pumping -Hours of Restriction:- Scales 6 & 7 - 15h30 to 18h30
Scale 7 only - 07h30 to 10h30

SW/5342E

TABLE 2.3 (CONTINUED)

DURBAN CITY COUNCIL - ELECTRICITY UNDERTAKING

SCHEDULE OF ELECTRICITY CHARGES FOR BULK SUPPLY AGREEMENTS.

Tariff	Voltage	Demand Charge per kVA	Discount per kVA of restriction between 16,30 and 18,30	Energy Charge per kWhr	General Discount %	General Discount Subject to Notified Minimum Demand of	Minimum Demand Charge = Demand Charge on
L.V. 3 part	380	R9,15	R2,05	1,33 cents	1	2 000 kVA	Service Charge R25,00 per mth
[illegible] 3 part	6 600 and 11 000	R8,90	R2,05	1,30 cents	1 2 3 4 5	2 000 kVA 4 000 6 000 8 000 10 000	1 000 kVA
S.T. 3 part	33 000	R8,65	R2,05	1,28 cents	1 2 3 4	4 000 kVA 6 000 8 000 10 000	2 000 kVA
L.V. 2 part	380	R5,80	-	First 5 000 @ 5,57 cents Next 10 000 @ 3,55 cents Remainder @ 2,15 cents	1	2 000 kVA	Service Charge R25,00 per mth
H.V. 2 part	6 600 and 11 000	R5,60	-	First 5 000 @ 5,54 cents Next 10 000 @ 3,52 cents Remainder @ 2,12 cents	1 2 3 4 5	2 000 kVA 4 000 6 000 8 000 10 000	1 000 kVA
Large Users 2 Part No. 1	33 000 and 132 000	R7,35	-	1,27 cents	-	-	22 500 kVA
Large Users 2 Part No. 2	6 600 and 11 000	R7,70	-	1,28 cents	-	-	15 000 kVA
Large Users 2 Part No. 3	6 600 and 11 000	R8,05	-	1,28 cents	-	-	10 000 kVA

NOTE:
(i) All energy charges subject to coal cost adjustment
(ii) Three part tariffs offer special charges for excess night and weekend demands
(iii) All tariffs are subject to 8,5% overall surcharge w.e.f. 01.08.1982.

2.5 MARKET SEGMENTATION, TIME BASED TARIFFS AND THE SYSTEM LOAD CURVE

The undertaking purchases electricity from ESCOM and sells it to the Consumers. The purchase cost of electricity from ESCOM is roughly R10.00 per KVA, plus 1 cent Kwh unit.

Most municipalities simply apply a fixed percentage markup to the ESCOM tariff to determine their selling tariff.

The main disadvantages of this simple two-part tariff is that it does not contain any demand-conservation information for the consumer, and is definitely not the best priced tariff for many consumers. Fig 2.8 shows the typical load curve of the Undertaking. The two part tariff does not inform the consumer that the system experiences peaking at certain times, and does not present him with a benefit if he arranges to remove load during peak periods.

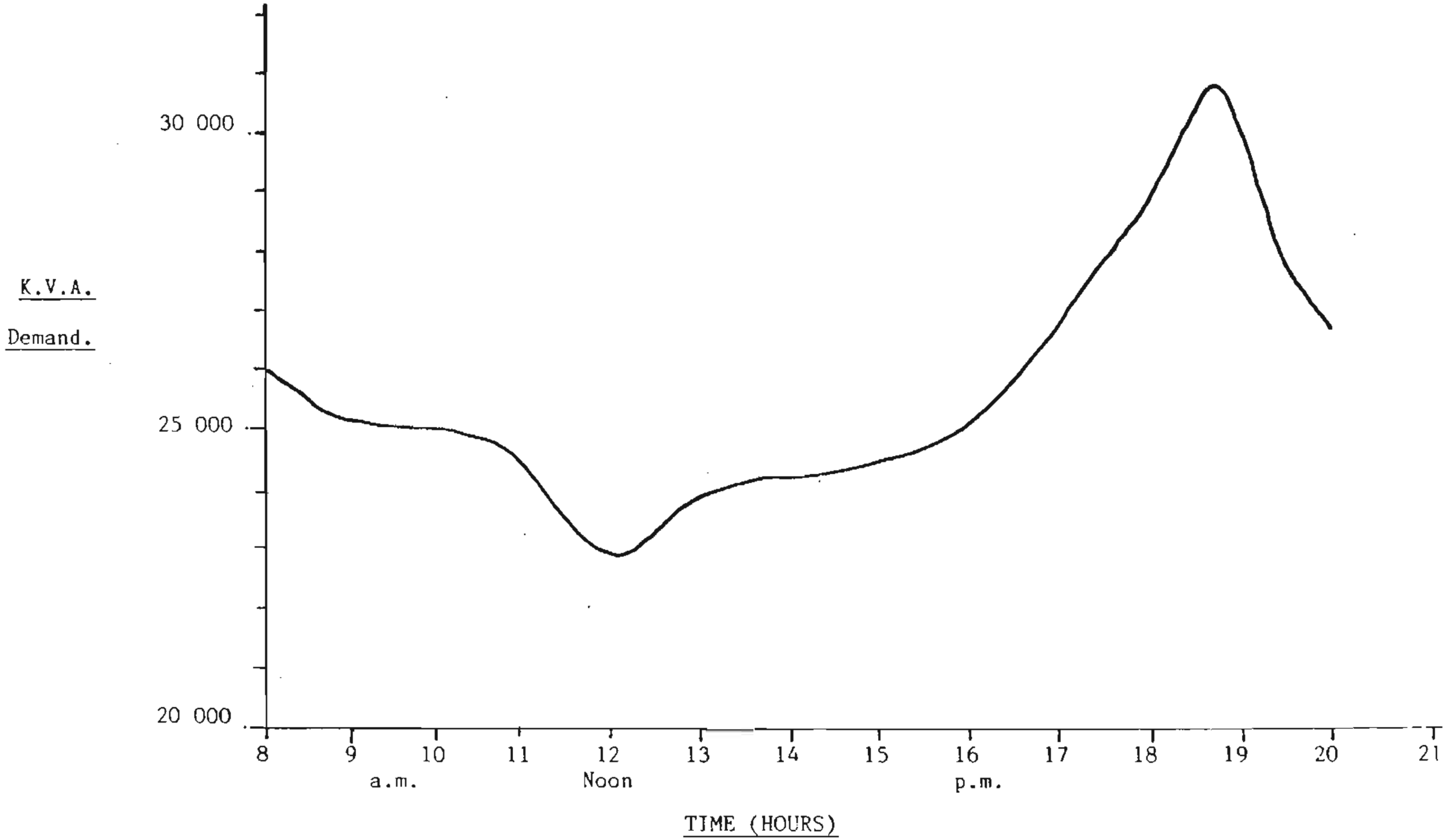

FIGURE 2.8

TYPICAL LOAD CURVE OF UNDERTAKING

The extent to which time-based tariffs can benefit both the consumer and the Undertaking can be illustrated by the following example investigated for the Stanger Municipality.

Stanger Municipality presently uses a simple two part tariff for the sale of electricity. The Stanger load curve is shown in Fig. 2.9.

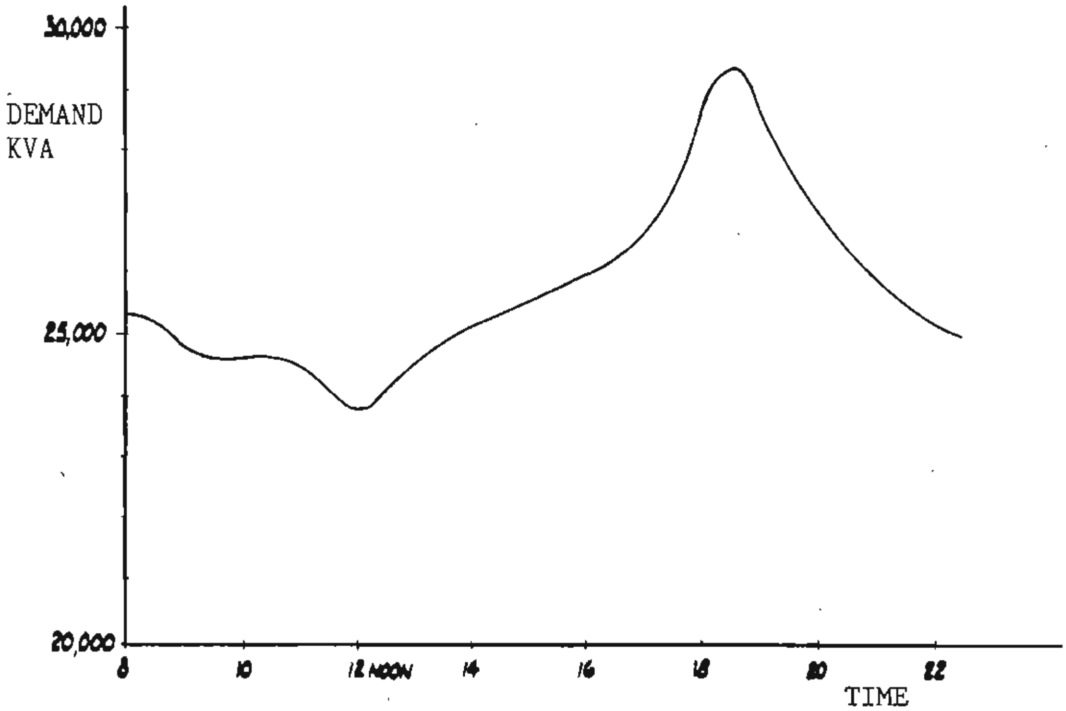

FIG. 2.9

DAILY LOAD CURVE FOR STANGER

One of its main consumers, Gledhow Sugar Mill, generates its own electricity during the crop season, but reverts to municipal mains on every other Monday, while its generating plant is serviced. Since the tariff is not time-based, it does not affect Gledhow Sugar Mill if they run into the peak period before switching back to their own supply. However, if they run into the peak period, it increases the ESCOM-measured peak and the town loses a great deal of revenue to ESCOM.

The actual times that Gledhow Sugar Mill switched back to their own supply is shown in Table 2.4.

Date	Time	Load (KVA)
23.5.83	17.20	1560
7.6.83	14.50	1600
21.6.83	14.30	1500
5.7.83	16.00	1500
19.7.83	15.30	1440
2.8.83	14.25	1440
15.8.83	16.35	1450
30.8.83	17.40	1440
12.9.83	15.00	1440

DATES, TIMES AND LOAD WHEN GLEDHOW SUGAR MILL REVERTED TO ITS OWN SUPPLY

TABLE 2.4

The Stanger load curve, shown in Fig 2.9shows that their main peak commences at about 16.30 hrs. A study of the above table shows that Gledhow Sugar Mill adds its load to the peak for only a few minutes each month, yet ESCOM will charge Stanger for this demand as if it had been used the whole month. Discussions with Gledhow's Engineers established firmly that it is the lack of time-information in the tariff that caused them to change over at any arbitrary time in the afternoon. Their Engineers have confirmed that if a three part tariff was introduced, which gave them a rebate of say R4.00 per KVA saved after 16.00 hr, then they would ensure that they are off municipal supply by then,which would save them R6000.00 per month, and would save Stanger R15000.00 per month. (1500 KVA @ R10.00 from ESCOM).

It should be evident that the more sophisticated tariff structures are of benefit to both the consumer and the municipality.

2.6 MODIFYING CONSUMER BEHAVIOUR : LOAD MANAGEMENT

For all practical purposes electricity cannot be stored. In order to meet the increasing peak demand it is necessary for the supply authorities to construct "Peaking Stations". These peaking stations are only operated for short times during the peak period, and in South Africa the peaking plant consist of conventional hydroelectric, gas turbines, coastal coal power stations, and pumped storage. In this latter method, off-peak power is used to pump water to a higher dam, and to convert this stored energy into electricity via turbine alternators when it is required.

The largest pumped storage scheme in Europe is Dinorwig which has a capacity of 1800 MW and was constructed at a cost of £425-Million.[2.]

ESCOM recently commissioned its Drakensberg Pumped Storage Scheme which has a hydroelectric component of 540 MW.[3.] Plans are under way for a pumped storage scheme in the vicinity of the Palmiet River in the Western Cape. This will be capable of generating 400 MW and will cost an estimated R233 million.[4.]

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2. Knoll, D. Dinorwig - Europe's largest pumped Storage power Station", February 1985, p. 34.
3. Van Robbroek, T.P.C., "The Drakensberg Project : Water and Power for South Africa". The Transactions of the S.A. Institute of Electric Engineers, August 1982, p. 132.
4. "New hydro scheme for Western Cape" ESCOM News October 1982 Number 1 p. 13.

These are joint ventures by ESCOM and the Department of Environment Affairs, where ESCOM is responsible for the construction of the power stations, and the Department of Environment Affairs for the building of the reservoirs.

Cape Town itself recently commissioned its Steenbras pumped storage scheme with a rating of 50 MVA at a cost of R63,9 Million.[5]

Due to the high capital cost required to meet the increasing peaks, attempts are being made by numerous supply authorities throughout the world to influence the behavior patterns of its consumers. This is increasingly being referred to "Load Management". Load Management refers to any sustained attempt aimed at modifying or controlling the load curve, to reduce the maximum demand, and these measures may be characterised as "hard" or "soft".

The "soft" categories covers the range of economic incentives, such as time-of-day pricing etc. The "hard" kind of load management actually controls customer loads with radio or ripple control. Hard control also covers network voltage reduction methods, and peak demand augmentation schemes.

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5. ARGENT , G.G.R. "Steenbras pumped storage scheme" The transactions of the S.A. Institute of Electrical Engineers, March 1981, p. 47.

2.7 SOFT LOAD MANAGEMENT AND DOMESTIC CONSUMERS

Domestic consumers are forced by rigidly applied behaviour patterns to undertake similar activities at almost identical times. These activities include meal preparation, washing up, bathing, etc. The rigidly enforced behaviour patterns are the fixed times that school starts and ends, the "normal" working hours, the time that evening T.V. commences, etc.

It is therefore unrealistic to expect domestic consumers to spread their electrical loads uniformly over the day. Equally, the social factors involved are such that no amount of incentive tariffs will entice them to shift the bulk of their loads. For example, if a tired and dirty worker arrives home and normally has a shower before settling down in front of T.V., it is unlikely for a few rands rebate, that he will postpone his shower until after the peak period, say 9.00 p.m.

It is for these reasons that domestic loads do not respond well to soft load management. Nevertheless there is a component of the domestic load which can be shifted out of the peak period, provided sufficient incentive if offered.

Due to the increasing use of energy-intensive electrical appliances, such as high speed kettles, microwave ovens, instantaneous water heaters, rapid air coolers etc, the instantaneous maximum demand of domestic consumers is reaching very high levels. For example, Durban Corporation will install 80 Amp circuit breakers for normal householders. This is equivalent to 18 KVA demand. The average number of kWh units consumed by domestic consumers is about 1000 per month.

The load factor per consumer is therefore about 7,5%. However, the time required to boil a kettle of water, or to heat up a high-speed steam iron, or to prepare a complete meal in a microwave oven, is actually very short, and since numerous factors determine the exact time that any activity takes place it follows that, although these activities are confined to a few hours each day, a considerable amount of diversity will take place. For example, the peak period may be two hours, while microwave cooking takes 10 minutes, and boiling a kettle of water takes 3 minutes.

From these considerations it follows that the combined load of numerous domestic consumers will definitely peak at this time, but by using high speed appliances each consumer uses about 20 minutes of the two hour peak period, which effectively reduces his diversified maximum demand to less than one-sixth of its instantaneous value (i.e. five other consumers can use the same demand for 20 minutes each consecutively).

Numerous recordings taken at substations in Mooi River, Stanger, Kokstad and Tongaat indicate that the diversified average maximum demand of domestic consumers is about 2,5 KVA. (compared to the 18 KVA actually consumed for short periods. This means that only one house out of every 6 or so is actually consuming maximum power for short periods in the two hour peak period).

These considerations lead to a conclusion which could be of considerable benefit to consumers in numerous towns which use restrictive tariffs such as Stanger, Ballito, Kokstad and others.

Consider the following argument :

1. The peak period is determined by factors such as normal working hours, accepted times for meals, commencement of serious T.V. viewing etc. This means that invariably the domestic peak commences at about 4.30 p.m. when workers return home, get cleaned up, prepare meals etc, and the peak ends at about 7.30 p.m. by which time most cooking has been completed, coffee and tea has been made, dining room and kitchen lights can be turned off etc.

2. Irrespective of the energy source or the tariff structure,

an almost fixed amount of energy is required during this peak period per householder to cook the meal, boil the kettle, draw hot water etc. This amount of energy is about 9 kWh per householder over the peak period. This concept of a fixed energy requirement is very often misunderstood. It should be noted that to heat one litre of water from room temperature of 25°C to 100°C will require 75 kilojoules of energy irrespective of whether it is done within a few mintues in a high speed kettle, or over a longer period on a slow stove. The higher energy source is simply used for a shorter period.

3. Given the above two statements that :

   (a) The peak period is fixed, and exists for three hours.

   (b) The amount of energy each householder uses during the peak period is fixed at 9 kWhr.

then it must follow that the diversified average maximum demand for a number of consumers must be (9kWhr÷3 hrs) = 3 KVA

This is a very important conclusion with far reaching implications, because many municipalities, in an attempt to reduce the overall load peak, limit the size of the householder's main circuit breaker to 20 or 25 Amps, in the mistaken belief that these current-limiters must reduce the peak that would otherwise occur if 80Amp breakers were installed. They reason that the instantaneous maximum demand of an 80 Amp breaker is (80 x 230) = 18,4 KVA whereas for a 20 Amp breaker it is limited to (20 x 230) = 4,6 KVA.

The fact of the matter is that the higher demand is used for a shorter period, as argued above, leaving more time for other high-demand consumers, so that the overall average is not affected, and remains about 3 KVA.

To prove the above theory, load demand tests were carried out over a period of three months at Stanger and Tongaat. These two towns were selected for the following reasons :

1. The two towns are geographically in very close proximity to each other, being separated by only 50 km. They are both within 10 kilometres of the coast. The two towns will therefore experience virtually identical weather conditions over the period.

2. The two towns are of roughly equal size and comprise very similar population groups with respect to race, cultural background, stage of development etc.

3. The fundamental difference lies in the electricity tariff applied to domestic consumers. Tongaat has an unrestricted tariff system and installs 80 Amp circuit breakers for domestic consumers. Stanger, in complete contrast, has a very restrictive tariff system, and installs typically 20 Amp circuit breakers and in addition, installs a load shedding device which switches the water-geyser off when other appliances are used.

The following load demand test was carried out to determine whether the restrictive current limiter in fact reduces the system peak.

2.7.1 DESCRIPTION OF LOAD DEMAND TEST

At a substation supplying 45 domestic consumers in Stanger, a combination maximum-demand/energy meter was installed, and was monitored by the Stanger Municipality Electricity Department over a three month period.

At Tongaat, a similar substation in a domestic suburb supplying 42 domestic consumers was selected and a similar combination maximum-demand/ energy meter was installed, as was monitored by the Tongaat Town Board Electricity Department over the same three month period.

Typical readings obtained are shown in Table 2.5 which reveals some very interesting facts.

Firstly, the highest demand occurred at both substations on the same day. This clearly illustrates the dependence of the maximum load on external factors, such as weather conditions, etc. Secondly, it is evident that Stanger has a higher maximum demand per householder than Tongaat although Stanger is the one who is actively attempting to reduce the peak by restrictive measures.

Test No	Date	Tongaat Watsonia Substation		Stanger Radiyat Substation	
		Total 42 Houses KVA	Demand per house KVA	Total 45 Houses KVA	Demand per house KVA
1	13.1.84	88.8	2.1	105.6	2.34
2	16.1.84	79.2	1.88	94.4	2.09
3	17.1.84	79.2	1.88	96.0	2.13
4	18.1.84	82.8	1.97	110.1	2.45
5	19.1.84	84.0	2.0	112.0	2.48
6	23.1.84	96.0	2.29	114.0	2.53
7	1.2.84	84.0	2.0	111.0	2.46
8	6.2.84	86.4	2.05	112.0	2.48
9	14.2.84	86.4	2.05	108.0	2.41
10	25.2.84	81.6	1.94	101.0	2.24
11	20.2.84	84.0	2.0	110.0	2.45
12	21.2.84	81.6	1.94	112.0	2.48

COMPARISON OF MAXIMUM DEMANDS PER HOUSE AT STANGER AND TONGAAT FOR VARIOUS DAYS

TABLE 2.5A

	Tongaat	Stanger
Total energy consumed over above period of 38 days	34560 kWh	37348 kWh
Average energy consumed per house :	650 kWh/month	655 kWh/month

COMPARISON OF ENERGY CONSUMPTION PER HOUSE PER MONTH

TABLE 2.5B

The average demand per consumer in Tongaat is 2,29 KVA, whereas in Stanger it is 2.53 KVA.

It is obvious that restrictive tariffs do not reduce the diversified average maximum demand.

The fact that it is indeed higher (and similar increases were noted by the author for Kokstad when compared to Mooiriver) may be due to the fact that the restricted demand usage (in Stanger) forces the consumers to maintain their maximum loads for the entire period, giving the slow-acting demand meter ample time to respond to the actual maximum, whereas the unrestricted use of power (in Tongaat) is for such short periods that the thermal maximum demand meter does not respond fully to the actual maximum.

It would be of tremendous benefit to thousands of consumers if municipalities were to accept the above conclusion. It is extremely annoying, demoralizing and frustrating to be locked into a current-limiting tariff.

Consider the following :

TABLE 2.6

Typical current requirements for domestic Appliances

10 lamps of 100 watts	5 Amps
Kettle	8 Amps
Iron	5 Amps
Stove (2 plates)	10 Amps
Oven	15 Amps
Vacuum cleaner	5 Amps
Air Conditioner (or heater)	10 Amps

If you are restricted to 20 or 25 Amps, then clearly you have to select carefully between the appliances you can switch on at the same time, which can be most annoying if more than two people are involved. And who benefits? According to the results of the tests everyone loses. The consumers are put to a lot of inconvenience, the maximum demand is not reduced, and the profitability of the undertaking actually drops, since the amount of units sold actually decreases while the demand remains unchanged. The municipal undertakings and the consumers would all benefit if restrictions on domestic consumption were removed.

2.7.2 TIME-OF-DAY TARIFFS FOR DOMESTIC CONSUMERS

Domestic Consumers prefer to operate appliances simultaneously, and hence create a peak. This is due to the fact that labour-saving devices need to be monitored but do not require full time attention. The result is that the person decides to utilize his/her time more efficiently and operates several appliances simultaneously. For example, a housewife may load clothes into a washing machine and set for a hot-water wash cycle. While this is in progress she may load the dish-washer and set this too on a full wash cycle. While she is waiting, she may decide to par-cook the evening supper. While keeping an eye on all these activities she may decide to iron some clothes. At the end of the wash cycle she may load the washing into a tumble-drier and while it is drying, she may load a second wash in the machine before resuming her ironing. She may even decide to switch the kettle on for some tea while all this is taking place.

As the labour saving decices become more efficient (on saving labour) the user tends to operate more of them in order to utlize her time as effectively as possible.

In the absence of any other considerations the above behaviour pattern tends to cause the system to experience considerable peaks at certain times, since external trigger mechanisms will cause numerous domestic consumers to operate appliances at the same time. These external triggers could be such things as "convenient times" at mid morning, the arrival home of numerous working housewives, deadlines set by the commencement times of favourite T.V. programmes etc.

There are two methods which can be employed in an attempt to reduce the resulting peak. Firstly, current limiters can be used which will prevent the consumer from operating a large number of appliances simultaneously. This method has a large number of disadvantages viz :

a) As shown in section 2.7.1 the use of restrictive tariff structures reduces the individual maximum demand but does not reduce the diversified maximum demand of a residential area, and therefore serves no purpose.

b) The consumer is denied the opportunity of operating numerous appliances (user efficiently) even at off-peak periods.

c) The consumer receives no incentive to shift load out of the peak period.

A second method which is being used to reduce the peak created by domestic consumers, (and one that is gaining worldwide support) is to provide large amounts of power to domestic consumers at cheaper rates during off-peak periods, and to limit the amount of power available to them only during system peak periods. The advantage to the domestic consumer is that high activity periods will still be possible at off-peak periods.

At least two large scale applications of this method are presently being undertaken. The South California Edison Company recently installed a demand limiting service for 1000 000 residential consumers which is expected to reduce the peak by 140 MW.[6.] In this scheme, the customer can choose his own level of service for peak periods. The lower he sets this figure, the greater is the incentive rebate. This level of service is only a constraint during system capacity peaks; at all other times it is overridden by a remotely controlled switch, allowing the consumer unrestricted consumption at off-peak periods.

In the U.K., Britains Electricity Council has installed some 2000 microprocessor-based radio teleswitches for nation-wide tariff switching trails. The intention is to remotely switch multiple time-of-day and seasonal tariffs to allow control by providing the customer with more price signals which will hopefully motivate him to move some of his load to cheaper off-peak periods.[7.]

2.8 SOFT LOAD MANAGEMENT OF COMMERCIAL CONSUMERS

Incentive tariff structures must be carefully designed and intelligently worded to ensure that they can be applied easily by non-technical commercial consumers. It is not sufficient to simply state that an incentive is available for demand reduction in the peak period,

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6. "California backs load Management to trim System Peaks", Electric Review, Vol. 211, No. 4, 1982

as it does not contain user-information. Technically worded tariff structures in terms of KWhr, KVA, restricted periods etc, have been found to have an intimidating effect on commercial consumers and they are extremely wary of these tariffs.

Incentive tariffs for commercial consumers should therefore clearly indicate their specific uses. The following extracts from Table 2.3 demonstrates how Durban Corporation draws attention to its off-peak tariffs :

	Tariff	CHARGE PER KWhr
a)	Business & General	5,75c
b)	Business Cooking	3,20c
c)	Industrial Heating	Supply restricted for 3 hours per day
	Water Heating	2,80c
	and pumping	Supply restricted for 3 hours per day
		2,30c

TABLE 2.7

EXTRACTS FROM DURBAN CORPORATION ELECTRICITY TARIFFS ILLUSTRATING THE WORDING

As Turvey and Anderson put it "Finally it is evident that consumers must have an understanding of what it is they are being charged for. A high rate provides both a message that special economy is called for an encouragement to do something about it. But consumers by themselves may not understand the message and may not know how to do anything about it. They need help, and it is part of the job of the electricity enterprise to provide it. Tariff making very much needs to be supplemented by technical advice. For large consumers, the advice of commercial engineers is needed. For small consumers individual advice is not practicable, and, though tariffs are already simple, a certain amount of advertising still may be required. By helping consumers adapt to the tariff structure, electricity companies help themselves"[8].

As electricity becomes more expensive one can expect that increasing use will be made of incentive tariffs.

2.9 SOFT LOAD MANAGEMENT AND INDUSTRIAL CONSUMERS

Industrial Consumers (sometimes referred to as Large Power Users) differ from Commercial consumers in that they invariably have full time electrical engineers on their staff. This means that, unlike the commercial consumer, it is generaly sufficient to state the incentive tariff in technical terms. The firm's electrical engineer can easily and readily indentify plant and equipment which can be scheduled for operation during off-peak periods, and he is best suited to present proposals for load-shifting to his superiors. It is nevertheless, equally important for the undertaking to market its rebate tariffs to these plant engineers. There is ample evidence in practice and in the literature which supports soft load Management.

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8. Turvey, R and Anderson D., "Electricity Economics", World Bank Research Publication, John Hopkins University Press, 1977, p. 17.

The response of larger customers of the Pacific Gas and Electric Company, San Francisco, California, to time-of-use rates was investigated by S.P. Reynolds and T.E. Creighton.[9.]

The old tariff for PG&E was a flat two part tariff of approximately $3.00 per KVA (from 6.30 a.m. till 10.30 p.m.) and 2,5 cents per KWhr.

The new time-of-use tariff for winter months is shown in Table 2.8 below.

Time-of-use	Cost per KVA	Cost per KWhr
10.30 p.m. till 8.30 a.m.	Nil	2,25 cents
8.30 a.m. till 4.30 p.m.	$0.28	2,45 cents
4.30 p.m. till 8.30 p.m.	$2.50	2,65 cents
8.30 p.m. till 10.30 p.m.	$0.28	2,45 cents

TABLE 2.8

SCHEDULE OF TIME-OF-USE TARIFFS FOR PG&E

Source : Reynolds, S.P., and Creighton T.E., Ibid, page 149.

The above tariff structure identifies the peak period, partial peak periods and off peak period.

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9. REYNOLDS, S.P., and CREIGHTON, T.E., "Time-of-use Rates for very large Customers on the Pacific Gas and Electric Company System", IEEE Transactions on Power Apparatus and Systems, Vol PAS-99, No. 1. Jan/Feb 1980, p. 147.

These authors reported that generally speaking the shorter peak period of the time-of-use schedule have made it economical for firms to shift load and a significant number have done so, and they add that corporate policy makers are beginning to make these rates an important engineering consideration in planning future facilities.

The authors add that the study of individual responses does suggest that time-of-use rates may pose a problem for system planning because most firms seem to be able to shift load only when their plants are operating below capacity. As these plants approach their capacity, their on-peak demand will increase sharply. This could increase uncertainty about future loads and capacity needs, which might become more sensitive of fluctuations in the business cycle.

2.10 SOFT LOAD MANAGEMENT OF IRRIGATION LOADS

Gordon M. Sloan[10] reported on the joint effort between farmers and the Sulphur Springs Valley Electric Co-operative, Inc., Arizona, in which a method was devised to accomplish load management using control of irrigation pumps.

This tariff consisted of off-peak rates, with only partial recovery of demand costs and an incentive discount of up to 25%, in exchange for allowing the co-operative to shut off the irrigators' pump, as needed, by means of radio-controlled remote switching. An

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10. SLOAN, G.M., "Irrigation Load Management Considerations for a small Electric Utility", IEEE Transactions on Power Apparatus and Systems, Vol PAS-101, No. 9 Sept 1982, p. 3187.

An override switch is available to the farmer anytime he wants to irrigate his crop, and such demand is metered normally. Computerised load tracking enabled the co-operative to minimize time-off for the pumps.

The scheme was adopted by 75 irrigation consumers, and has reduced the system peak by some 3,5 MW.

The utility reported excellent consumer acceptance of the off-peak controlled irrigation rate.

2.11 HARD LOAD MANAGEMENT OF DOMESTIC WATER HEATERS

Portion of the domestic load is made up of water heaters, which hold sufficient energy to allow a flywheel effect. That is, the heater can be turned off for up to two hours and then turned on again without noticeable effect.

Remote control of domestic water heater by means of radio or ripple receivers is in widespread use, and is gaining in popularity.

Numerous municipalities in South Africa report excellent results using this form of load management. For example, discussions with Town Engineers and Town Treasurers indicate that Sasolburg saves around R750,000.00 per annum on reduced Escom demand charges, Roodepoort saves over R1-million rand per annum, and Randburg reports a savings of over R1,5-million per annum. However, the results in certain cicumstances can be very disappointing.

There are many municipal undertakings that could derive considerable financial benefit from geyser control, but the very high capital cost involved, at around R1-million for a medium size town (±5500 geysers) makes it imperative that a suitable analytical model be developed, to enable undertakings to determine their controlled load curve from which the estimated load reduction and viability of the scheme can be determined.

The reason for the increasing popularity is no doubt due to the increasing cost of electricity and serious attempts to reduce the peak created by domestic consumers. Remote control of water heaters always appears to be an easy and effective method of switching a sizeable amount off the system peak, and this temptation is to some extent exploited by large commercial firms.

The reason for the poor results is a combination of the normal diversity occuring in water-heater loads, and the "pay back" effect.

Water heaters are fitted with thermostats which switch the power on and off to maintain the required temperature. Before the peak period very few water-heaters are actually drawing electricity, since they will be at the required temperature and the diversified demand of a group of geysers is then low, being around 20%. As domestic activity increases, more hot water is used and the diversified demand of the geysers increases to about 50% during the peak period. This is discussed further in section 2.11.3.2.

Clearly therefore, if all the water-heaters are switched out the load is reduced by some 20% to 50% of the connected load of the water heaters. However, when these water heaters are returned to normal several hours later they will all require electricity simultaneously to get back to the required temperature, and 100% of the connected load is added to the system load, which invariably causes a new peak of even greater magnitude than the original peak. This "payback" phenomenon results in significant complications in the operation of this form of load management.

In certain cases the shape of the load curve makes it very difficult to accommodate the payback demand. To ensure that a new peak is not created it may be necessary to switch out less than 25% of all heaters in the first two hours, and to switch off the remaining 75% in groups to control the payback demand when the first 25% are returned to normal. The important point here is that of the 25% of water heaters which were switched out during the first period, only 20% to 50% of them would have been operating anyway. This means that under these circumstances the actual reduction in the system peak is of the order of 10% of the connected load of all water heaters and this rather small reduction rarely warrants the very expensive and sophisticated equipment required for remote switching of thousands of water heaters.

B.F. Hastings, reporting on the operating experience of Detroit Edison (USA) with a remote controlled water heater load management system involving 200 000 domestic consumers states "Using time clocks to switch the water heaters to reduce the summer peak without creating a higher peak during the payback period was beyond the capabilities of the load management system.[11].

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11. HASTINGS, B.F. "Ten years of operating experience with a remote controlled water heater load Management System at Detroit Edison," IEEE Transactions on Power Apparatus and Systems, Vol. pass - 99, No. 4 July/Aug 1980 p. 1437.

The system was converted to a radio signal remote switching system incorporating a centralised programmable controller capable of handling up to 100 programs. He reported that even with these improvements the summer peak can be reduced by only 50-60 MW out of a total water heater connected load of 700 MW, to avoid creating peaks at later hours of the day.

His final conclusion is "considering all these factors, a very careful assessment of overall cost effectiveness must be made by anyone involved in the planning for full scale load Management." [12.]

2.11.1 MODELS FOR WATER HEATER LOAD MANAGEMENT

The foregoing discussion indicated the need to develop a suitable analytical model to enable an undertaking to determine whether its load curve will respond favourably to geyser control, and which will allow the financial implications to be calculated.

To this end, two recent papers dealing with the payback characteristics of water-heaters are summarised below. These findings are discussed and extended, and an analytical model is developed, which can be used to estimate the controlled load curve and hence the viability of geyser control for municipal undertakings.

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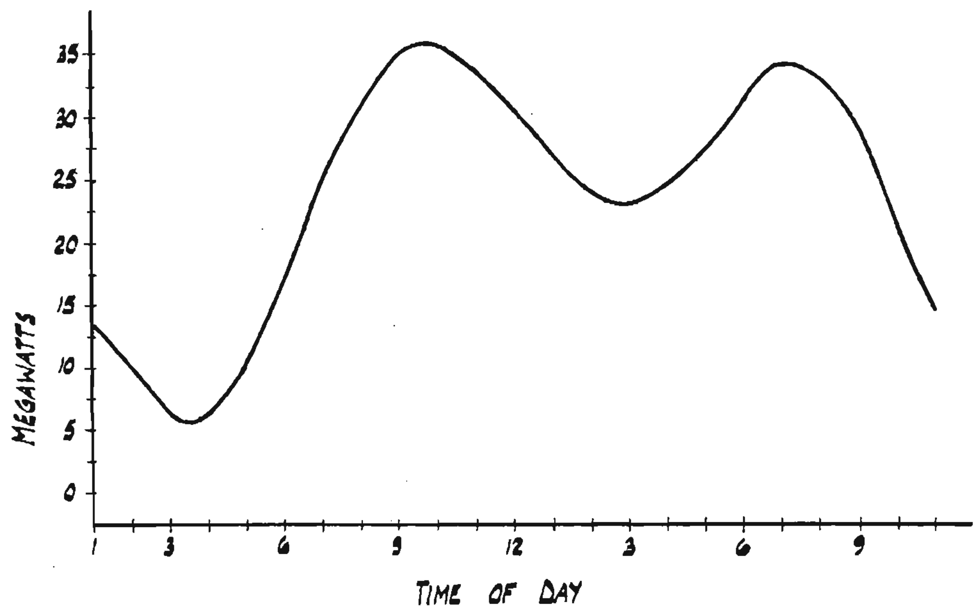
12. HASTINGS, B.F., Ibid, p. 1438.

2.11.1.1 Payback Model : Wisconsin Electric Power Company

R.F. Bischke and R.A. Sella, of the Wisconsin Electric Power Company, reported on the design and controlled use of water heater load management, based on the results obtained from an installation involving approximately 90 000 water heaters.[13] The diversified demand of water heaters on a Monday in February is shown in Figure 2.10.



Source : See footnote 13.

WISCONSIN ELECTRIC POWER COMPANY

WATER HEATER DIVERSIFIED DEMAND

FIG. 2.10.

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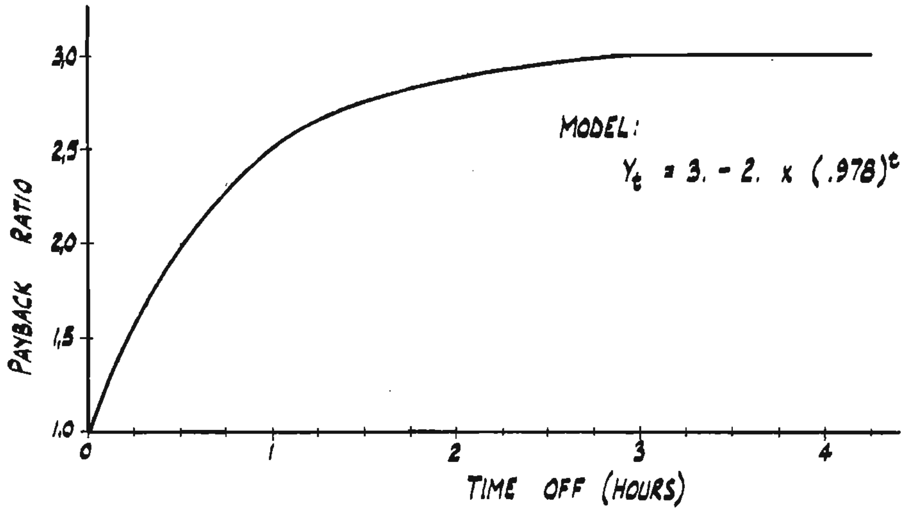
13. BISCHKE, R.F., and SELLA, R.A., "Design and Controlled Use of Water Heater Load Management." IEEE Transactions on Power Apparatus and Systems, Vol PAS - 104, No 6, June 1985, pages 1290-1293.

The general shape of the curve is maintained throughout the year with variations in the peak diversified demand and the daily total energy from season to season and day to day.

The load drop per controlled water heater equals the diversified demand at the time of load shed. When they return to normal the payback demand can be several times greater than the amount shed. Figure 2.11 shows the buildup of the initial payback demand for constant diversity as a function of the load shed period. This model is simply equivalent to the exponential growth model of the population of heaters that are moving from the off condition to the wanting to be on condition.

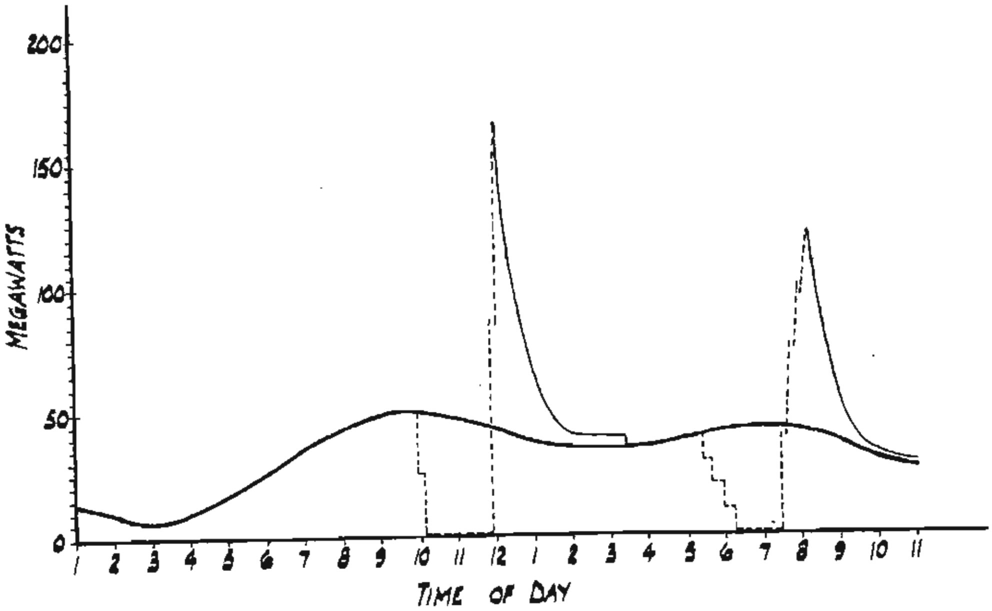
$Yt = 3 - 2 \times (.978)^t$ where t is in minutes.



Source : See footnote 13 on page 2.51

WATER HEATER
PAYBACK RATIO vs TIME OFF
FIG. 2.11

They point out that this payback phenomenon can cause serious operating problems if not handled properly. The load shed of 25 megawatts of water heater load can build up to an initial payback demand of 80 to 90 megawatts. Figure 2.12 showns the payback characteristics when the water heaters are controlled as two groups and four groups with staggered on and off times.

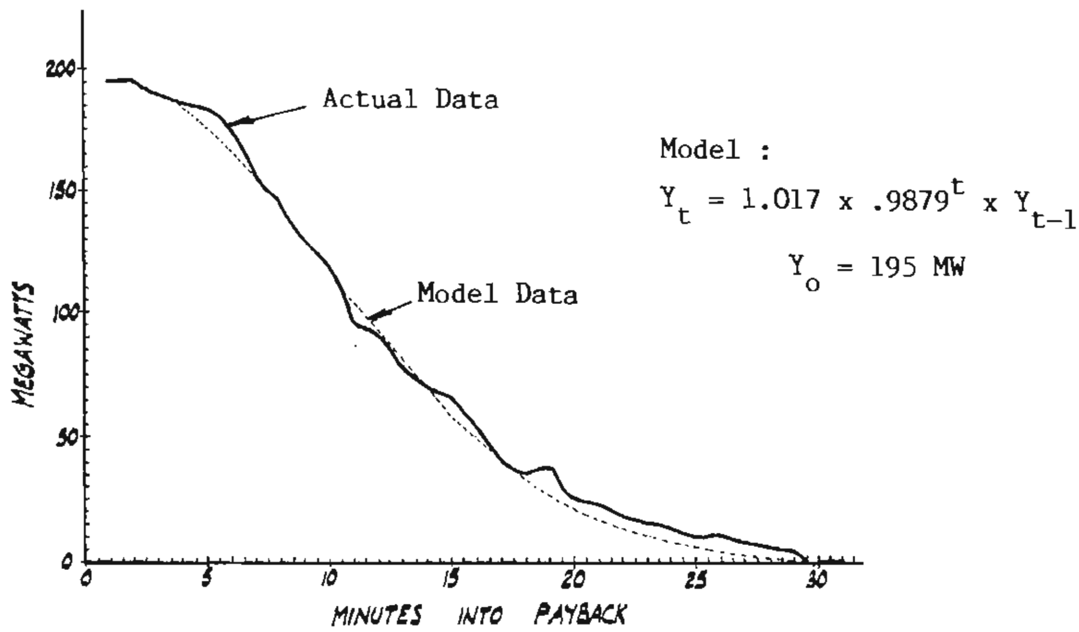


Source : See footnote 13
on page 2.51

LOAD SHED AND PAYBACK CHARACTERISTICS OF WATER HEATERS

FIG. 2.12

Figure 2.13 is a model for the payback characteristic, and is of the form $Yt = A \times B^t \times Y_{t-1}$, where A is from the model of Figure 2.11, B is a constant which defines the shape of the payback curve and t is in minutes. The advantages of this model is its speed in calculation and ease in implementing on an operating system. Once an initial payback demand is calculated (Figure 2.11) the calculation of remaining payback demand can be made.



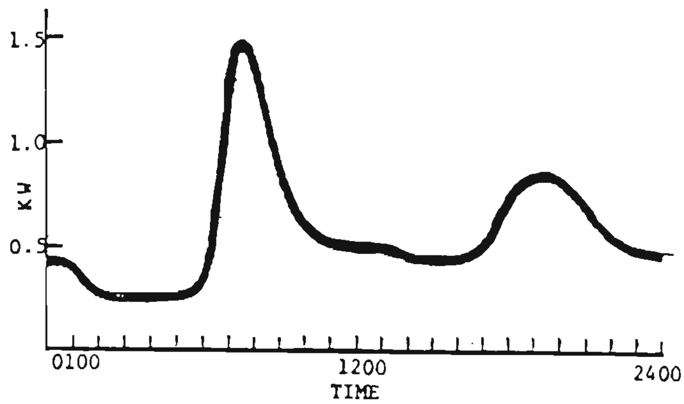
Source : See footnote 13 on page 2.51

MODELING OF WATER HEATER PAYBACK CHARACTERISTICS

2.11.1.2 Payback Models : Carolina Power & Light Company

S.H. Lee and C.L. Wilkins presented general modelling techniques to provide utility companies with a tool for analyzing the data collected from their own systems.[14] The first step in assessing economic benefits resulting from water heater load control is to estimate the payback pattern of a controlled water heater load. The shape of the controlled water heater load will then be provided to the optimization models as an input.

The typical daily diversified water heater demand curve, obtained from load control experiments during the two winters of 1979-1980 and 1980-1981 is shown in Figure 2.14.



Source : See footnote 14

TYPICAL DAILY DIVERSIFIED
WATER HEATER DEMAND IN WINTER

FIG. 2.14

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14. LEE, S.H., and WILKINS, C.L., "A Practical Approach to Appliance Load Control Analysis : A Water Heater Case Study". IEEE Transactions on Power Apparatus and Systems, Vol. PAS-102, No 4, April 1983, pages 1007-1013.

Demand Reduction

With regard to Demand Reduction, they observe that there are some residual demands during the control periods due to failure of control devices and for other unknown reasons. Based on a number of controlled diversified demand curves and using regression analysis techniques, the residual load during the control period is estimated to be :

$$R = 0.0094 + 0.029b \text{ (kW)} \qquad \text{Eq(1)}$$

where b is the average of the normal kW demands during the control period.

Net Restore Demand : Payback

During the payback period, the additional kW demand in excess of the normal diversified demand is termed the net restore demand. The following observations were made :

The net restore demand and the payback pattern during the payback period are dependent on the amount of energy which would be normally consumed during the control period without interruption of service.

The length of payback period is not related to the time off.

To facilitiate notational convenience E is defined as :

E = The amount of energy (kWh) which would otherwise be consumed during the period of interruption, under the normal operating condition.

When the least-squares curve fitting method was applied to the data collected from load control tests, the net restore demand during each of the 15-minute intervals over the payback period was obtained as a function of E and is summarized in Table 2.9. It is noted that the net restore demand immediately following the control period is a quadratic function of E while it becomes linear in E thereafter.

Time elapsed after restoration of service	Net Restore Demand	
	For E ≦ 3.164 kWh	For E ≧ 3.164 kWh
0:15	$-0.2173\ E^2 + 1.3750E + .2666$	2.442
0:30	Max (o, 0.6E - 0.1)	1.798
0:45	Max (o, 0.486E -0.243)	1:295
1:00	Max (o 0.32E - 0.16)	0.852
1:15	Max (o, 0.2E - 0.1)	0.533
1:30	Max (o, 0.207E - 0.166)	0.489
1:45	Max (o, 0.16E - 0.16)	0.346
2:00	Max (o, 0.231E - 0.554)	0.177

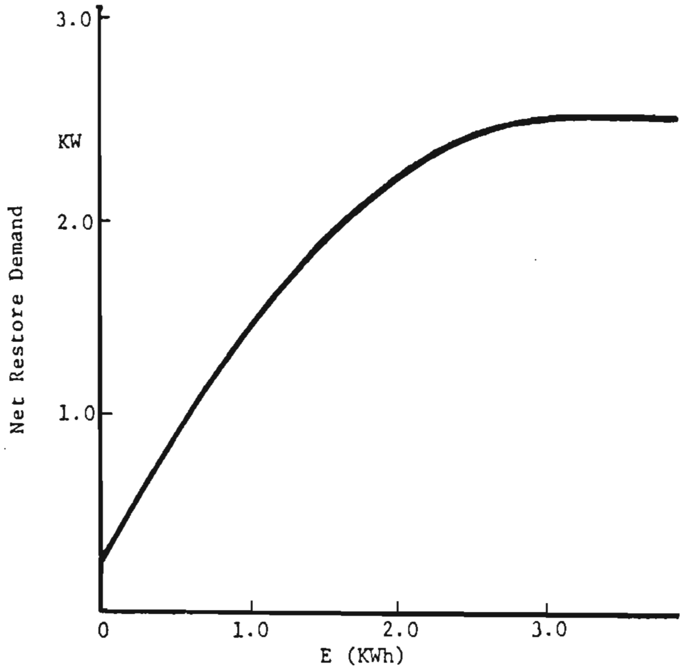
Net restore demands during the payback period are shown to be a function of E. The notation max (o,...) means that for small values of E for which the second term becomes negative, the net restore demand is zero. Therefore, the length of the payback will be short if the value of E is small.

Source : See footnote 14 on page 2.54

Net Restore Demand for Water Heaters

TABLE 2.9

Figures 2.15 and 2.16 show the relationships between E and the net restore demands during the consecutive two 15-minute intervals immediately following the control period.

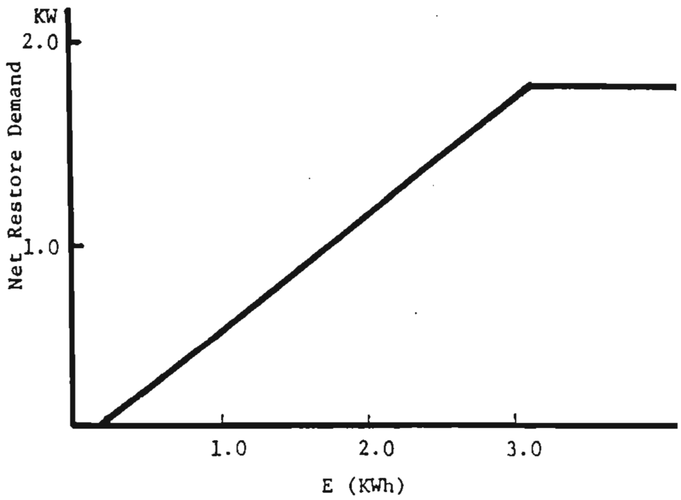


Source : See footnote 14 on page 2.54

NET RESTORE DEMAND AS A FUNCTION

OF DISPLACED ENERGY IMMEDIATELY FOLLOWING CONTROL

FIG. 2.15



Source : See footnote 14 on page 2.54

NET RESTORE DEMAND AS A FUNCTION OF

DISPLACED ENERGY 30 MINUTES FOLLOWING CONTROL

FIG. 2.16

The controlled diversified demand can be predicted by :

- Adding the net restore demand to the uncontrolled diversified demand over the payback period.

- Replacing the normal diversified demand during the controlled period by the residual demand.

Effective Controlled Diversified Demand

To determine the impact of water heater load control on the system load curve, the difference between the controlled and the uncontrolled water heater demands must be examined, which is termed the "effective controlled diversified demand".

Let each of the candidate control schemes be represented by index j, j, j = 1,2 .... For notational convenience, a day is broken down into 96 15-minute intervals, and each interval is numbered and represented by idex i, i = 1, ..., 96.

Now let

A_{ij} = The effective controlled diversified demand of a water heater during the i^{th} interval, when the j^{th} control scheme is exercised.

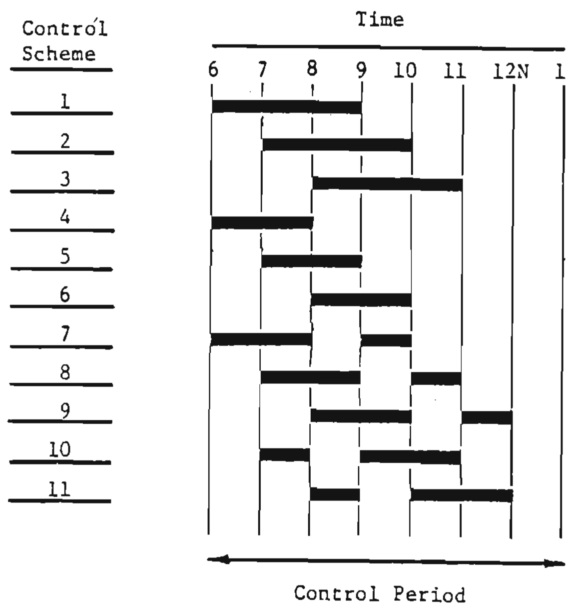
A will be negative during the control period associated with the j^{th} control scheme, and positive during the payback period. Outside the control and payback periods A_{ij} are set equal to zero.

Maximum Peak Reduction

Controlling water heaters on an individual basis is not possible, therefore the decision variables are :-

- Control schemes (time and duration of interruption of service)
- The number of water heaters which are to be controlled by each control scheme.

For demonstration purposes, 11 control schemes as depicted in Figure 2.17 are examined.



Source : See footnote 14 on page 2.54

WATER HEATER CONTROL SCHEMES

FIG. 2.17

For each control scheme, the effective controlled diversified demand can be readily computed using Eq(1) and Table 2.9. Assume there are N controllable water heaters and let X_j be the number of water heaters to be controlled in the j^{th} control scheme where $j = 1, 2 \ldots\ldots\ldots, 11$. The unknown variables X_j's are then constrained by

11

The values of X_j for which the system peak can be reduced the most are those which optimize the following linear program :

Minimize Z (Z is new system peak value) subject to :

$$Z - \sum_{j=1}^{11} A_{ij} X_j \geqq d_i, \quad i = 1, \ldots , 96$$

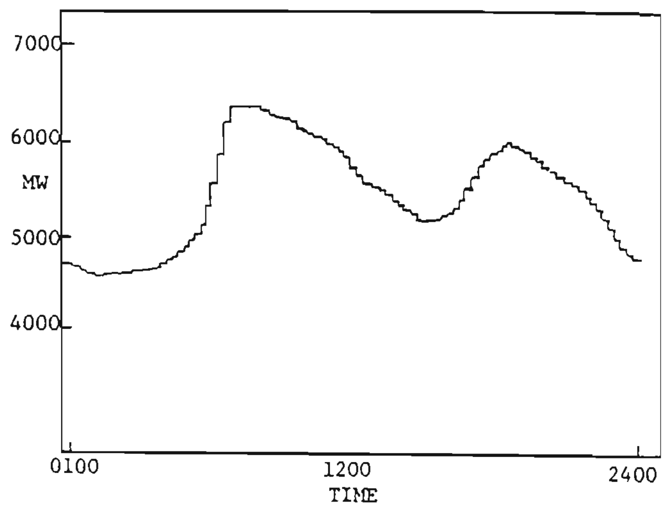
$$\sum_{j=1}^{11} X_j \leqq N \qquad \text{Eq(3)}$$

$$X_j \geqq 0, \quad j = 1, \ldots., 11.$$

where d_i is the CP&L system demand during the i^{th} interval, and is available from Figure 2.18. Note that

$\sum_{j=1}^{11} A_{ij} X_j$ represents the amount of load change during the i^{th} interval.

It can be seen that many of the constraints in Eq(3) above are not active. X_j is required to take on only integral values. For all practical purposes a good integral solution can be chosen based upon the non-integral solution obtained from Eq(3).



Source : See footnote 14 on page 2.54

CP&L WINTER SYSTEM DEMAND

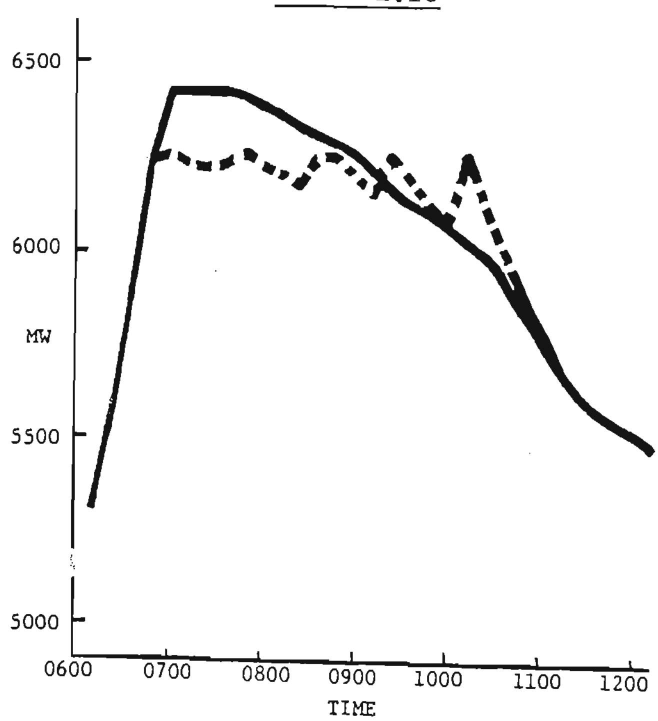
The linear programming problem Eq(3) has been solved for various values of N as summarized in Table 2.10. The result for N = 200 000 is shown in Figure 2.19. It is noteworthy that for large values of N, the average contribution per water heater toward peak reduction decreases.

NUMBER OF CONTROLLABLE WATER HEATERS	OPTIMAL CONTROL STRATEGY	REDUCTION IN SYSTEM PEAK (MW)	AVERAGE CONTRIBUTION PER WATER HEATER TOWARD PEAK REDUCTION (KW)
N=15,000	x_1 = 10,473 x_2 = 4,527	18.36	1.224
N=50,000	x_1 = 34,909 x_2 = 15,091	61.22	1.224
N=100,000	x_1 = 30,091 x_2 = 56,632 x_8 = 9,240 x_{10} = 4,037	117.37	1.174
N=200,000	x_1 = 10,929 x_2 = 68,307 x_3 = 46,485 x_8 = 39,566 x_{10} = 26,393 x_{11} = 8,320	168.41	0.842

Source : See footnote 14 on page 2.54

SYSTEM PEAK REDUCTION FOR VARIOUS VALUES OF N.

TABLE 2.10



Source : See footnote 14 on page 2.54

OPTIMAL SYSTEM PEAK REDUCTION

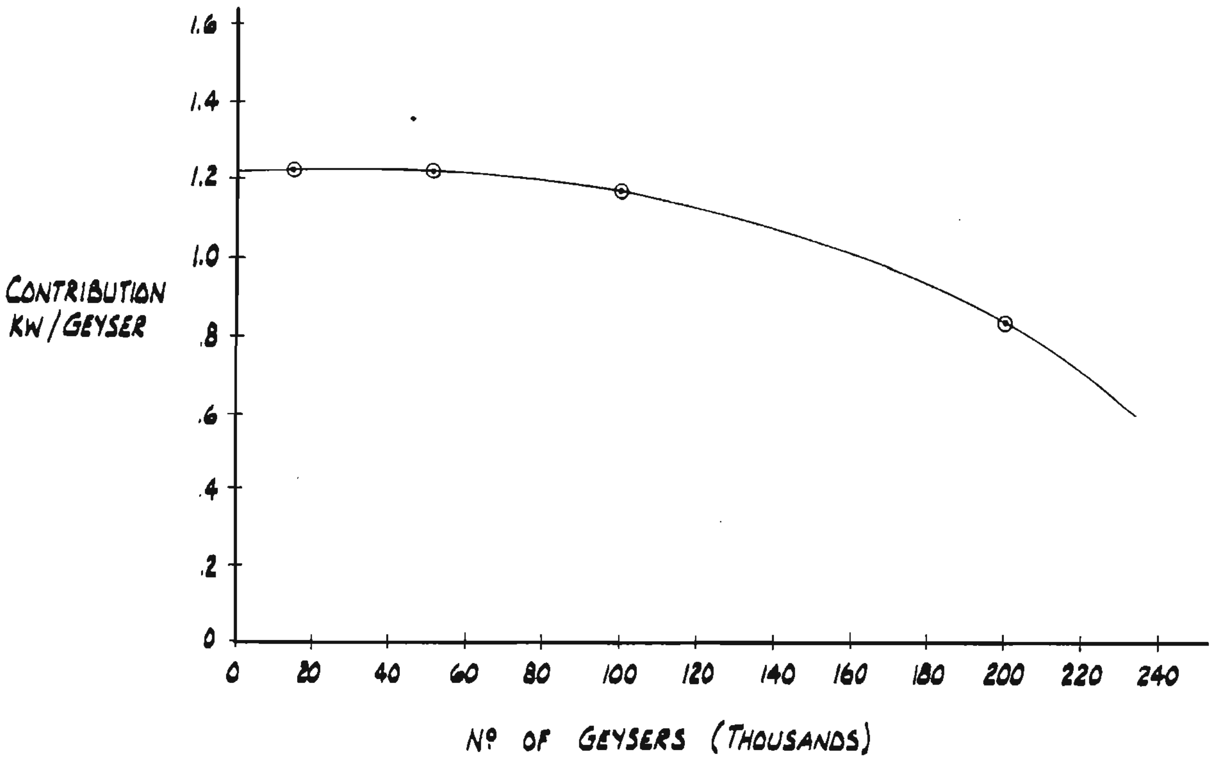
WITH 200,000 CONTROLLED WATER HEATERS

FIG. 2.19

2.11.2 DISCUSSION ON THE ABOVE MODELS

One of the most important aspects which is only commented on briefly in the above reports is the diminishing returns obtained when the number of controlled geysers is increased.

As shown in Table 2.10 for the Carolina Power and Light Company the contribution to the reduction in peak demand reduces from 1,224kW per geyser to 0,842 kW per geyser as the number of controlled geysers increases from 15 000 to 200 000 (Telephonic enquiries established that there are over 300 000 geysers in this system). Figure 2.20 depicts these results graphically, and it clearly illustrates the rapid fall-off in contribution which can take place as the number of controlled geysers is increased.



SOURCE : DERIVED FROM TABLE 2.10

GRAPH SHOWING FALLOFF IN CONTRIBUTION AS N INCREASES

FIG 2.20

This has significant implications for South African application. In the U.S.A. the electricity utility companies supply very large areas which usually incorporate several hundred thousand geysers, of which only a portion are controlled. In South Africa, the supply of electricity is largly undertaken by the various municipalities and the number of geysers available for control by each municipality is very much smaller. The degree of saturation is therefore very much higher and, depending on the original shape of the uncontrolled load curve, the resulting contribution per geyser could be disappointingly low.

Table 2.11 shows some results obtained by South African municipalities. These results were obtained during informal discussions with employees of the various municipalities.

Municipality	Number of Controlled geysers	Peak Reduction KVA	Contribution per geyser toward Peak Reduction KVA
Sasolburg	4 500	5 000	1.11
Johannesburg	35 000	31 000	0,89
Randburg	21 000	15 000	0,71
Carltonville	6 000	4 000	0,66
Bloemfontein	18 000	7 000	0,39
Roodepoort	28 000	8 000	0,28
Pretoria	Poor results : System being discontinued		
Pietermaritzburg	Poor results : System being discontinued		

Source : Informal discussions with municipal employees

CONTRIBUTION PER GEYSER TOWARD PEAK REDUCTION

FOR VARIOUS MUNICIPALITIES

TABLE 2.11

There are two reasons for the fall-off in contribution as the number of controlled geysers is increased. Firstly, there is the existance of other loads in the system which may form a base load after the peak period. This limits the amount of pay-back load which can be added back immediately after the control period, and hence only a portion of the additional controlled geysers can be used for load reduction as the remainder must be used to limit the payback peaks. Clearly, this problem will be more evident in systems which have an early morning peak since industrial and commercial loads will be increasing after the domestic peak.

The second and more important reason for the fall-off in contribution is the rapidly widening time base of the control period as the target load is reduced.

This is illustrated in Figure 2.21.

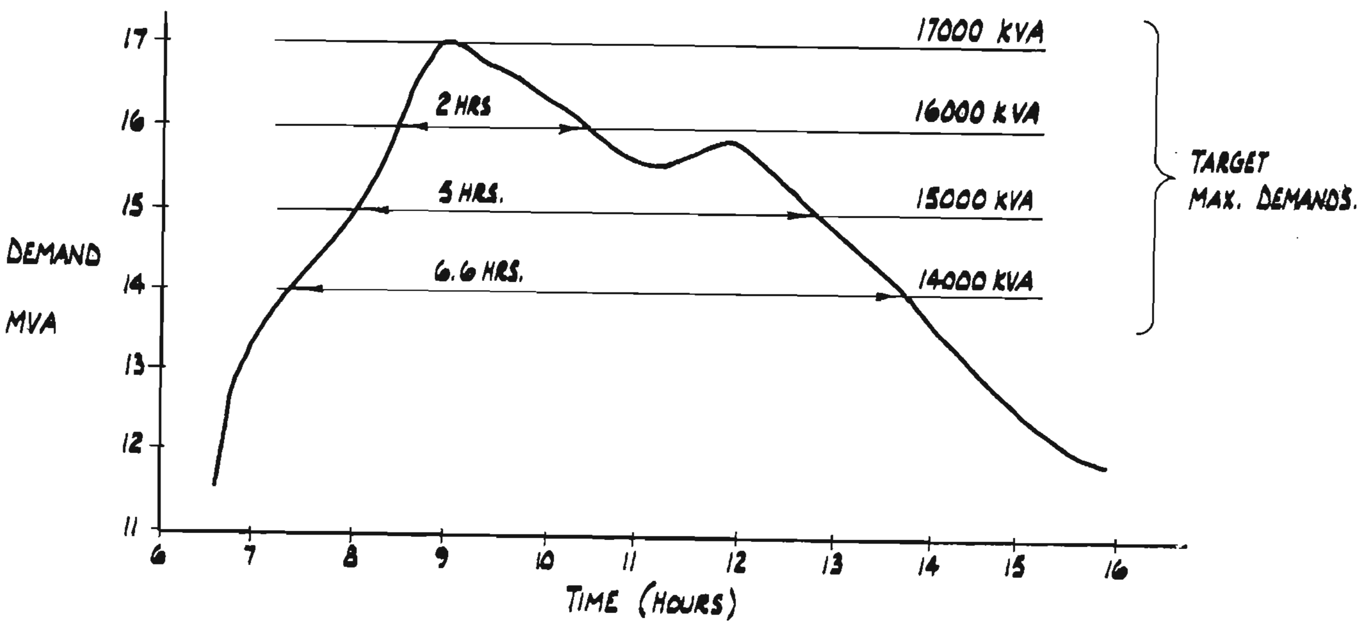


FIGURE ILLUSTRATING INCREASING TIME BASE AS TARGET LOAD IS REDUCED

FIG 2.21

Since geysers must not be turned off for longer than 2 1/2 hours (to avoid cold-water problems) it is obvious that it will require an increasingly larger number of geysers to be rotated for each incremental reduction in peak demand, to meet the increased time base in each increment.

The fall-off in contribution toward peak reduction as the number of geysers is increased is obviously a very important consideration.

The above discussions and results clearly show the need for carefully designed feasibility studies to be done before any municipality embarks on, or extends, its water-heater load management system.

2.11.3 MODEL FOR FEASIBILITY STUDY FOR WATER-HEATER LOAD MANAGEMENT

The proposed Feasibility Study Model is based on a worksheet, which is discussed in section 2.11.4. It requires models of the following components of the system :

2.11.3.1 The Representative Daily Load Curve.

2.11.3.2 The Undisturbed Diversified Demand of Geysers.

2.11.3.3 The Net Restore Demand Characteristics of the Geysers.

The maximum demand meter normally used by ESCOM on municipalities which have water heater load control is the 30-minute block interval meter. This is a rotating disc instrument which integrates the KVA-hours over every half-hour and thus measures the average KVA of each half-hour interval. The recorded maximum demand will be the highest half-hour average. This instrument produces a pulse at the start of each half-hour period which permits the control equipment to synchronize its operation with the metered periods.

These are important considerations as it allows the above models to be simplified for easier use in feasibility studies, and permits an eight hour period to be examined conveniently as 16 half-hour segments, which is very manageable.

2.11.3.1 The Representative Daily Load Curve

Various methods of determining the daily load curves were discussed in section 2.2.

It is necessary to construct a representative daily load curve for each season, based on a careful assessment of the shape of the various recorded daily load curves.

The representative daily load curve for each season should reflect the most likely highest peak superimposed on the most likely highest off peak formation, for that season.

Various possible alternative load curves could be constructed and each could be tested in a feasibility study to determine the sensitivity of the viability to the various possible load curves.

The representative daily load curve is now prepared for the feasibility study by, firstly, dividing the peak period and the follow-on period into half hour intervals and numbering them 1 through 16 (or more if necessary). The average, or midpoint, of the demand in each interval is highlighted for later use in the feasibility study. Secondly, a study is made of the overall shape of the load curve and a realistic "Target Demand" is drawn as a horizontal line through the load curve. It must be kept in mind that load shifted out of the peak period will have to be supplied at a later stage, and hence the area above the line in the peak period must be equal to, or less than, the area under the line during off peak periods.

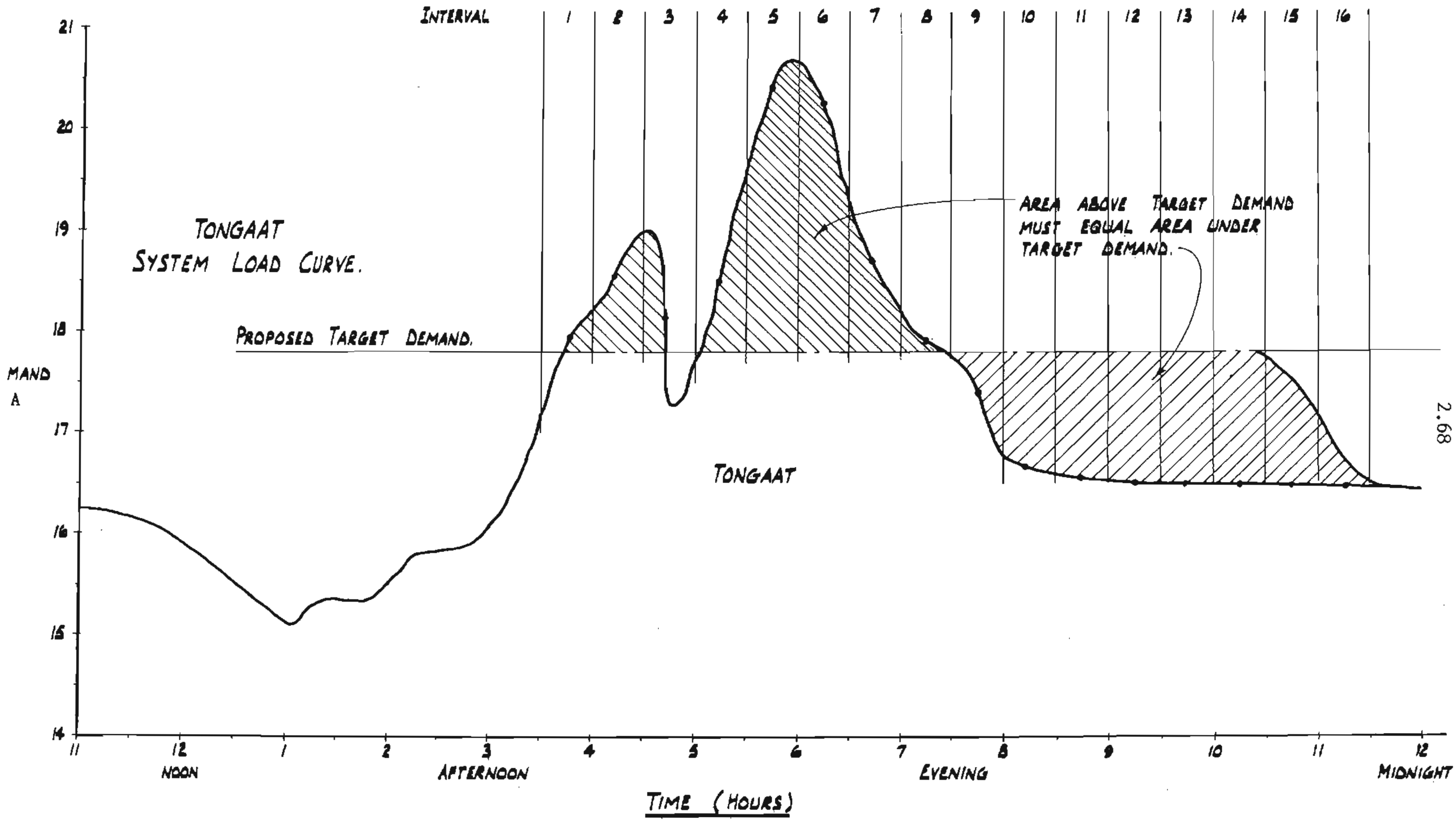
A daily load curve, prepared for the feasibility study, is shown in Fig 2.22.

2.11.3.2 The Undisturbed Diversified demand of the Geysers

It is necessary to make a very careful assessment of the number of geysers, and of the average capacity and size of the heating elements of the geysers.

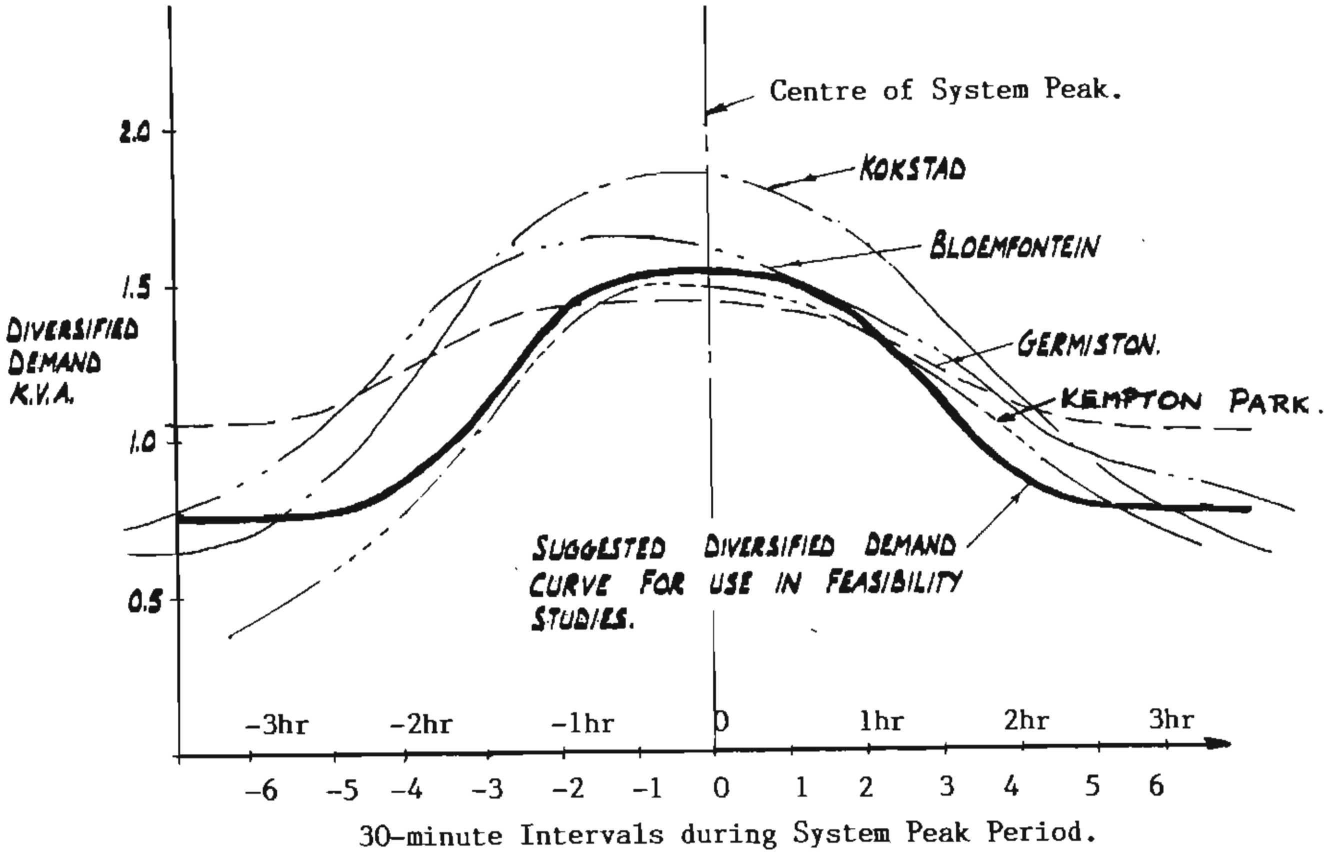
It is extremely expensive to measure the actual diversified demand of uncontrolled geysers in a town, as it will require magnetic recorders with transducers to be installed on approximately 100 individual geysers to get representative samples, and then these recordings must be summated on a master tape to derive the diversified demand pattern. However, a suitable model of the diversified geyser demand can be obtained from the following.

It is a simple matter to obtain the diversified geyser demand in a town which has remotely controlled relays installed on some of its geysers, and which has not yet commissioned its load control management system. In such a case, it is merely necessary to switch all geysers off for a brief period and to note the reduction in total load. This is then repeated at regular intervals, say every half hour, to determine the diversified geyser demand curve. The results of several such tests are shown in Fig 2.23. As discussed later, consumer behaviour is definately affected by geyser control, and the undisturbed diversified geyser demands cannot be obtained from tests



DAILY LOAD CURVE PREPARED FOR FEASIBILITY STUDY

FIG. 2.22A



Source : Informal Discussions with Municipal Employees

UNDISTURBED DIVERSIFIED GEYSER DEMANDS

FIG 2.23

The suggested diversified geyser demand curve for use in the feasibility study is shown in the above figure. As stated earlier, the 30-minute block interval meter responds to the average demand in the half-hour intervals, and hence from Fig 2.23 it can be seen that the diversified geyser demand is 0,75 KVA for all half-hour periods except across the domestic peak period, where the 7 half-hour intervals will have the following values :

1,0   1,25   1,5   1,5   1,5   1,25   1,0

↑ Centre of geyser peak

These are average figures. Winter demands are approximately 10% greater, and summer demands are about 10% less.

It is important to position the "centre of geyser peak" correctly relative to the system load peak. In a town in which there is a mix of consumer types it is advisable to offset the "centre of geyser peak" by the same amount that the peak of sample minor domestic substations is displaced from the system load peak.

Geysers which are switched off remove their diversified demand from the system load. Again, different ranges of diversified geyser demands can be used in the studies to determine the sensitivity of the viability to the geyser demand.

Geysers must not be turned off for a period so long as to deprive the consumers of a reasonable quantity of hot water. It is the flywheel effect that is to be tapped for the community's benefit and this can only be realized if the off-periods are sufficiently short to ensure that the consumers do not experience cold-water problems. Experience has shown that off-periods of about 2 to 2 1/2 hours on large capacity geysers (250 ℓ) and between 1 1/2 and 2 hours on medium capacity geysers (150 ℓ) will go unnoticed by the consumers. There are several negative reactions which set in if consumers are continually deprived of hot water. Firstly, vandalism of the relay units increases markedly, as irate consumers purposefuly damage the controllers to prevent them from operating. Secondly, a large amount of load shifting takes place, as consumers will tend to save the geyser water for baths and take to heating water on the stoves or in the electric kettles for washing up etc.

There are also several instant water heaters on the market which can easily be installed. These actions mean that the load is replaced on the system, and frequently exceeds the diversified load of the geyser which was switched out since these appliances (stoves, kettles etc) were not designed for the efficient heating of water, and are not insulated to conserve the energy.

It is very important, therefore, to ensure that off-times are kept to about 2 to 2 1/2 hours in the feasibility study.

2.11.3.3 The Net Restore (Payback) Demand for the Geysers

A group of geysers which has been switched off to achieve a certain reduction must be switched back on, within 2 1/2 hours, and the net restore "payback" demand must be added to the system over the next 4 half-hour periods, as discussed below.

Table 2.9 indicates the net restore demand (payback) of the geysers 15 minute intervals. The 30 minute block-interval meter responds to average demands, and since the payback curve is very smooth it will be sufficiently accurate to use the midpoint reading as the average demand in that interval. The energy that a geyser would normally have consumed is half of the sum of the half-hour demands in the controlled off period. By substitution in Table 2.9 we get Table 2.12A. This table considerably simplifies the feasibility study as it allows the payback to be entered on the worksheet immediately.
Example : 100 geysers are turned off for 3 consecutive half-hour periods at the beginning of the peak period when their diversified demands would have been 0,75 - 1,25 - 1,5 KVA respectively in the half-hour intervals.

Payback Demand per Geyser (KVA)					
	Sum of demands in controlled half-hours (KVA)	Half-hour Periods after Control			
		First	Second	Third	Fourth
	0,50	0.5	-	-	-
	0,75	0.7	-	-	-
	1.00	0.9	-	-	-
	1.25	1.0	0.1	-	-
	1.50	1.2	0.1	0.1	-
	1.75	1.3	0.2	0.1	-
	2.00	1.4	0.2	0.1	-
	2.25	1.5	0.3	0.1	-
	2.50	1.6	0.4	0.2	-
	2.75	1.7	0.4	0.2	0.1
	3.00	1.8	0.5	0.2	0.1
	3.25	1.9	0.5	0.2	0.1
	3.50	2.0	0.6	0.3	0.1
	3.75	2.1	0.7	0.3	0.1
	4.00	2.1	0.7	0.3	0.2
Limit for 2 kW Geysers	4.25	2.2	0.8	0.3	0.2
	4.50	2.3	0.9	0.4	0.2
	4.75	2.3	0.9	0.4	0.2
	5.00	2.3	1.0	0.4	0.2
Limit for 2,5 kW Geysers.	5.25	2.4	1.0	0.4	0.3
	5.50	2.4	1.1	0.5	0.3
	5.75	2.4	1.2	0.5	0.3
	6.00	2.4	1.2	0.5	0.3
Limit for 3 kW Geysers.	> 6.00	2.4	1.3	0.5	0.4

Source : Derived from Table 2.9 : See Text

TABLE 2.12 A

NET RESTORE DEMANDS IN PERIOD FOLLOWING CONTROL

The sum of their demands in the controlled off period is 0,75 + 1,25 + 1,5 = 3,5 KVA. From Table 2.12 the payback net restore demand per geyser over the next 4 half hour intervals would be

2,0   0,6   0,3   0,1.

Since there are 100 geysers the controlled demands over the 7 half-hour periods would be :

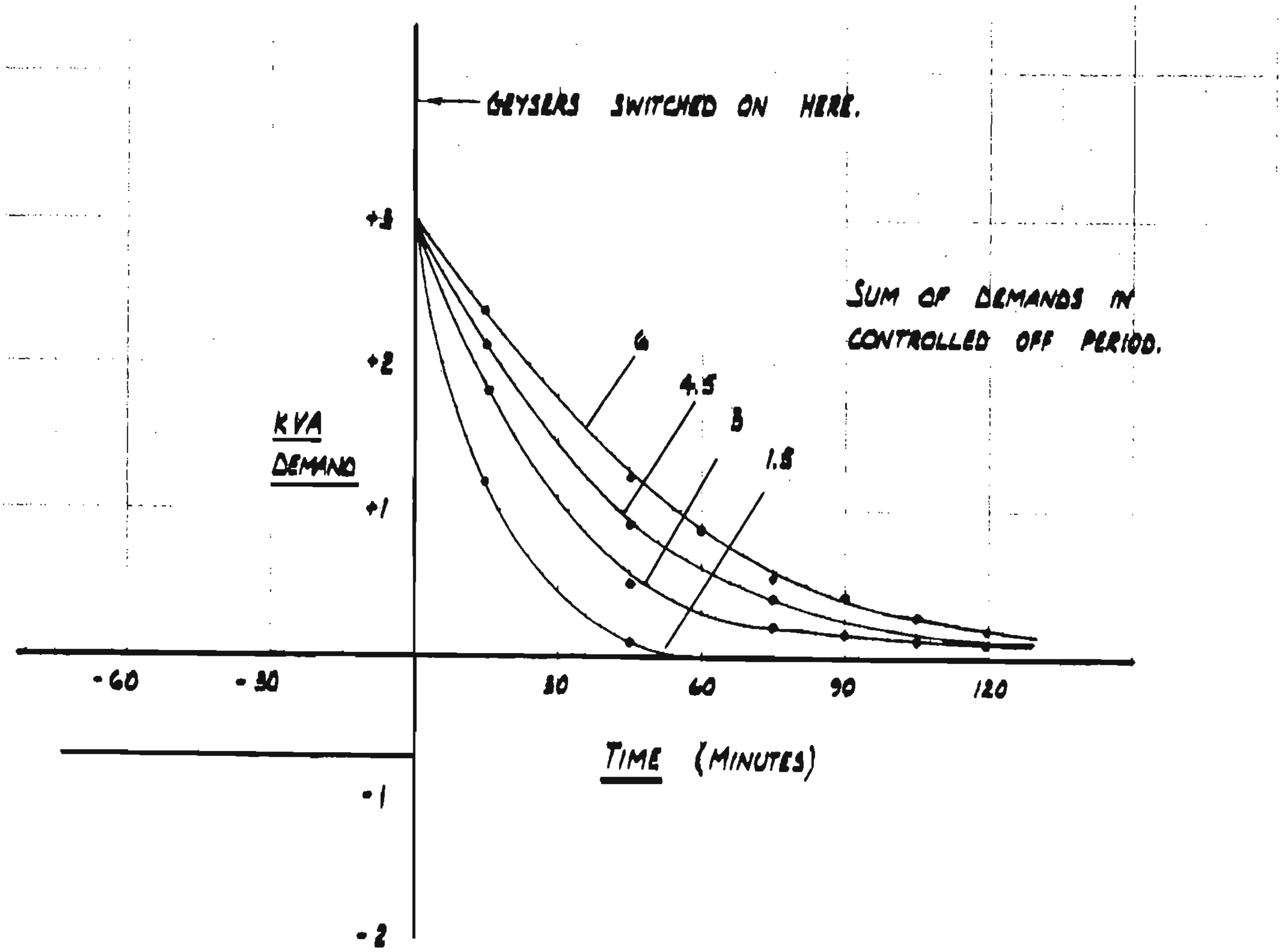
-75   -125   -150   +200   +60   +30   +10.

As shown in the above example the net restore demand in the first half hour of restore is high.

This initial restore demand can be reduced by switching the geysers back on midway during a 30 minute metered interval. Groups of geysers which have been turned <u>off</u> to reduce the peak load are turned back <u>on</u> shortly after the peak period. As discussed in the previous section, the diversified demand of the geysers returns to 0,75 KVA per geyser shortly after the domestic peak period, and hence it will be sufficiently accurate for the purpose of feasibility studies to assume that all groups of geysers are back in this range when being returned to the <u>on</u> condition.

Table 2.9 indicated the net restore demand (payback) of the geysers at 15 minute intervals, as a function of the energy that would have been used by the geysers had they not been turned off.

As discussed previously the 30 minute - block interval meter responds to average demands in each half hour interval. It has also been shown that the net restore demand of any group of controlled geysers rapidly approaches two to three times its undisturbed diversified demand after being turned off and it may therefore be necessary to return these units to their <u>on</u> condition some 15 minutes into a metered interval, so that the large net restore demand in the first half-hour period during restore is tempered by the initial reduction of 0,75 KVA per geyser, for the first 15 minutes. The demands in subsequent half-hour periods can be determined directly from Table 2.9.



NET RESTORE DEMAND FOR GEYSERS

FIG 2.24

It can therefore be seen from Fig 2.24 that under these conditions the net restore demand per geyser in the first half hour approximates the average of a reduction of 0,75 KVA and the restore demand for the first 15 minutes. The second half hour demand approximates the restore demand after 30 minutes into restore, and so on for the four half-hour intervals.

Using this approach, and by substitution in Table 2.9 we get Table 2.12B. This is used in the same manner as Table 2.12A for the feasibility study as it allows the payback to be entered on the worksheet immediately.

Example : 100 geysers are turned off for 3 consecutive half hour periods, when their diversified demands would have been 0,75 1,25 1,5 KVA respectively in the half-hour periods. The sum of their demands in the controlled off period is 0,75 + 1,25 + 1,5 = 3,5 KVA. From Table 2.12B the net restore demand per geyser over the next 4 half hour intervals would be

0,92 1,05 0,44 0.23

Since there are 100 geysers the controlled demands over the 7 half-hour periods would be -75 -125 -150 +92 +105 +44 +23

The net restore demands to be entered in the worksheet can therefore be determined from either Table 2.12A or 2.12B.

It is very important when undertaking a feasibility study, that groups of geysers should not be switched off for longer than 2 to 2 1/2 hours and after being returned to on should not be turned off again until the net restore demand drops to below 0,25 KVA per geyser, to avoid cold water problems.

Sum of demands in controlled half-hours (KVA)	Payback Demand per Geyser (KVA)			
	Half Hour periods after Control			
	First	Second	Third	Fourth
,75	.62	.23	.02	0
1,0	.65	.31	.06	0
1,25	.68	.38	.08	.03
1,5	.71	.46	.12	.05
1,75	.74	.53	.16	.06
2,0	.77	.61	.20	.08
2,25	.80	.68	.24	.10
2,5	.82	.76	.28	.13
2,75	.85	.83	.32	.15
3,0	.87	.91	.36	.18
3,25	.90	.98	.40	.21
3,5	.92	1.05	.44	.23
3,75	.93	1.13	.48	.26
4,0	.94	1.21	.52	.28
4,25	.95	1.28	.56	.31
4,5	.96	1.36	.60	.34
4,75	.97	1.43	.64	.36
5,0	.98	1.51	.68	.39
5,25	.98	1.58	.72	.41
5,5	.98	1.66	.76	.44
5,75	.98	1.73	.80	.46
6,0	.98	1.80	.84	.48
>6,0	.98	1.80	.85	.49

TABLE SHOWING NET RESTORE DEMANDS IN THE FOUR HALF-HOUR PERIODS AFTER CONTROL WHEN RESTORE COMMENCES APPROXIMATELY 15 MINUTES INTO FIRST HALF HOUR PERIOD

TABLE 2.12B

2.11.4 Developing the Feasibility Study Model

The proposed worksheet for the feasibility study is shown in Figure 2.25.

Row 1

From the representative daily load curve, the actual half hour demands corresponding to the numbered intervals are entered into Row 1, for the 8-hour period under consideration.

Row 2

The tentative "target maximum demand" which was drawn as a horizontal line across the load curve, is entered in Row 2.

Row 3

The difference between the target demand (Row 2) and the actual demand (Row 1) represents the amount of demand which must be cut or which can be added back, and this difference is entered in Row 3. A negative amount indicates that load reduction is required, and a positive amount indicates the load that can be added to the system load.

	Interval	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Time																
1	System M.D.																
2	Target M.D.																
3	Change Reqd.																
4	Diversified Geyser Demand																
5	Group A																
	Group B																
	Group C																
	Group D																
	Group E																
	Group F																
	Group G																
	Group H																
6	Total Change																
7	Final M.D.																

WORKSHEET FOR FEASIBILITY STUDY

FIG 2.25

Row 4

In row 4 the uncontrolled diversified demand per geyser is entered.

As stated earlier, the diversified geyser demand to be entered in Row 4 will be 0,75 KVA for all half-hour periods except across the domestic peak period where the 7 half-hour intervals will have the following values :

1,0 - 1,25 - 1,5 - 1,5 - 1,5 - 1,25 - 1,0
↑
centre of geyser peak

It is important to position the "centre of geyser peak" correctly relative to the system load peak and to offset it by the same amount that the peak of sample minor domestic substations is displaced from the system load peak.

Row 5

Row 5 is divided into a number of groups, which represent groups of geysers which are to be turned off or on to remove or add the required load in the half-hour periods as scheduled in Row 3. For a feasibility study 8 groups are generally sufficient, but the number of groups can be increased if necessary. The total number of geysers available for control approximates the number of domestic consumers, but should exclude remote rural consumers as signal reception may be unreliable, and maintenance and cold-water callouts could be prohibitively expensive. The total number of available geysers for control must be divided amongst the 8 groups, and need not necessarily all be equal.

Each off geyser removes its uncontrolled diversified demand from the system load curve. Therefore, if a channel is off, then the product of the number of geysers in that group and the diversified geyser demand in that half hour is entered into the corresponding block as a negative quantity.

Within 2 to 2 1/2 hours (four or five intervals) these geysers must be returned to normal. As discussed before, the diversified geyser demands in Row 4 is added together for the intervals that the geysers were off, and from Table 2.12 the net restore demands per geyser can be read off for the next four half-hour intervals. The product of the number of geysers, and these net restore demands are entered into the next four corresponding blocks.

Row 6

Row 6 summates the demands of the groups of geysers, and indicates by means of 'plus' or 'minus' signs whether this total must be added to, or taken away from, the original system demand (Row 1).

Row 7

Row 7 represents the controlled system demand and is obtained by algebraically adding the total geyser demands (Row 6) to the System Demand (Row 1).

The highest half hour reading in Row 7 will be the new maximum demand of the controlled system.

A completed worksheet, for the load curve shown in Fig 2.22 is shown in Table 2.13 and the modified load curve is shown in Figure 2.22B

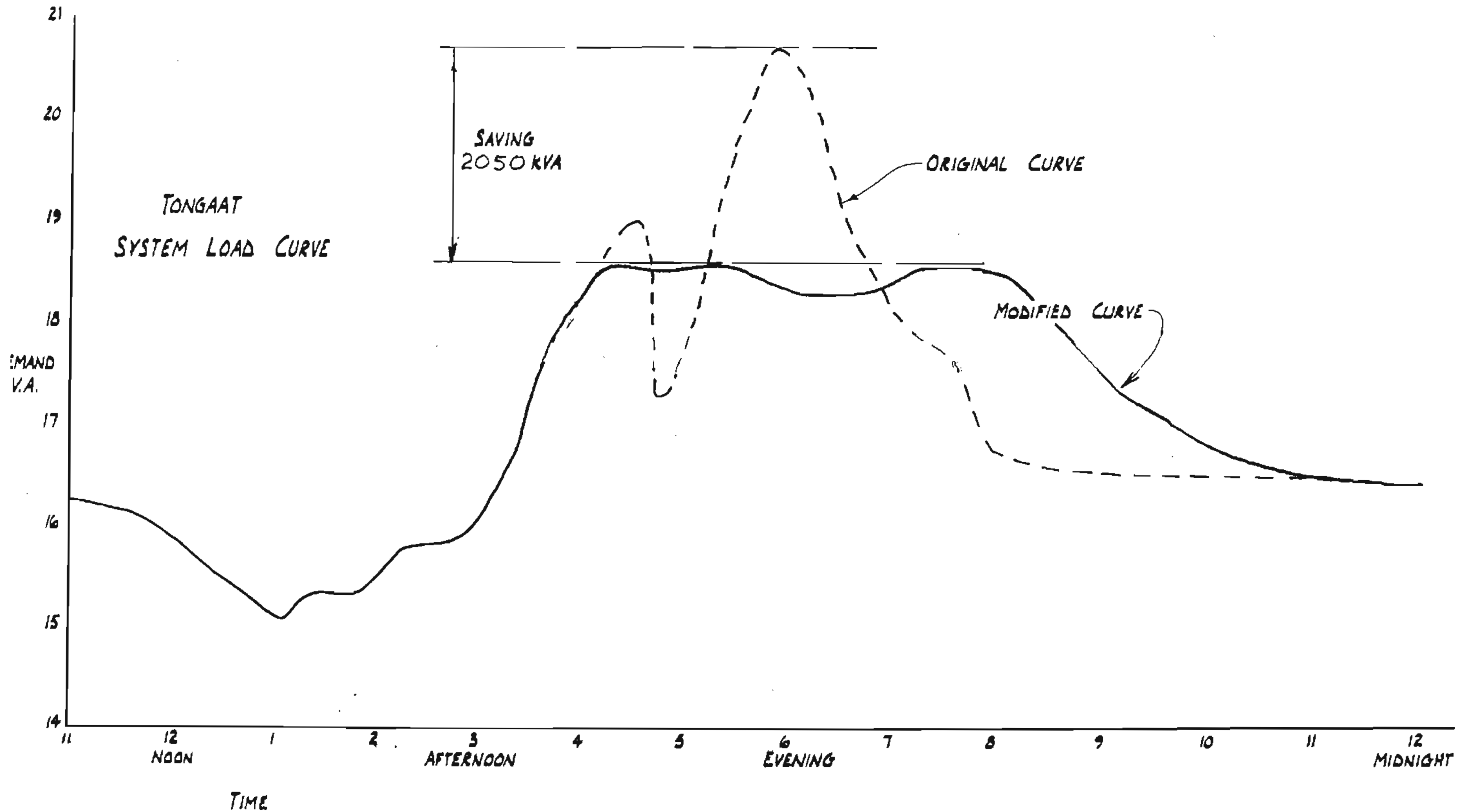
		Interval	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Time	3.45	4.15	4.45	5.15	5.45	6.15	6.45	7.15	7.45	8.15	8.45	9.15	9.45	10.15	10.45	11.15
Row 1		System M.D.	18000	18500	18500	19000	20600	20000	18700	17300	17300	16800	16800	16500	16500	16500		
Row 2		Target M.D.	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600		
Row 3		Change Reqd.	–	–	–	-400	-2000	-1400	-100	+820	+1300	+1800	+1800	+2100				
Row 4		Diversified Geyser Demand	.75	1	1.25	1.5	1.5	1.5	1.25	1	.75	.75	.75	.75				
Row 5	Group A	300				-450	-450	+540	+150	-300	-225	+480	+60	+30				
	Group B	300					-450	-450	+540	+150	+60	+30	–	–				
	Group C	300					-450	-450	+540	+150	+60	+30	–	–				
	Group D	300					-450	-450	-375	+660	+240	+90	+60	–				
	Group E	300					-450	-450	-375	+660	+240	+90	+60	–				
	Group F	300						-450	-375	-300	+630	+210	+90	30				
	Group G	300							-375	-300	-225	+540	+150	60	30			
	Group H	—																
Row 6		Total Change				-450	-2250	-1710	-270	+720	+780	+1470	+420	+120	+30			
Row 7		Final M.D.	18000	18500	18500	18550	18350	18290	18430	18520	18080	18270	17220	16620	16530			

SYSTEM M.D. : 20 600 KVA
CONTROLLED M.D. : 18 550 KVA
REDUCTION : 2 050 KVA

NO. OF GEYSERS 2100
CONTRIBUTION : 1 KVA/GEYSER

COMPLETED FEASIBILITY WORKSHEET FOR FIG 2.22A

TABLE 2.13



MODIFIED DEMAND CURVE DERIVED FROM ROW 7 ON TABLE 2.13.

FIG. 2.26

2.11.5 Interpreting the Feasibility Study

The above calculations will indicate whether the "target maximum demand" was set at the correct level. An inability to handle the ever-increasing payback demand will indicate that the target was set too low. Conversely, the "target maximum demand" was set too high if the target can be reached without using either all the geyser groups, or using very short off-periods for the groups.

The highest reading in Row 1 represents the Maximum Demand of the uncontrolled system. The highest reading in Row 7 represents the Maximum Demand of the controlled system. The difference between these two represents the reduction in the peak load, and the contribution per geyser can be obtained by dividing the reduction by the number of geysers.

The following analysis shows that a minimum contribution of around 0,5 KVA per geyser is required for a new installation to be financialy attractive.

Consider a town of 5000 domestic consumers. At 2,5 KVA per consumer the maximum demand will be approximately 12 500 KVA, which at R11.80 per KVA will cost R147 500.00 in demand charges from ESCOM The present day cost for a geyser load control system for 5000 geysers is approximately R750 000.00. The monthly instalments to repay capital and interest at 15% over 20 years is R11,250.00. In addition, the geyser control system is a long term investment which requires a certain amount of attention and supervision to be fully effective, since the load has to be tracked, the target load must be determined and preset, cold water callouts must be co-ordinated etc. In effect the control system must contribute something towards the running of the Electricity Department before the "profit" is determined. Even if only portion of the salaries of the supervisor and maintenance electrician, with transport and spares is taken into account, it amounts to around R5000.00 per month. Finally the purpose of this installation is to produce a reasonable reduction in the cost of electricitiy to consumers, or alternatively, to make a reasonable contribution to the operating surplus of the undertaking. A net savings of 10% on demand charges would seem to be the absolute minimum considering the relatively large investment (R750,000.00), the high level of supervision required, and the cold-water nuisance factor introduced into the community. There is also a risk factor involved, since changes in the shape of the load curve, improvements in water heating technology and changes in the ESCOM two-part tariff structure could all contribute to reducing or even eliminating the savings. The proposed minimum net savings of 10% on demand charges results in a payback period of about 4,25 years which should be sufficiently short to avoid the possible long term risks.

Based on the above considerations the minimum acceptable contribution per geyser can then be calculated as follows :

Net monthly savings required :		
10% of R147,500.00		R14,750.00
Add		
- Monthly repayments on loan of R750,000.00	11,250.00	
- Supervision & Maintenance	5,000.00	16,250.00
Gross Monthly savings required :		R31,000.00

At R11.80 per KVA, and for 5000 geysers the contribution per geyser is then

Contribution = R31 000.00 = 0,52 KVA per geyser

Table 2.11 shows that it is not possible for all municipalities to realize this contribution due to the shape of their uncontrolled load curve.

On the other hand there are numerous municipalities which have load curves which are very suitable for geyser control. For example Sasolburg reports a contribution of 1.11 KVA per geyser. (See Table 2.11) Their officials state that their load curve is rather unique due to the very large number of residents employed by SASOL. Due to shift-work, the domestic peaks are very sharp (as numerous workers return home simultaneously) and, interestingly, the domestic peak occurs on a Sunday, as SASOL does not work Sunday shifts.

Hence, in the example discussed above, if the contribution for each geyser was 1,11 KVA the net savings would be :

Reduction in peak demand :
5000 @ 1,11 KVA = 5550 KVA

We would then have :

Gross monthly savings 5550 KVA @ 11.80		R65,490.00
Less		
Repayments on Loan of R750 000.00	9,876.00	
Maintenance & supervision	5,000.00	14,876.00
Net monthly savings		R50,614.00

The net annual savings would then be R607,368.00.

Clearly this is a considerable net annual savings for an investment of R750,000.00, and is likely to increase as ESCOM increases its

2.11.6 Use of the Feasibility Study Models

The proposed feasibility study model is indeed a powerful analytical tool as it provides a clear method of identifying whether the system load curve will respond favourably to geyser control, or whether alternative forms of load management should rather be persued.

It is therefore proposed that as a starting point for the formulation of comprehensive marketing policies for the undertaking, feasibility studies should be undertaken on its representative daily load curves to determine the contribution per geyser toward peak load reduction.

As a guideline, those undertakings whose load curves result in a contribution of 0,5 KVA per geyser or more should install geyser load control systems and should adapt all their policies accordingly as discussed further in section 8.6. Conversely those undertakings where the contribution returns less than 0,5 KVA per geyser would probably benfit more from various forms of soft load management (off-peak pumping and heating tariffs etc) as well as other forms of hard load management such as localized load shedding, voltage reduction, etc.

Further uses of the feasibility study models are :

a) It can identify the required range of diversified geyser demands which are necessary to make a geyser control system viable. This then allows specific tests to be done on samples of geysers to determine whether this range is realistic for the undertaking.

b) It allows the load control engineers to design their own load shedding programmes and thereby enhance the performance of existing geyser control systems.

c) It allows the additional load reduction to be calculated when extensions are being considered for existing control systems.

d) It permits the original uncontrolled load curve to be determined from the controlled load curve by using the reverse procedure. This enables the undertaking to calculate more accurately the peak load reduction.

e) It can replace the present "load curve simulation" methods currently being used to estimate the peak load reduction. These simulation methods do not take the degree of saturation of controlled geysers into account, and frequently merely balance the load shed above the "target demand" with the load valleys under the "target demand", without fully considering the off-periods required, or the payback problems which will follow. Such estimates will grossly exceed the actual results. In the informal discussions held with numerous municipal electrical engineers frequent mention was made of the vastly different estimates of load reduction they have received from the different suppliers of equipment when tenders are called for.

2.11.7 VERIFYING THE PROPOSED FEASIBILITY STUDY MODEL

In order to verify the accuracy of the results obtainable from the proposed feasibility studies, it was necessary to obtain the co-operation of ESCOM and of a town which has a geyser load management system, in order to undertake the following tests for demonstration purposes. As the proposed analytical model could be of considerable benefit to numerous municipalities, co-operation was readily obtained.

Somerset West was approached to participate in the test and after responding favourably, undertook to liase with ESCOM.

The theoretical cost of the tests was around R41 820.00, being the cost of the increased demand charges resulting from the tests, which ESCOM had agreed to waive.

Basically the test would be to let the town freewheel for one day (i.e. not to control the geysers for that day) and to compare the controlled load curve with the uncontrolled load curve. The accuracy of the results obtainable from the proposed feasibility studies could then be determined in the following ways, viz,

a) Using the uncontrolled load curve, the normal feasibility study could be done to determine the theoretical shape of the controlled load curve, and this could then be compared to the actual controlled load curve for the following day.

b) From the feasibility study, the theoretical contribution per geyser toward peak load reduction can be calculated, and this can be compared to the actual contribution obtained, which can be determined by noting the difference in the recorded maximum demands for the two days, and dividing this by the number of geysers.

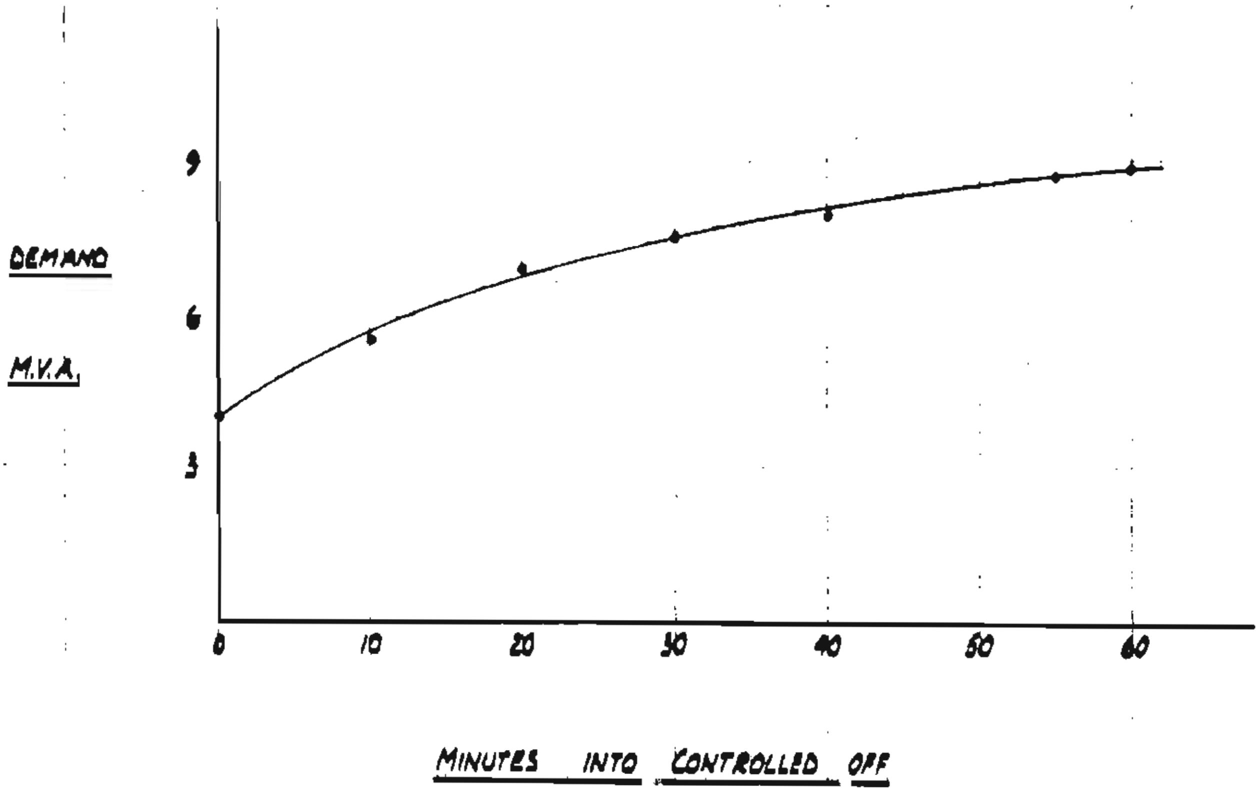
In addition to the above several other tests were conducted as described below.

RESULTS OT TESTS UNDERTAKEN AT SOMERSET WEST

1) BUILD-UP OF PAYBACK DEMAND WITH TIME

Although this information was not required, it is of interest to demonstrate the rapid buildup of payback demand after geysers are switched off.

On the 31st July 1986, all the geysers in Somerset West were switched off at 8h00, and at five minute intervals were switched back on briefly to determine the increase in demand. The results obtained are shown graphically in Fig 2.27 and clearly demonstrates how the initial savings of 4 MVA rapidly increases to a payback demand approaching 9 MVA.



GRAPH SHOWING INCREASE IN PAYBACK DEMAND WITH TIME

FIG 2.27

2) UNDISTURBED DIVERSIFIED GEYSER DEMAND

As stated in section 2.11.3.2 the undisturbed diversified demand for geysers is considerably affected by geyser load management.

The reason is that, intentionally or unintentionally, the consumers' consumption pattern for hot water is definitely modified since the geysers are always switched off for around two hours during the peak period and this must mean that the lavish use of hot water during this period will result in cold water later in the period. Hence, hot water is used more carefully, and in some instances, results in bathing being shifted completely out of the evening activity and being done in the morning before work. This means that the demand for hot water reduces during the peak period and is more evenly spread throughout the day. The result is that the diversified demand of geysers drops markedly. Therefore, during a day when the control equipment is not operating, the daily load curve will be flatter than it would have been had there not been load management.

This is very important, as it means that the undisturbed diversified geyser-demands for use in feasibility studies for new installations must not be determined from towns which have geyser load control. Conversely, the geyser diversified demands determined for towns which do not have geyser load control cannot be used in towns that do have geyser load control. It was therefore first necessary to determine the geyser diversified demand for Somerset West.

This was determined during the freewheeling day, by turning the geysers off briefly every 10 minutes and noting the reduction in the total demand. The results are shown in Table 2.4.

There are 4370 controlled geysers in Somerset West, and it can be seen from Table 2.4 that the diversified geyser demand remains at about 0,75 KVA per geyser throughout the period.

3) FEASIBILITY STUDY FOR SOMERSET WEST

The uncontrolled load curve for Somerset West is shown in Fig 2.28.

The feasibility study for this load curve is shown in Fig 2.29. The only difference between this feasibility study and those undertaken for a new installation is the diversified geyser demand as discussed above. The feasibility study indicates that a reduction of 2970 KVA is possible, using 4370 geysers, when no group is off for longer than 2,5 hours. The theoretically calculated controlled load curve is shown superimposed over the actual controlled load curve for the following day. It can be seen that the calculated curve matches the actual curve very accurately.

The actual contribution obtained in Somerset West between the two days is

$$\text{Contribution} = \frac{20400 - 17400}{4370} = 0{,}69 \text{ KVA per geyser}$$

The calculated contribution, as shown on the worksheet is 0,68 KVA per geyser.

It can therefore be concluded that the results obtainable from the proposed feasibility studies are accurate.

SOMERSET WEST MUNICIPALITY

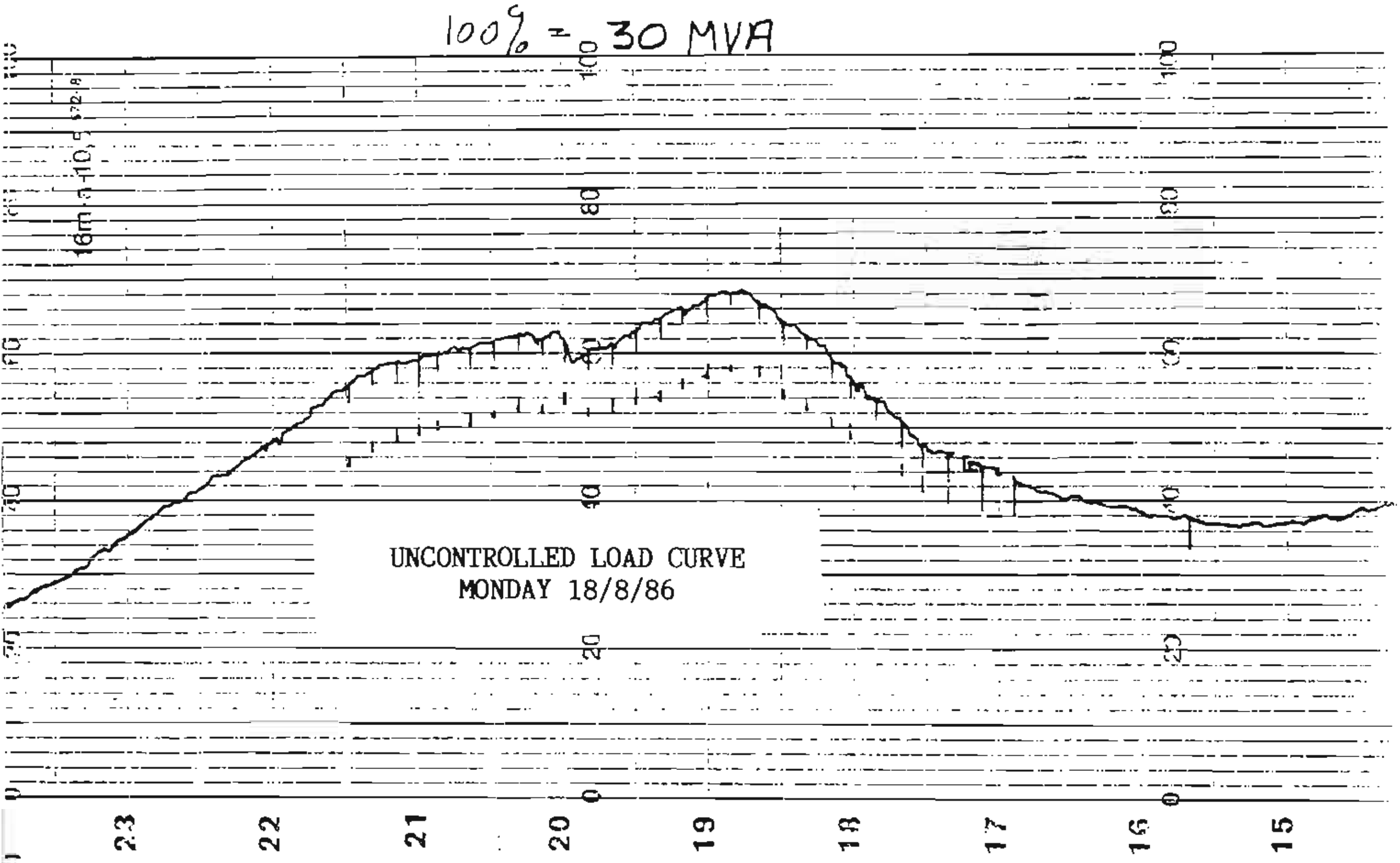
TEST CONDUCTED 1986-08-18 & 19 IN COLABORATION WITH ESCOM
(Ripple Control System Switched Off)

Time	Town Load in MVA		Diversified Cyl. Load		Cyl. Load as % of Total Load
	Cylinders On	Cylinders Off (Briefly)	MVA	KVA/geyser	
17h00	13,0	11,4	1,6		12,31%
17h10	13,5	11,6	1,9		14,07%
17h20	14,0	12,0	2,0	,46	14,29%
17h30	14,5	12,4	2,1		14,48%
17h40	15,4	13,1	2,3		14,94%
17h50	16,3	13,8	2,6	,59	15,34%
18h00	17,2	14,6	2,6		15,12%
18h10	18,0	15,1	2,9		16,11%
18h20	19,0	15,8	3,2	,66	16,84%
18h30	19,6	16,3	3,3		16,84%
18h40	20,4	17,1	3,3		16,18%
18h50	20,7	17,3	3,4	,77	16,43%
19h00	20,5	17,1	3,4		16,59%
19h10	20,1	16,7	3,4		16,92%
19h20	19,5	16,2	3,3	,75	16,92%
19h30	19,0	16,0	3,0		15,79%
19h40	18,5	15,9	2,6		14,05%
19h50	18,2	15,6	2,6	,59	14,29%
20h00	18,7	16,1	2,6		13,90%
20h10	18,7	15,7	3,0		16,04%
20h20	19,0	15,9	3,1	,71	16,32%
20h30	18,6	15,6	3,0		16,13%
20h40	18,3	15,3	3,0		16,39%
20h50	18,2	15,1	3,1	,71	17,03%
21h00	17,9	14,9	3,0		16,76%
21h10	17,8	14,6	3,2		17,98%
21h20	17,5	14,2	3,3	,75	18,86%
21h30	16,8	13,6	3,2		19,05%

DIVERSIFIED GEYSER DEMANDS FOR SOMERSET WEST

TABLE 2.4

THE MUNICIPALITY OF
SOMERSET WEST



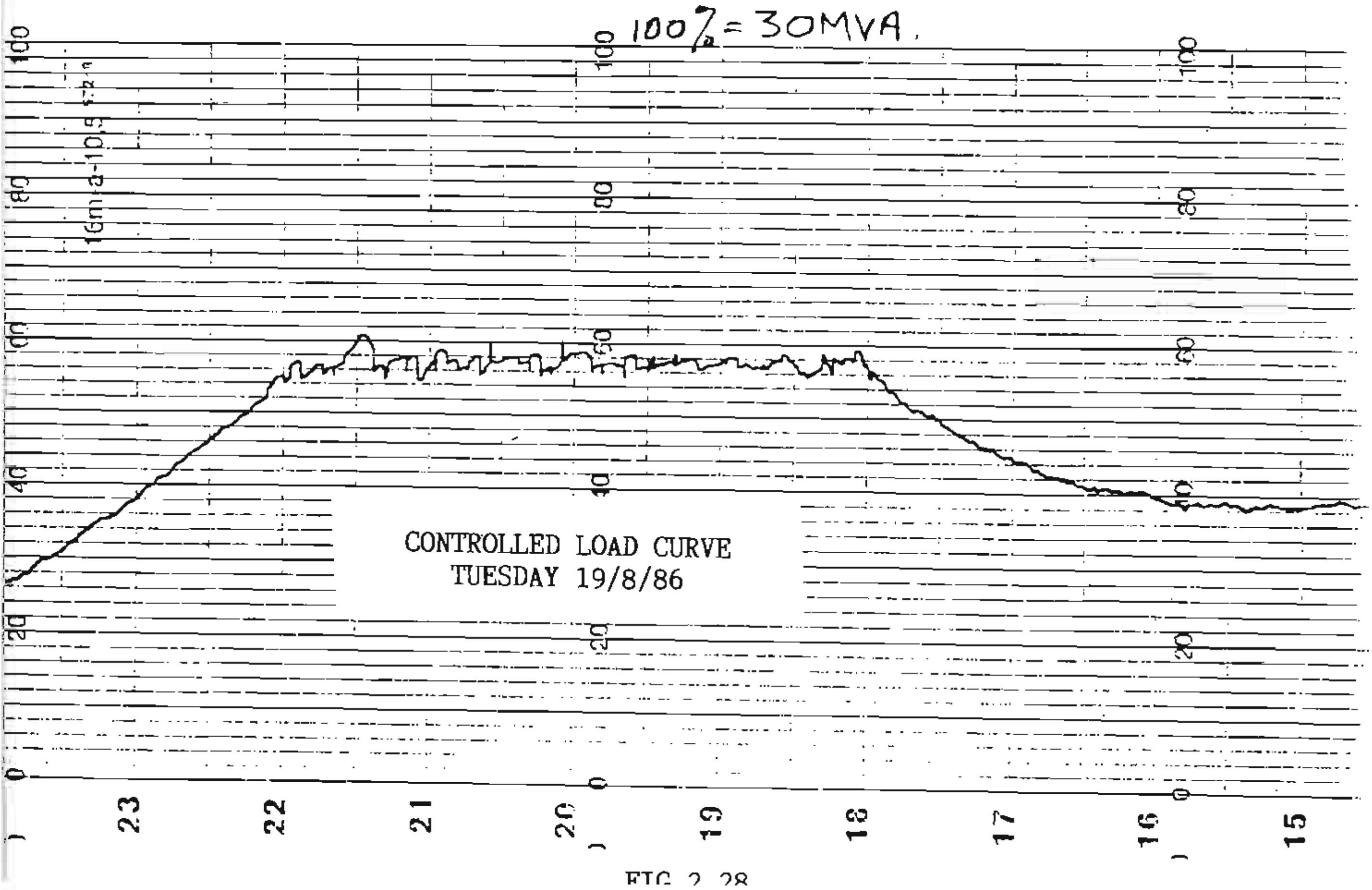


FIG 2.28

INTERVAL	1	2	3	4	5	6	7
TIME	17.45	18.15	18.45	19.15	19.45	20.15	20.45
EXIST MD	15400	18000	20400	20100	18500	18700	18300
TARGET	17400	17400	17400	17400	17400	17400	17400
DIFFERENC	2000	-600	-3000	-2700	-1100	-1300	-900
KVA/GEYSE	.75	.75	.75	.75	.75	.75	.75
GEYSERS							
450	0	-337.5	-337.5	-337.5	675	135	-337.5
350	0	-262.5	-262.5	248.5	161	-262.5	-262.5
350	0	0	0	-262.5	-262.5	-262.5	-262.5
500	0	0	-375	375	355	230	0
600	0	0	-450	-450	-450	480	408
650	0	0	-487.5	-487.5	-487.5	-487.5	-487.5
750	0	0	-562.5	-562.5	-562.5	-562.5	-562.5
720	0	0	-540	-540	-540	-540	626.4
TOTAL CHANGE		-600	-3015	-2766.5	-1111.5	-1270	-878.1
NEW MD	15400	17400	17385	17333.5	17388.5	17430	17421.9

	8	9	10	11	12	13	14	15
	21.45	22.15	22.45	23.15	23.45	00.15		
	17800	15600	13500	12300	12200	0	0	0
	17400	17400	17400	17400	17400	17400	17400	17400
	-400	1800	3900	5100	5200	17400	17400	17400
	.75	.75	.75	.75	.75	.75	.75	.75
	-337.5	-337.5	360	306	0	0	0	0
	-262.5	287	266	0	0	0	0	0
	304.5	318.5	126	0	0	0	0	0
	-375	-375	345	0	0	0	0	0
	-450	-450	426	0	0	0	0	0
	598	682.5	236	0	0	0	0	0
	690	787.5	330	0	0	0	0	0
	-540	259.2	129.6	0	0	0	0	0
	-372.5	1172.2	2278.6	306	0	0	0	0
	17427.5	16772.2	15778.6	12606	12200	0	0	

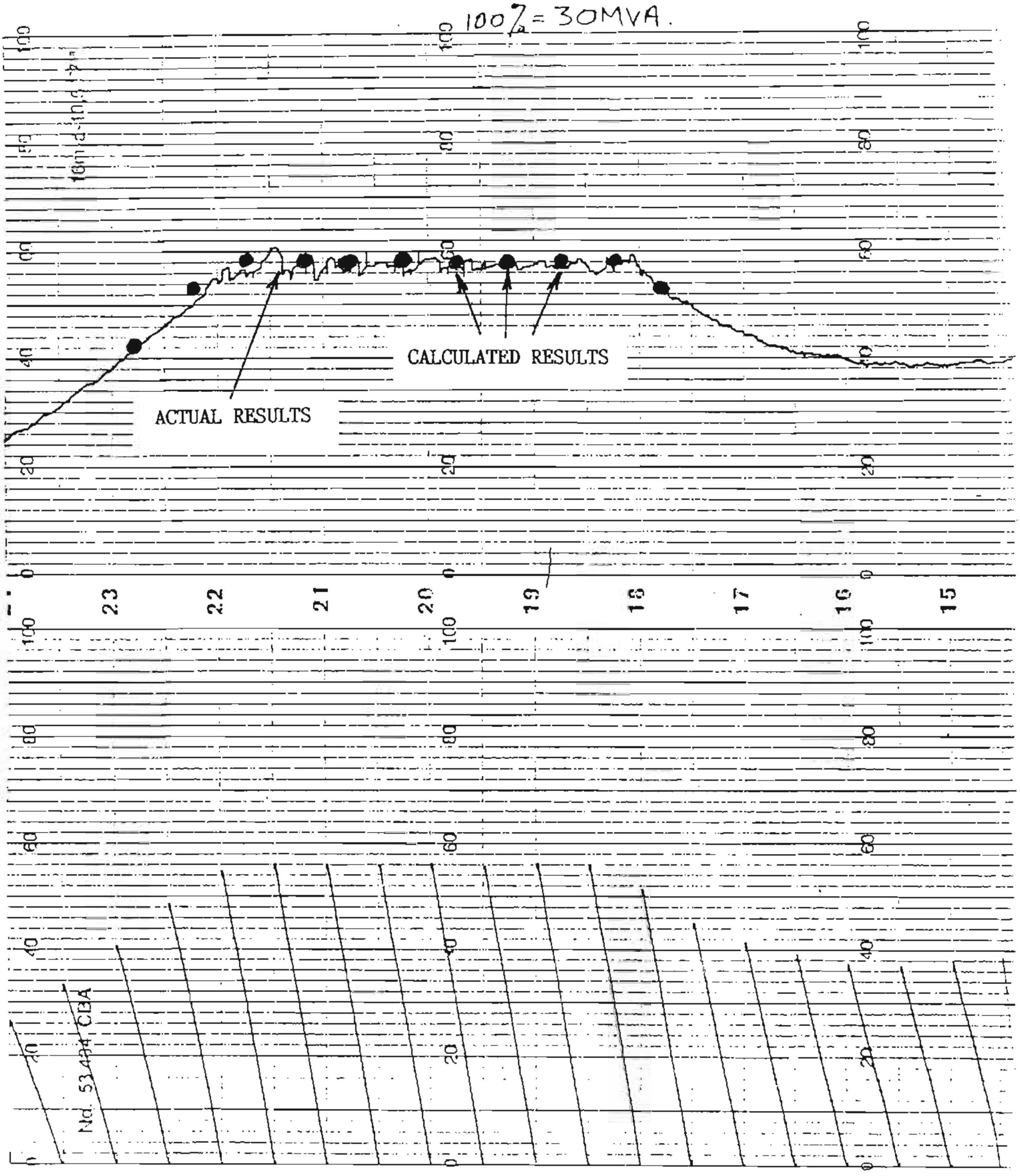
GEYSERS	[illegible]
EXIST MD	20400
NEW MD	17430
REDUCT	2970
CONTRIB	[illegible]

SOMERSET WEST 18/08/86

FEASIBILITY STUDY FOR UNCONTROLLED LOAD CURVE FOR SOMERSET WEST

FIG 2.29

THE MUNICIPALITY OF
SOMERSET WEST



CALCULATED CONTROLLED LOAD CURVE SUPERIMPOSED ON ACTUAL CONTROLLED LOAD CURV

FIG 2.30

2.12 HARD LOAD MANAGEMENT BY VOLTAGE REDUCTION METHOD

A very practical method of load reduction which can easily be employed is to reduce the system voltage during the peak period.

For resistive loads we have, from Ohm's Law :

$$W = \frac{V^2}{R}$$

where W = Power in Watts

V = voltage in volts

R = Resistance in Ohms

For practical reasons the voltage should not be reduced by more than 5%. For a voltage reduction of 5% we will then have :

$$W = \frac{(0.95V)^2}{R} = \frac{0{,}9025\ V^2}{R}$$

That is, a 5% reduction in voltage will result in an approximate 10% reduction in load (for resistive loads).

Numerous studies have been carried out on the effects of reducing system voltages for energy and demand conservation, and the results in all these reports indicate a favourable relationship between lower voltage and energy conservation.[15.]

M.W. Gustafson[16.] points out certain shortcomings of the voltage reduction program. In particular he notes that for filament lamps

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15. CHEN, M.S., et al, "The effects of reduced Voltages on the efficiency of electric loads", IEEE Transactions on Power Apparatus and Systems, Vol. PAS-101, No 7, July 1982, p 2158.

16. GUSTAFSON, M.W., "Residential and use Load affected by Voltage Reduction."

the consumer loses more than what the undertaking saves. Since the resistance of a filament lamp is affected by its temperature and since light output is also a function of filament temperature, it follows that a reduction in voltage will affect both resistance and light output, and it has been found that a 5% voltage reduction will reduce energy consumption by 8%, but will reduce light output by 16%. He agrees that for all other loads, particularly resistive loads such as water heaters, stoves etc, there will be a 2 percent load reduction for every 1 percent voltage reduction.

Voltage reduction can be achieved very easily. Every major substation is equipped with transformers which have automatic tap-changing equipment, which automatically adjust the output voltage to compensate for voltage variations. It is a very simple matter to rig up a change-over relay which, when operated, increases the sensed voltage which will permit the automatic tap changer to step down, thereby reducing the voltage in the system. After the peak period the relay is de-energised and the transformer steps back to the normal voltage.

2.13 CONSUMER BEHAVIOUR : VOLTAGE REDUCTION TEST

The writer undertook a voltage reduction test at Tongaat Substation for the following reasons :

a) To determine experimentally the approximate reduction in load for a 5% reduction in voltage.

b) To determine if any consumers are adversly affected by a 5% reduction in voltage.

2.13.1 Reasons for choosing Tongaat Substation for Voltage Reduction Tests.

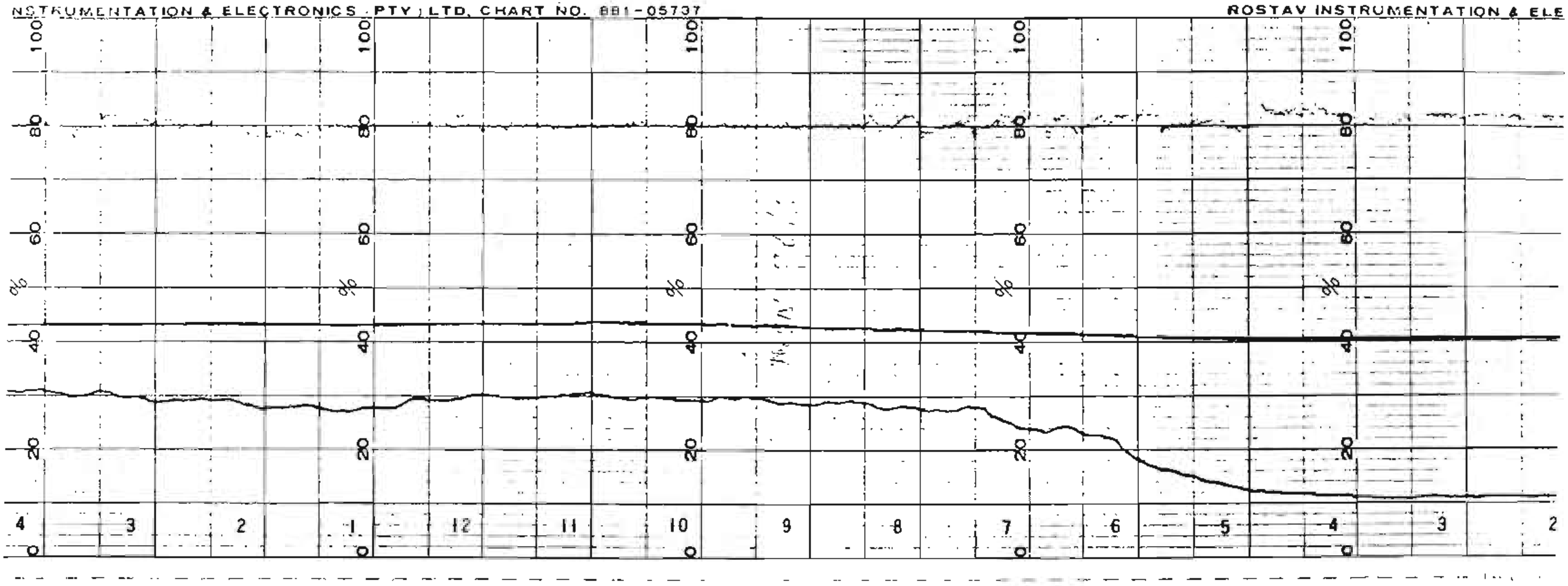
The reasons for choosing Tongaat Substation for the voltage reduction tests were :

1. The tariff structure is non-restrictive, and the levels of load demands are therefore determined only by the consumer, and not by his reaction to restrictive measures.

2. Tongaat Substation supplied mainly domestic consumers, and it is particularly these consumers that are responsible for creating the afternoon peak, and whose loads are expected to show the greatest response to voltage reduction.

2.13.2 Details of the test

The daily load curve was measured at Tongaat substation for six days prior to the test. During these six days, the system voltage, power demand and temperature were recorded as shown in Fig. 2.10.



TOP TRACE : SYSTEM VOLTAGE

MIDDLE TRACE : AMBIENT TEMPERATURE

LOWER TRACE : SYSTEM LOAD DEMAND

FIGURE 2.30

PHOTOCOPY OF MULTI-CHANNEL CHART RECORDING

BEFORE VOLTAGE REDUCTION

On 3rd April, 1984 the system voltage was reduced by 5%, from 11250 volts to 10750 volts and this reduced voltage was kept at this level for three days, from the 3rd April 1984 to the 5th April 1984.

The Tongaat Electricity Department employees were advised of this voltage reduction and were instructed to be constantly on the alert for any negative feedback from consumers who may suffer inconvenience on the lower voltage.

The reduced voltage was maintained at 95% of normal voltage for the three days, and not a single consumer appeared to have noticed this phenomenon as no-one contacted the electricity department.

Fig 4.9 shows sections of the demand recording, and illustrates the effect of the voltage reduction.

It should be remembered that normal small power fluctuations continually causes the demand curve to waiver, and this makes accurate assessment of the result somewhat difficult, but nevertheless the following effects can be clearly discerned.

a) The reduction was made at 10.00 a.m., as recordings over previous days indicated this to be a level load period. Careful comparison of the loads recorded show that the load reduction is about 7%. (for a voltage reduction of 5%)

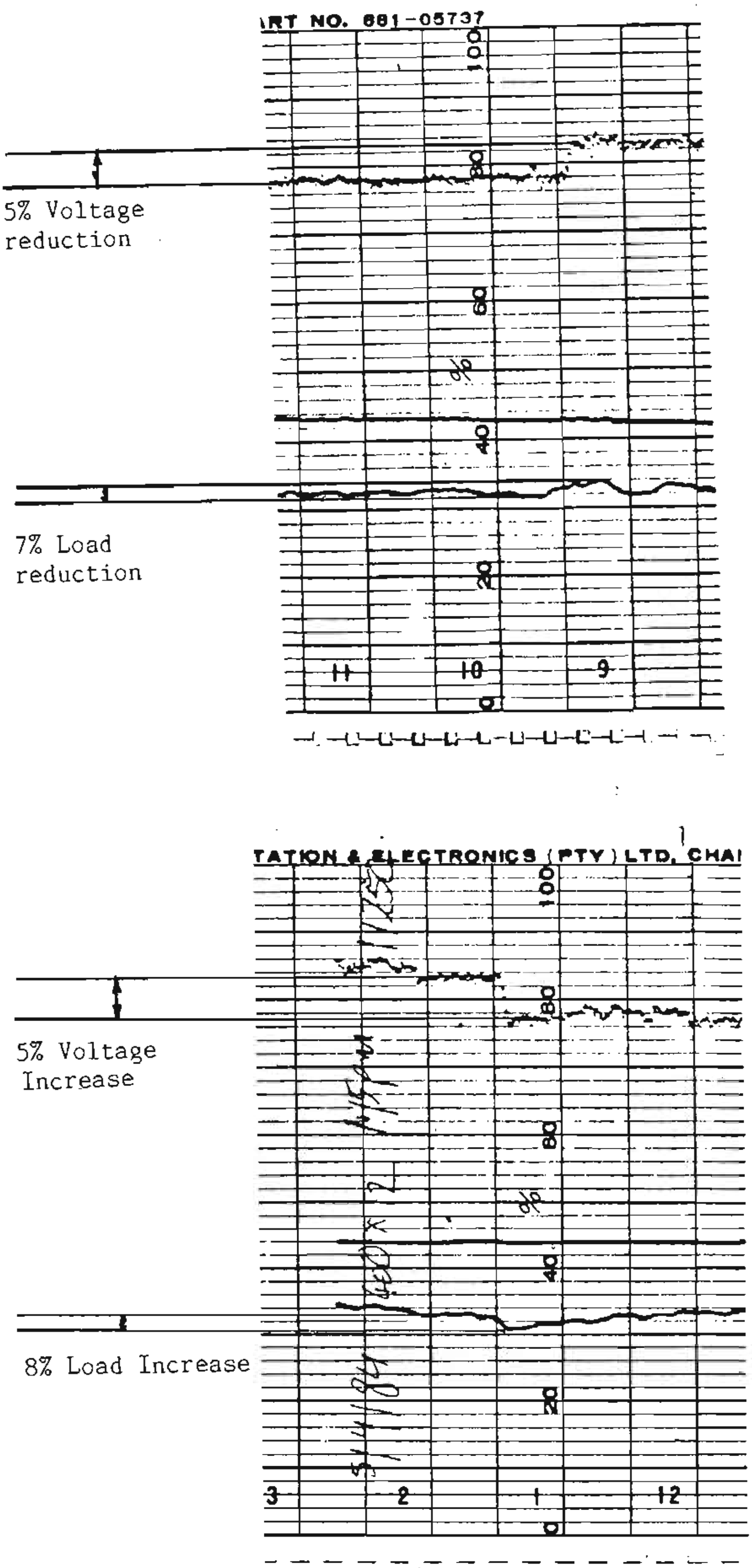


FIGURE 2.31

EFFECT OF VOLTAGE REDUCTION

b) Voltage was restored three days later at 1 p.m. which is also a period which previous recordings showed to be level load period.

It can be seen that there was an immediate increase in demand of about 8% following the 5% increase in voltage.

It would therefore appear that demand can be manipulated by a very simple system of voltage reduction at peak load times. For planning purposes it is probably better to assume a one-for-one reduction ratio rather than the two-to-one that purely resistive loads would give. If a town such as Tongaat or Stanger used such a voltage reduction technique, and reduced voltage automatically by 5% during peak periods, and achieved a 5% demand reduction on say 15 000 KVA, then the annual savings to the town derived from reduced demand charges levied by ESCOM would amount to about R100,000.00 per annum. (5% of 15000 KVA = 750 KVA, which at R10.00 per KVA for 12 months totals R90,000.00).

2.14 FORECASTING CUSTOMER DEMANDS : LOAD FORECASTING

Load forecasting is an essential ingredient if load management is to be as efficient as possible. The need for accurate forecasting is to eliminate as far as possible needless power interruptions on controlled equipment such as irrigation pumps, and needless voltage reductions in the system. For example, it serves no purpose to reduce load every day if a higher peak has already been recorded earlier in the month. The next hard load control need only be exercised on those days when the load approaches its previous maximum. Continual load monitoring and load forecasting is therefore essential for effective load management.

Fig 2.32 shows the highest monthly recorded maximum demand for Mooi River for a 12 month period together with the average monthly temperatures as recorded by the Weather Bureau in Estcourt.
The strong relationship between Maximum Demand and temperature obviously suggests that temperature monitoring and weather forecast information would be major components in a load forecasting model.

Work done by Dehadashti, Tudor and Smith of the University of Missouri-Columbia, proposed a method of forecasting hourly load by pattern recognition using up to 16 weather variables.[17]

They report that this forecasting model gave average accuracies of 2% for even the hottest day, with a lead time of one hour.

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17. DEHADASHTI, A.S., TUDOR J.R., and SMITH, M.S.
"Forecasting of Hurly Load by Pattern Recognition - a Deterministic Approach". IEEE Transactions on Power Apparatus and Systems, Vol PAS-101, No 9 September 1982 p. 3290-3293.

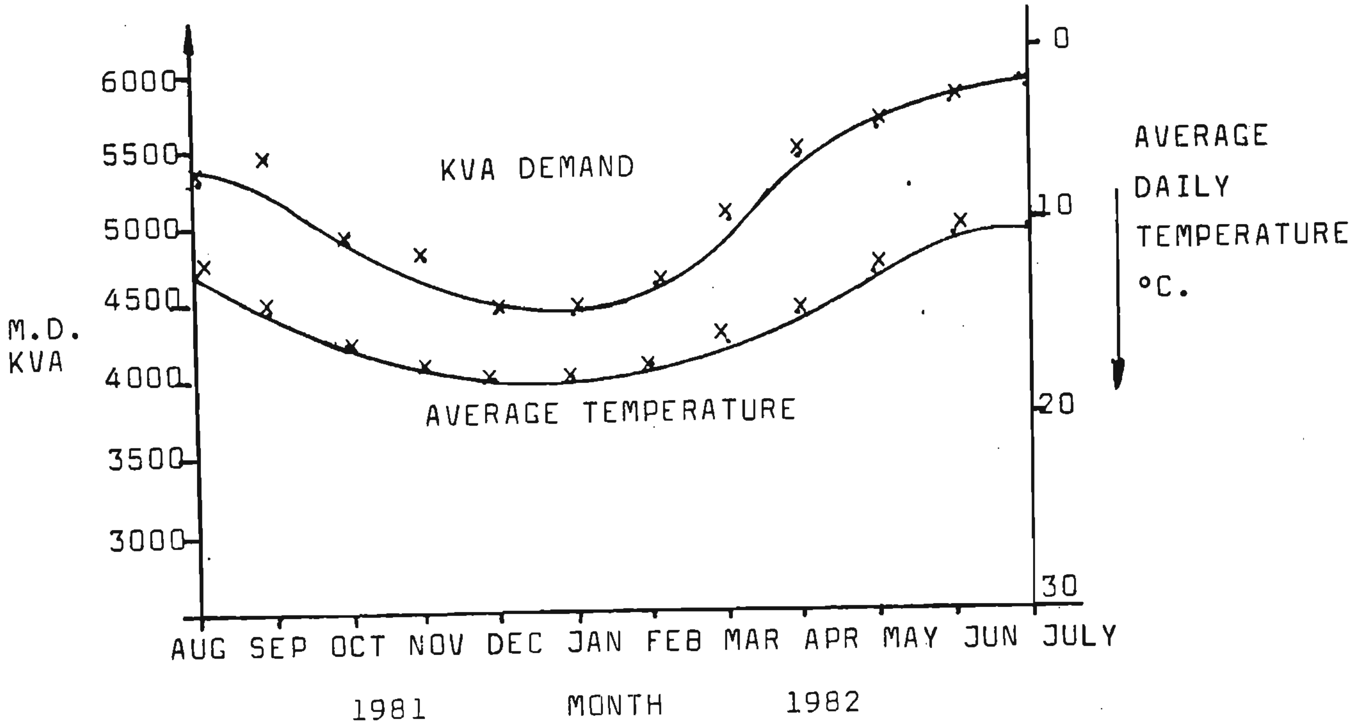

FIG 2.32 RELATIONSHIP BETWEEN AMBIENT TEMPERATURE AND MAXIMUM DEMAND FOR MOOIRIVER.

Source : Breytenbach C.J., "An Investigation into the demand for electricity of typical South African Towns and Cost effect methods to reduce the maximum demand without reducing utility with special reference to Mooi River". MBA Dissertation : University of Durban Westville 1983, page 29.

Gellings and Taylor, of the Public Service Electric and Gas Company (PSE&G) of the USA recently published details of a computer simulation model of electric utility load shape.[18].

Their method differs from the previous model in that their model synthesises the total system load from end-use components. The loads produced by any component are either "base" or "weather sensitive" loads.

Basically, the load demand for each type of weather dependent component is determined for various types of weather conditions The demand forecast for any weather condition can then be simulated by summating the individual loads of the weather dependent components and adding the "base" components which are not affected by weather.

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18. GELLINGS, C.W., TAYLOR, R.W., "Electric Load Curve Synthesis - A Computer Simulation of an Electric Utility Load Shape". IEEE Transactions on Power Apparatus and Systems, Vol PAS-100, No 1, January 1981, p. 60-65.

CHAPTER 3

PUBLIC UTILITY PRICING POLICIES

2.1 THE NEED FOR ELECTRICITY TARIFFS [1.]

On 1st September, 1882, just over 100 years ago, some of the world's first electric street lights were switched on in Kimberley, merely three years after Edison's invention of the incandescent lamp.

Within a mere 12 years the gold mines had power driven machinery of 14997 kW in use. By 1915 four power stations with a total installed capacity of 160 Megawatts had already been erected, these being at Brakpan, Simmerpan, Rosherville and Vereeniging. Today, ESCOM's total installed generating capacity exceeds 20 000 Megawatts, and electricity has become an indisputable necessity for the present and future development of South Africa.

As stated by Herrmann, electricity is a unique form of energy, because of the ease with which it can be transported and converted into to other forms of energy. Nevertheless electricity has certain peculiarities that makes pricing very difficult. According to Herrmann the reasons that electricity requires a complex price structure is that economically speaking electrical energy is not a uniform product. He identifies the main characteristics which distinguishes

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1. Information and historical facts for this introduction were obtained from :

   "Electricity 100 years" Megawatt No 71 April 1982 pages 2-6

   "Chairmans review" Electricity Supply Commission Annual Report 1981, pages 10-13

   "Electricity Tariffs : The Principles underlying their design and structure with some reference to conditions in Southern Africa". G.F.K. Herrmann. pages 1.3 - 1.17.

electricity from other goods and services to be :-

a) For all practical purposes electricity cannot be stored and must be produced at the moment when it is demanded.

b) Suitable equipment and appliances must first be purchased before a consumer can use electricity.

c) It is impossible to predict accurately the peak value that the fluctuating load may reach. This implies that excess capacity must be provided for to meet any eventuality.

d) Because of demand fluctuations with time of day and seasons there is a varying surplus capacity available over and above that required to provide for maintenance and growth. This surplus capacity, which is often regarded as available at marginal cost of production (since the fixed costs are regarded as having already been recovered), is therefore a potential source of low cost energy.

e) While economists draw attention to the time dependence of electricity costs there is in fact no simple way of indicating to the consumer that all available supply is presently being consumed.

f) The supply system cannot distinguish between demands from different consumers so as to supply on a first-come first-served basis, nor can it refuse a consumer's demand when maximum output has been reached. Excessive demand will result in partial or total disruption of supplies. The electricity supply industry therefore cannot operate on the basis of a production optimum where the available equipment is fully utilised over long periods of time.

Complex tariffs are therefore needed to take account of these characteristics.

3.2 HISTORICAL DEVELOPMENT OF TARIFFS[2].

The development of the filament lamp heralded the commercial use of electricity and the early suppliers became the "electric light companies". Electricity charges were based on the number and rating of the lamps used, and this type of flat rate tariff is still in use and has been extended to include the ratings of various appliances such as water heaters, refrigerators etc. While certain appliances such as lamps, refrigerators etc have predictable usage patterns which permit such a flat tariff, the mulitude of present day appliances in which there may be wide discrepancies in the extent of use between different consumers warranted improved tariffs structures. When lighting formed the main load it was in use for only a small part of each day and the generating equipment was idle for the remaining part. As industrial and motive power uses were found to take up some of the unused capacity it meant that some of the same plant capacity was now used for different consumers at different times and this presented problems in cost allocation which persist to this day.

In 1892 Dr. John Hopkinson proposed the subdivision of costs into "standing costs" which he called costs relating to the readiness to supply electricity, and "running costs", which he regarded as those in the actual operation of the plant.

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2. This summary of the historical developemnt of tariffs is based directly on Herrman G.F.R. Ibid p. 1.11-1.17

He proposed that the "standing costs" should be apportioned among consumers in proportion to their maximum rate of consumption, and would pay for "running costs" according to the energy consumed. This "Maximum Demand Tariff" is extensively in use today. Before suitable maximum demand meters were developed, the maximum demand was based on an assessment of the capacity of the installed equipment on the consumers premises. The maximum demand indicator was developed and introduced by Arthur Wright. He also introduced a different tariff to Hopkinson's, in that a certain number of kWh per kW demand were charged for at a high rate, while the remaining consumption was charged for at a lower rate.

Although these tariff structures represent a vast improvement on the flat rate tariffs, they ignore the time dependence of electricity costs. There is an obvious difference between two consumers, where the one uses a large amount of power during times when the system experiences peak load conditions (and may approach overload conditions) while the other consumer requires an equally large amount of power during slack times when there is ample surplus capacity.

Although time-of-day tariffs were proposed in the early days they attracted little attention, probably because of the high price and unreliability of metering and timing equipment then available.

Traditionally electricity tariffs have been determined mainly by the electrical and mechanical engineers involved in the generation and distribution of electricity. However the complexity of tariff design, involving as it does the allocation of fixed costs amongst various classes of consumers with widely differing usage patterns; determining the optimum level at which variable costs should be set to maximise the public welfare; formulating the optimum peak-load pricing policy, etc, means that engineers are generally inappropriately trained to tackle the task, and their tariff structures are criticized by economists for not properly reflecting economic principles. Engineers in turn criticize the economists for the impractical nature of their recommendations.

The subject of Public Utility pricing in general, and electricity pricing in particular has produced a vast volume of literature, but this has been of little practical benefit to the rate engineer.

An understanding of the underlying economic principles is of definite benefit to the tariff designer as well developed econometric models allow the tariff designer to understand more clearly the long term effects of changes to the individual components which make up the electricity tariff.

The fundamental question is : at what price should electrical energy be sold? Should it be at the average cost of production over the period in question, or should it be sold at the marginal cost that it would take to produce the extra unit of energy?

In recent times there has been a discernable consolidation of opinion amongst numerous writers on public utility pricing with wide support being expressed for marginal cost pricing.

The underlying economic principles are examined in sections 3.3 to 3.5. After careful consideration and argument this author has come to the conclusion that pricing based on marginal costs does not optimize public welfare, and an argument is presented in favour of average costing.

3.3 WELFARE ECONOMIC FOUNDATIONS

The "social welfare function" as presented by Crew and Kleindorfer holds "that the net social worth of a particular policy may be presented as the sum of consumers' and producers' surpluses generated by the policy in question."[3.]

According to Crew and Kleindorfer, the use of consumers' and producers' surpluses as a measure of welfare was apparently first proposed by Jules (1844) in connection with the evaluation of public-works projects. This concept was developed and extended by Alfred Marshall (1890), and Hotelling(1932,1938) used it as a basis for his proposals on public utility pricing.

According to Crew and Kleindorfer, the measure of welfare employed in evaluating public utility policies is then the following as shown in Fig 3.1 :

$$W = TR + S - TC \qquad \ldots\ldots \text{(A)}$$

where W = net social benefit

TR = Total Revenue

S = Consumers' surplus

TC = Total costs

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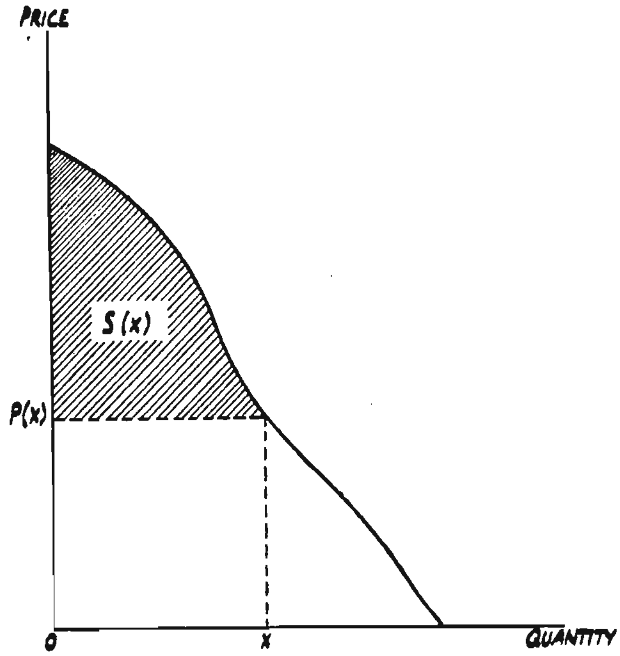
3. CREW, M.A., and KLEINDORFER P.R. Public Utility Economics. Macmillan 1979. page 6.



WELFARE FUNCTION

FIG. 3.1

Source : Crew, M.A. and Kleindorfer, P.R. Ibid. p. 7

In the case of a single product the net benefits in (A) accruing at a given output level x may be expressed as :

$$w = \int_0^x D(x)dx - \int_0^x MC(x)dx \qquad \ldots\ldots (B)$$

where D(x) is the demand function

MC(x) is the marginal cost function

The left-hand integral in (B) encompasses both the total revenue $TR(x) = P_{(x)}x$ as well as consumers' surplus $S_{(x)}$

From (B) we get:

$$\frac{dw}{dx} = D(x) - MC(x)$$

To maximize W we need to set $dW/_{dx} = 0$, we then have

$$D(x) = MC(x) \qquad \ldots\ldots (C)$$

That is, maximum net welfare benefit occurs at the output level when marginal cost equals marginal demand price.

3.4 ARGUMENTS AGAINST THE SOCIAL WELFARE FUNCTION AND MARGINAL COSTING

There should be no doubt that the aim of public utility pricing policies must be to maximize net welfare benefit.

However, the present method of measuring welfare benefit by representing it as the equivalent monetary surpluses which obtain at any given price, is in this writer's opinion a great disservice to humanity. It may well be acceptable for conditions pertaining in the highly developed countries but it is totally inappropriate for developing countries such as South Africa. Paul A. Samuelson, as far back as 1947 drew attention to the distortions created by the concept of Consumer's Surpluses in a chapter section headed "Why Consumers' Surplus is superfluous" in his book entitled "Foundations of Economic Analysis." He states that Professor Viner argues that it "is incorrect in using the area under the demand curve as an index of the gains from trade because this magnitude does not coincide with the amount which could be derived by an all or none offer, as if the latter were the primary and correct expression for consumers' surplus".[4]

The following two examples should clearly illustrate the shortcomings.

For thousands of African families who live on paltry incomes, their purchases of electricity, however meager, may represent light in the darkest night, heat on the coldest day, and convenient cooking of the most drab staple foods. Assume that an undertaking sold electricity

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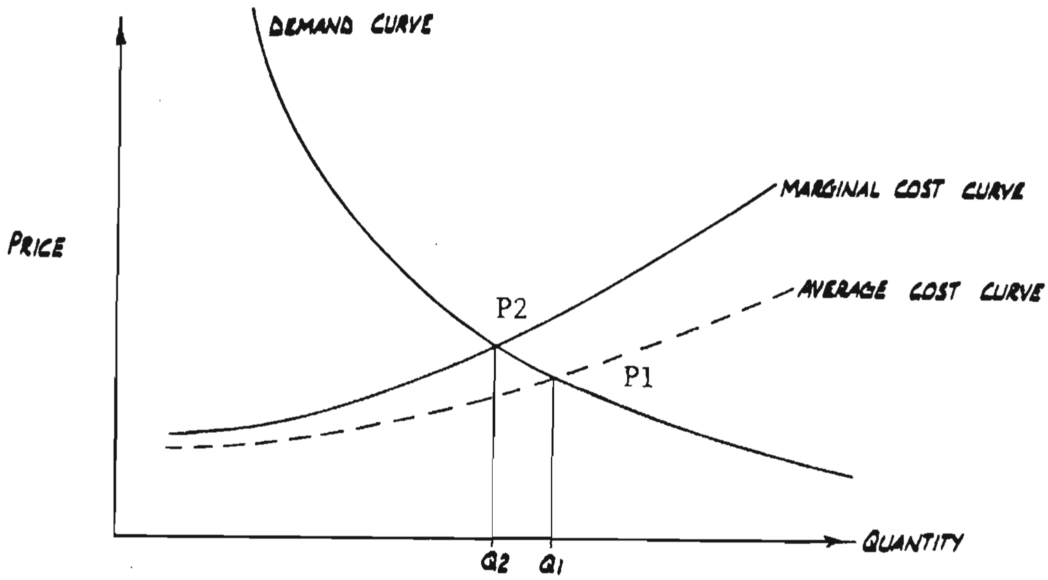
4. SAMUELSON, PAUL A. "Foundations of Economic Analysis" Cambridge Harvard University Press 1947 p. 197.

to these Africans at average cost, i.e. at a cost such that total costs are recovered by sales of all units at average price. Consider now that the owners of the undertaking (who really have social welfare at heart) should learn that they can maximize welfare benefit by increasing the tariff from average cost to marginal cost, remembering that for rising cost curves the marginal cost is always higher than the average cost. They can expect the total sales to reduce from Q_1 to Q_2 as a result of this increase in tariff as shown in Fig 3.2.



DEMAND AND SUPPLY CURVES FOR CONSUMERS

FIG. 3.2

Such an increase in tariff could price electricity out of the market for the poorest families. They will decide to revert to ineffectual paraffin lamps for lighting and scavenging for firewood for cooking and heating. Yet the utility owners may actually believe that they have increased the net welfare benefit.

Consider a second example.

The owner of a fleet of buses transports the above Africans from a

total cost by charging each passenger at average price. He has a fine fleet of buses, but the older and smaller buses have distinctly higher running costs than the larger and more fuel-efficient buses. He too now learns that he can improve the welfare benefit of the community by increasing all tariffs to the marginal cost of running the most inefficient of his buses. Numerous Africans, who earn apallingly low wages as unskilled workers, may not be able to afford the increase. Some may have to decide to get up at ridiculously early hours and walk long distances to work. Others may decide that since the low wages no longer meets the increasing expenses that it is no longer sensible to work, and may decide to stay home and help forage for firewood,which has become necessary as a result of the electricity undertaking increasing its tariff from average cost to marginal cost, supposedly also for his benefit. These examples must clearly demonstrate the injustice of measuring welfare in terms of M.C. pricing. The loss of revenue from the poorest families represents an insignificant reduction of utility on the welfare function if the tariffs are increased, but how does one account for the considerable loss of quality of life of the poorest Africans in the above examples?
There should be no doubt about it : setting prices equal to marginal cost maximizes the profit of the undertaking, but definitely does not maximize the welfare benefit of the community when externalities are taken into account.

A spurious argument in favour of marginal costing (which is totally incorrect) is that since average cost is less than marginal cost, then by pricing the goods at average cost it may stimulate further purchases which cannot be produced at the selling price. This argument is incorrect since, by construction, the maximum number of units which can be sold at the average price is where the average price intersects the demand curve. It cannot stimulate further demand.

Fig 3.2 shows the situation clearly, and indicates that additional sales cannot be stimulated by the average price at intersection (P1) but can only be stimulated by a further reduction in price. This fear then of being swamped by uncontrolled demand as a result of average cost pricing is therefore unfounded.

3.5 ALTERNATIVES TO MARGINAL COST PRICING

From the foregoing, the question must then be asked :

If one then rejects the basis for marginal cost pricing, then what alternative objective can one set to determine optimum prices? In this writers' opinion the answer is clear : one must set prices such as to obtain the maximum possible quantity of sales while recovering total costs. Hence, if all units are sold at one price, then the average cost of producing one unit will determine the price. More importantly, if price discrimination can be justified then a strong case can be made in favour of increasing the price where the consumers' surpluses are high and the demand is therefore very inelastic, and reducing the price where the consumers' surplus is low corresponding to high elasticity of demand. The total number of units then sold could increase dramatically with considerable improvement in the quality of life for the underprivileged section of the community. The demand curve represents the resultant of all consumers' demands. Since the poorest people are far more sensitive to price increases than rich people it follows that the left-hand-side of the demand curve represents the rich consumers, who will continue to purchase units even after significant price increases as shown by the demand curve. Any number of downward sloping price curves can be constructed, such that the area under the marginal cost is equal to the area under the price curve i.e. where total revenue equals total costs.

By implication, it suggests that the richer consumers should pay higher prices for electricity, and the poorer consumers should pay lower prices. This corresponds to taxation where the rich pay proportionately more taxes than the poor. It is relatively easy to charge the rich people more for their electricity. The poorer consumer uses very little electricity, perhaps 200 units per month. Increasingly richer consumers use increasingly more units, perhaps 2000 units per month or more. A suitable block tariff structure, for example, wherein the first 200 units are sold at one price, and additonal units in blocks of 500 or so are sold at increasing rates will result in the average price per unit being lower for the poorer consumer than for the richer consumer, and would have the desired result.

It should be noted however, that normally, reducing block tariff structures are used, which makes electricity on average cheaper for richer consumers than for poorer consumers since the latter do not consume sufficient units to purchase additional blocks at cheaper rates.

The extent to which the "unfairness" of these block tarrif is concerning South African tariff designers can be judged by the responses following Mr. Mc Cullough's presentation of a paper entitled "Electricity supply tariffs with special reference to Johannesburg", which was read at the AMEU convention in 1977.[5.]

Mr. A.K.L. Shepstone (a Durban City Councillor & Consulting Engineer) responding to the paper stated "My comment is that it means the poorer class of consumer always pays a higher overall unit rate than the wealthy consumer, who invariably gets down to the "follow-on" unit at approximately a third of the block rate. I accept your point, but I wonder why they can't both have the same overall rate without having to discriminate at all."[6.]

Responding to the same paper, Mr. C. Palzer (City Electrical Engineer Cape Town) said the following : "In conclusion, I would refer to the block rate. This rate, as almost universally applied to date, has been the so-called "declining" block rate that is, succeeding blocks are offered at progressively lower rates. Today, however, there is a move in the opposite direction and attention is now being given to the "inverted" block rates, largely in the interest of energy conservation. Under this rate succeeding blocks are offered at generally progressively higher rather than lower rates to discourage heavy consumption and wastage."[7.]

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5. S.G. McCULLOUGH. "Electricity Supply Tariffs with special reference to Johannesburg". AMEU Convention Proceeding May 1977. pages 158-169
6. Response to above paper : p. 170.
7. Response to above paper : p. 171.

In the author's opinion the concept of marginal cost pricing is faulty, as it is based on an incorrect Welfare Benefit model.

The distortions to the economy created by marginal costing can be demonstrated as follows :

Consider that society has to select from one of two "all-or-none" alternative commodities. Commodity A is cheap for small quantities and has a rising M.C. curve. Commodity B is expensive for small quantities and has a flatter M.C. curve. Figure 3.3 illustrates the relationship graphically.

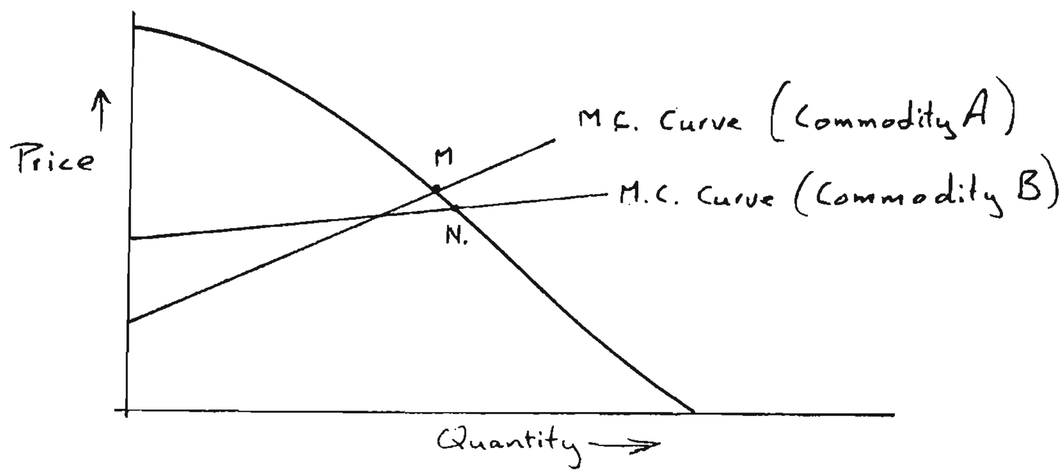


Diagram illustrating error in using M.C. pricing

Fig 3.3

From Fig 3.3 it can be seen that the total cost of production is higher for the commodity which has the lower M.C. at the demand curve. Hence the actual net welfare benefit will be less for the commodity selected on M.C. pricing indicating that the wrong commodity is selected by using the Welfare Benefit model.

The theory of Marginal Cost Pricing stems from the concept of consumer and producer surpluses. As shown before these surpluses are at their maximum when marginal cost price equals marginal demand price.

However a totally different result is obtained if one develops a concept of Welfare Activity.

We can define Welfare Activity to mean the sum of the net welfare benefit and the net cost of production.

This is shown graphically in Fig 3.4.

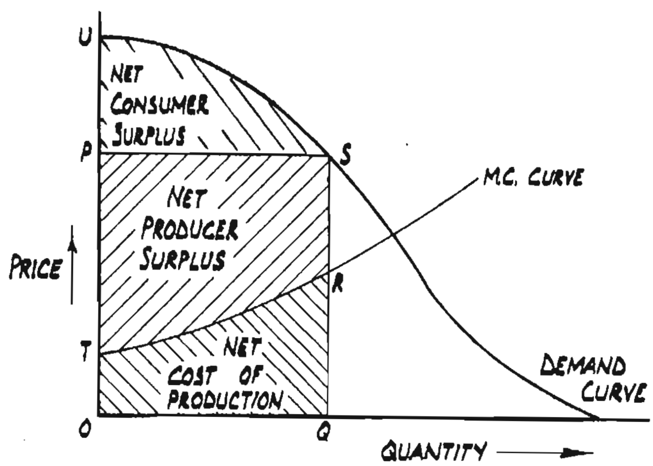


FIG 3.4(a)

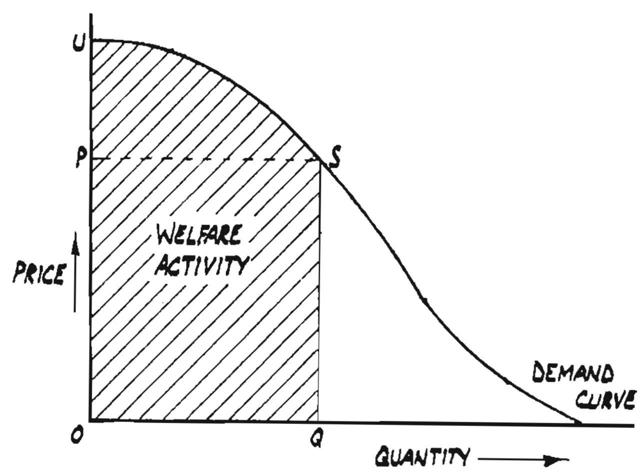


FIG 3.4(b)

WELFARE ACTIVITY

FIG. 3.4

From Fig 3.4 (a) we get the following :

At price P the quantity Q is purchased.

The net cost of production is area OTRQ.

The net producer surplus is area TPSR.

The net consumer surplus is area SPU.

The net welfare benefit is area TUSR.

The Welfare Activity is area OUSQ.

The above relationships are shown clearly in Figs 3.4(a) and Fig 3.4(b)

The concept of Welfare Activity may have several advantages over the present concept of Welfare Benefit.

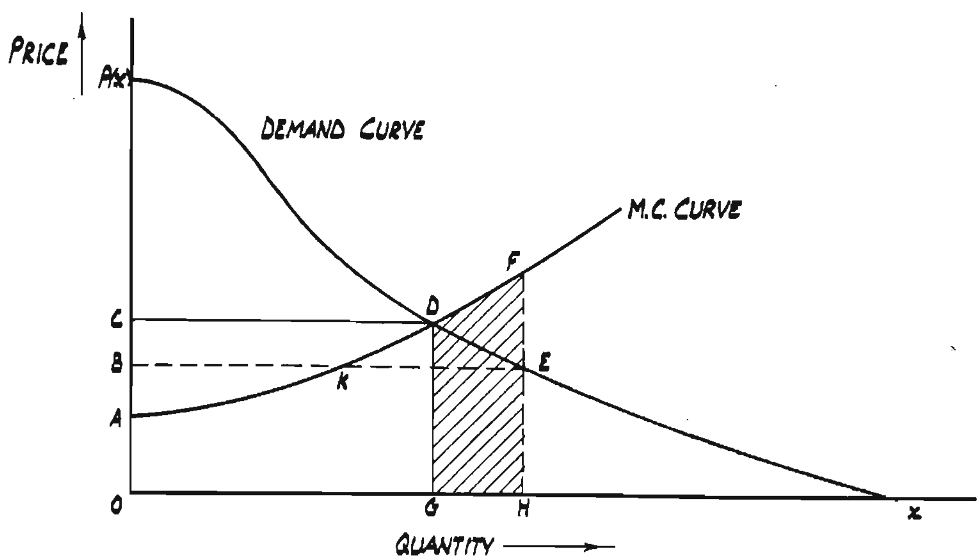
Firstly, it takes into account that employment, and the efficient use of other scarce resources are as important as mere surpluses.

Secondly, it illustrates the benefit of increasing production well beyond that as determined by the Welfare Benefit model.

Thirdly, it provides a better model for actual improvements in the standard of living, by representing it as an increase in Welfare Activity.

These aspects are illustrated in the following discussion, which also presents a solid foundation for average costing.

Figure 3.5 depicts the welfare function (demand curve) and the marginal cost curve.



Relationship between Demand Curve and Marginal cost curve

FIG. 3.5

The theory of marginal costing requires that the price be set at the level at which the M.C. curve intersects the Demand curve. Refering to fig. 3.5 this intersection occurs at point D which sets the price at C. Since all units are sold at this price the total revenue is given by the rectangle OCDG. The total cost of production is given by the area under the MC curve, viz. OADG. The profit made is given by the area ACD. Under these conditions the maximum profit is being derived.

If one now extends the discussion to include total Welfare Activity then it becomes obvious that Welfare Activity will increase if the price is reduced even though the net welfare benefit will decrease. The Welfare Activity will increase up to the point where the total revenue earned equals the total cost of production.

Hence we have :-

Total Revenue earned = Total Cost of Production.

$$P_{(x)} \cdot x = \int_0^x MC.\ dx$$

$$\text{Hence } P_{(x)} = \frac{\int_0^x MC \quad dx}{x}$$

$$= \quad \text{average cost.}$$

Therefore we have that the maximum Welfare Activity will take place where the average cost curve intersects the demand curve.

3.6 THEORY OF PEAK LOAD PRICING [8].

Peak-load pricing problems arise when a utility's product is economically non-storable and demand fluctuates with time.

A "peak-load pricing" policy is required to discourage consumption in peak periods and to encourage off-peak consumption.

According to Crew & Kleindorfer the basic peak-load model was originated by Boiteux in 1949, and Steiner in 1957, and was further developed by Hirshleifer in 1958 and Williamson in 1966.

The Boiteux-Steiner Model adopted the conventional welfare maximizing approach as discussed earlier, namely setting prices to achieve the maximization of the excess of expressed consumer satisfaction over the cost devoted to production.

Steiner assumes a typical day divided into two equal-length periods each governed by its own demand curve, denoted D_1 and D_2 below.

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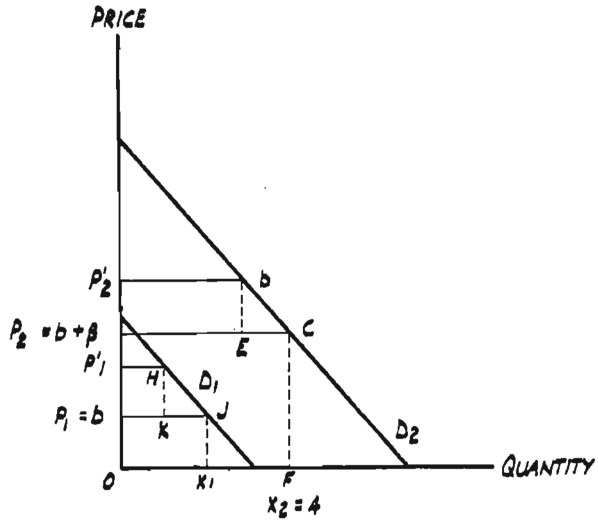
8. This summary of peak load pricing is based directly on Crew, Michael A., and Kleindorfer Paul R., IBID p. 25-27



PEAK-LOAD PRICING MODEL

FIG. 3.6

Source : See footnote 8 on page 3.18

The peak-load problem here results from the assumption that the one demand curve lies above the other for all price 'p'.

The demands are independent, in that the price charged in one period has no effect on the quantity demanded in the other.

Costs are assumed to be linear: b is the operating cost per unit, and β is the cost of providing a unit of capacity. Thus in the off-peak period, a unit will cost b, whereas if additional capacity has to be provided the unit will cost $b + \beta$

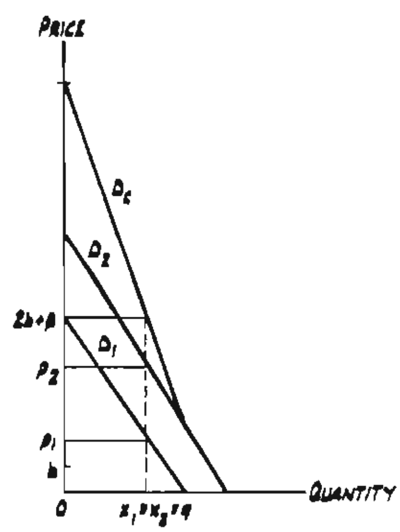
The solution to the two-period problem is shown in Fig 3.6 with prices set at $p_1 = b$ for the off-peak period, and $p_2 = b + \beta$ for the peak period.

To illustrate why this solution is optimal, consider a price p_2' slightly higher than p_2 for the peak-period.

By summing and comparing the areas of net-revenues and consumers' surpluses for the two cases we see that the Marshallian triangle (the Consumers' Surplus) is reduced by the triangle BEC by increasing the price from p_2 to p_2'

In the case where the peak-period demand curve lies close to the off-peak demand curve it may happen that the demand at $p_1 = b$ during off-peak periods may exceed the demand at $p_2 = b + \beta$ during peak periods. This is referred to as the shifting-peak phenomena.

The suggested solution, according to Crew and Kleindorfer, is to add the two demand curves vertically to get Dc as shown in Fig 3.7. The sum of the prices is b plus $b + \beta = 2b + \beta$ Where Dc cuts the horizontal line drawn at $2b + \beta$ this gives the optimal capacity q, allowing prices to be read off as p_1 and p_2 directly.



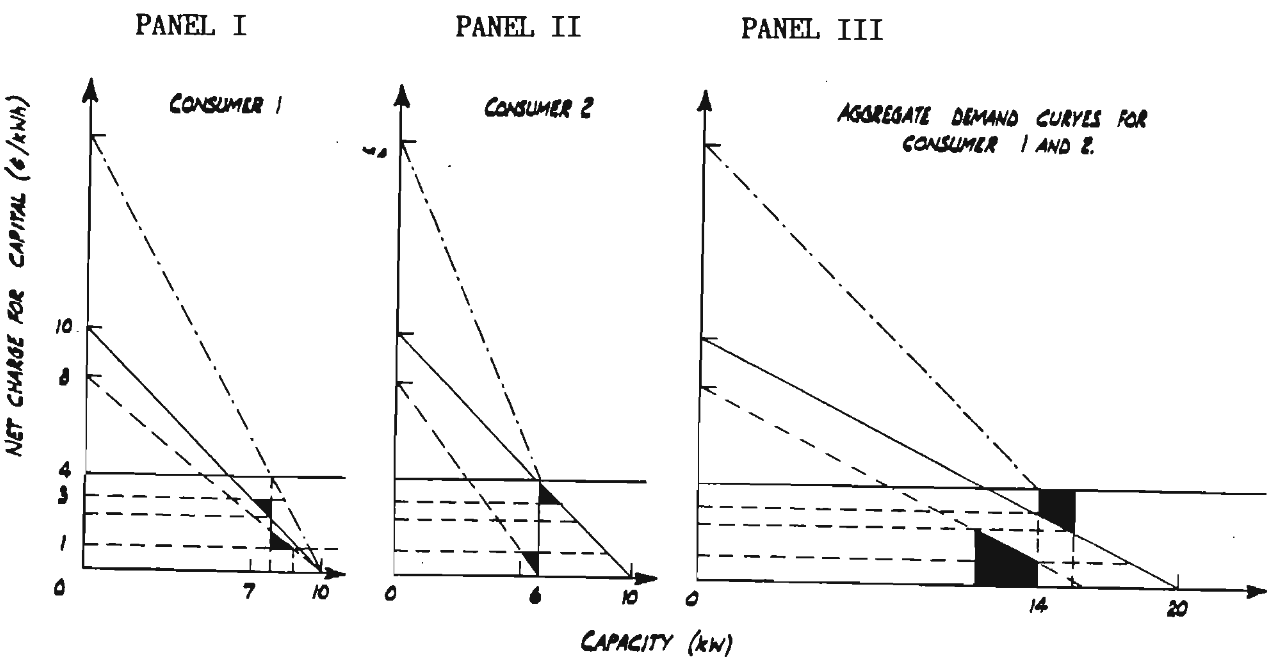
Source : See footnote on page 3.18.

<u>PEAK-LOAD PRICING MODEL FOR SHIFTING-PEAK CASE</u>

<u>FIG. 3.7</u>

Edward F. Renshaw (Dept of Economics State University of New York) extends the discussion by considering two subperiods and two types of consumers. 9.

For the sake of simplicity he assumes that there are two demand periods of equal duration and that the demand curves for electricity in each of these periods are independent of each other. The peak demand curve is shown as a solid line in the figure below, the off peak demand is shown as a dashed line, and the aggregate of these two is shown as a dot-dash line.



Source : See footnote 9

DEMAND CURVES FOR ELECTRICAL CAPACITY

FIG 3.8

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9. Renshaw Edward F., "Expected Welfare gains from peak-load electricity charges". Energy Economics, January 1980, p. 37-45.

To obtain a total aggregate demand for electricity capacity for each consumer, and for the market as a whole, a vertical sum is required of the prices consumers are willing to pay of electricity capacity in both sub-periods.

If the cost of electricity capacity is 4c then it can be determined from panel III that the capacity at which this price intersects the aggregate demand is 14 kW.

To induce the two consumers to consume that much capacity, the utility would have to charge a price for capacity of 3c in the peak period, and a price of 1c in the off-peak period.

This is the ideal pricing arrangement which will ensure a maximization of consumer and producer surpluses.

CHAPTER 4

PRACTICAL ASPECTS OF ELECTRICITY MEASUREMENT AND ANALYSIS

4.1 THE MARGINAL COST CURVES FOR ELECTRICITY

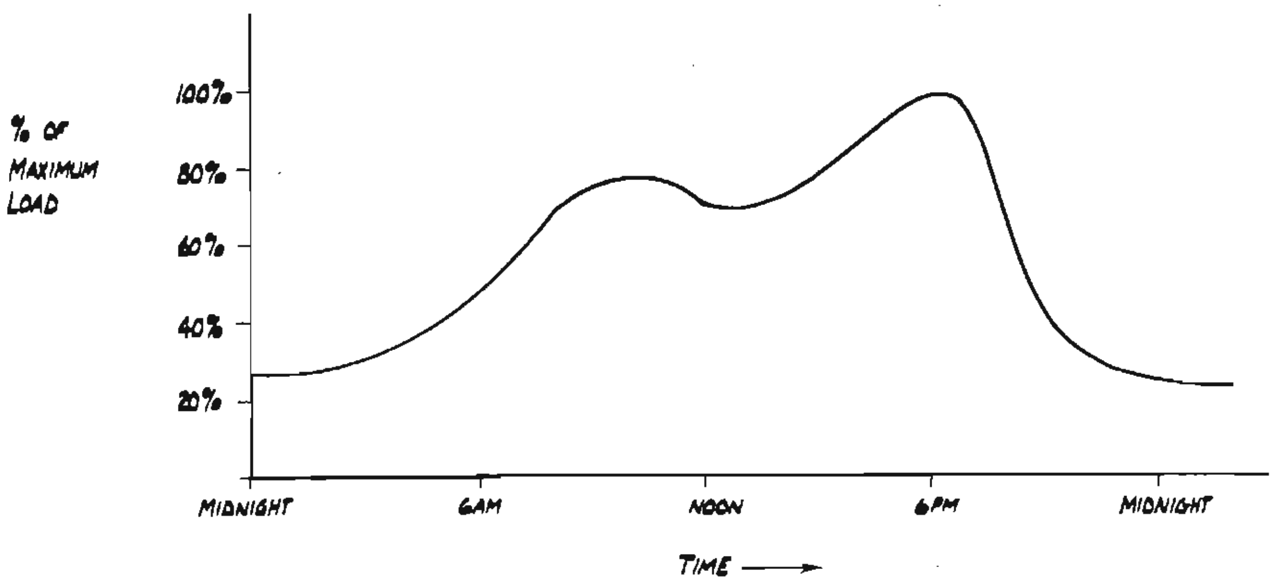
In order that the importance of the discussion on marginal cost pricing can be appreciated, it is necessary to first of all establish the marginal cost curves for electricity.

It is generally accepted that Marginal Cost (MC) should have only one meaning, and that is the cost at the intensive margin, or the cost of producing one additional unit of the good being considered. "This is more generally referred to as short run marginal cost (SRMC) and assumes that there is no change in the available plant capacity. SRMC then does not include any capacity costs but only those costs that are classed as escapable or avoidable in the sense that SRMC covers those costs that would have been avoided if the additional unit were not produced." The remaining costs are "sunk costs", costs in which the economist has little further interest in theory, however much they may in practice be of concern to the accountant (Herrmann p. 4.10).

In order to operate at lowest total cost the various generators of the main power stations are operated in merit order. Hence the most efficient plant is operated first and as load increases, increasingly less efficient plant is taken into service. It therefore follows that the marginal cost curves for the power stations have a definite upward slope over the operating range. Nevertheless ESCOM sells its electricity to all its major consumers (such as Municipal Undertakings) at a constant tariff, of R9.75 per KVA and 1.87c per KWh unit. (Tariff (A) 1986, for up to 33000 volts).

The marginal cost curves for the undertaking can be approximated by the following approach using readily available information such as the maximum demand, total units lost, load factor, etc.

Assume that the undertaking has the following load curve :



ASSUMED LOAD CURVE FOR UNDERTAKING
FIG. 4.1

The load factor represents the ratio of the average Demand to the highest recorded Demand. Hence if the highest demand recorded in a period is say 100 KVA, and the load factor is say 40% then it means that same total amount of power would have been consumed if 40 KVA was demanded continually over the period.

This follows, since we have :-

$$\text{Load factor} = \frac{\text{Total units consumed}}{\text{Maximum Demand x time}} \qquad \text{(eq D)}$$

Losses in the system can reach considerable proportions, usually far higher than even appreciated by Electrical Engineers. The system losses are usually refered to as the "units-lost-in-distribution" and is expressed as a percentage of total units distributed. Losses occur from two causes. Firstly, there are fixed losses of a constant level, which occur from items such as magnetising losses in transformers, unmetered lights in substations etc. The second group of losses are the load-dependent losses. These losses are primarily the so-called I^2R losses, that is the losses (dissipated as heat) caused by the current (I) flowing in the system conductors with resistance(R).

We have $W = I^2R$ (eq E)

where W = Watts

I = Amps

R = resistance in ohms

Now since $KVA = \sqrt{3}\, V \times I \times 10^{-3}$ (eq F)

We get $I = \frac{KVA \times 10^3}{\sqrt{3}\, V}$

and $I^2 \propto (KVA)^2$

and hence $Loss \propto (KVA)^2$ (eq G)

Since losses at any time are proportional to the square of the load at that time it follows that the system loss curve will take the overall shape of the load curve but will considerably amplify the undulations, since for example as the load doubles, the losses increase four-fold.

As stated before, the load-factor represents the ratio between the average power demanded and the maximum power demanded. In the same way one can conceptualise a loss-factor which represents the ratio of the average loss in the system to the maximum loss which occurs at maximum power demand.

It follows that the maximum loss occurs at maximum load. Also, if the load drops to half then the loss drops to quarter of its maximum level. Similarly, if the average load drops to half of the maximum value, then the average loss drops to quarter of its maximum value.

Therefore we have.

$$\text{Loss factor} = \left(\frac{\text{Load Factor}}{100}\right)^2 \times \frac{100\%}{1} \qquad \text{(eq H)}$$

Table 4.1 tabulates the Loss Factors corresponding the various Load Factors as calculated from eq H.

TABLE 4.1

Relationship between Load Factors and Loss Factors

Load Factor	Loss Factor
40%	16%
45%	20%
50%	25%
55%	30%
60%	36%
65%	42%
70%	49%
75%	56%

The above results can be shown graphically as in Fig. 4.2.

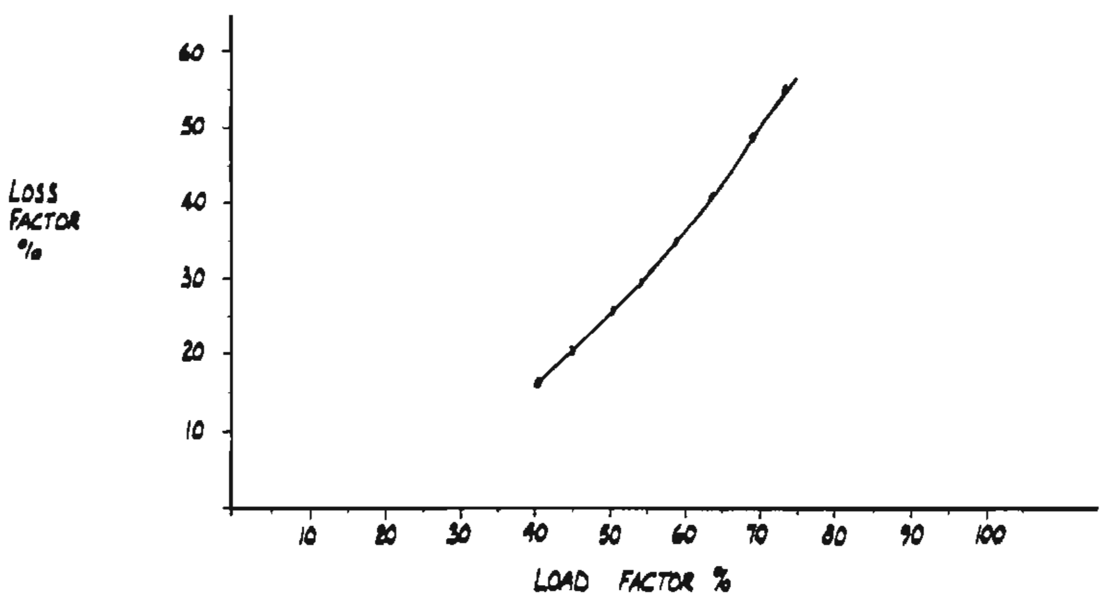


FIG. 4.2

Graph showing relationship of Loss Factor to Load Factor.

From the concept of load factors we have :-

$$\text{Load factor} = \frac{\text{Average Demand}}{\text{Maximum Demand}} \times 100\% \qquad \text{(eq I)}$$

similarly we will have

$$\text{Loss factor} = \frac{\text{Average Loss}}{\text{Maximum Loss}} \times 100\% \qquad \text{(eq J)}$$

$$\text{Hence Maximum loss} = \frac{\text{Average Loss}}{\text{Loss Factor}} \qquad \text{(eq K)}$$

The "average loss" can be determined relatively easily on a monthly basis by a process of unit-sales reconciliation. It is then possible to determine the value of the maximum loss which is occuring when the system reaches maximum load periods.

Table 4.2 summarises the results for various load factors and various average-%-units-lost, to illustrate the estimated maximum value of units lost which occurs at the peak period.

TABLE 4.2

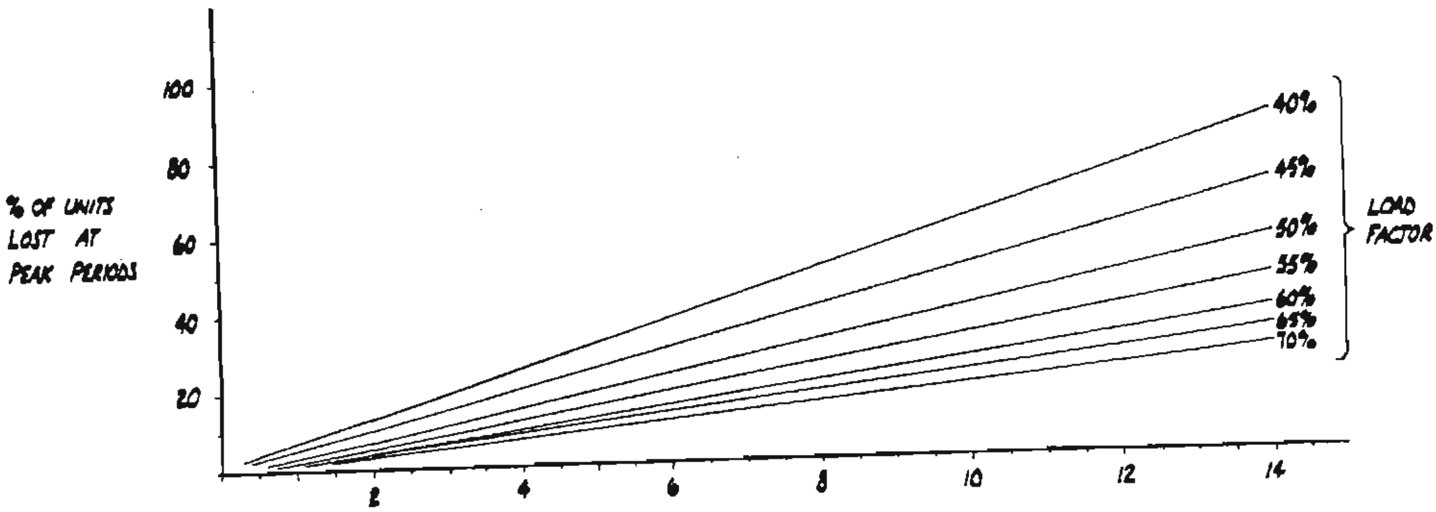
Percentage of units lost in distribution at periods of maximum load.

Average % units lost in Distribution.	Load factor (above) and corresponding loss factor (below)							
	40% 16%	45% 20%	50% 25%	55% 30%	60% 36%	65% 42%	70% 49%	75% 56%
2%	12	10	8	6	5	5	4	4
4%	25	20	16	13	11	9	8	8
6%	38	30	24	20	16	14	12	12
8%	50	40	32	27	22	19	16	16
10%	63	50	40	33	28	24	20	20
12%	75	60	48	40	33	28	24	24
14%	88	70	56	46	38	33	28	28

These results are shown graphically in Fig. 4.3.

FIG. 4.3

Relationship between Average-units-lost-in-distribution, and the maximum-units-lost at peak periods.



% Average-units-lost-in distribution.

This is indeed a useful conclusion since it is relatively easy to determine the load curve and the load factor, but the loss curve and the loss-factor cannot easily be determined directly and the above method allows one to deduce the loss curve. This loss curve is very necessary in order to determine the short-run-marginal-cost curves since at any load level the marginal cost will depend on the energy cost plus the cost of losses at that level.

The following table shows typical information relating to various towns :

TOWN	UNITS SOLD	UNITS LOST IN DISTRIBUTION	LOAD FACTOR
Knysna	14 669 477	13%	44%
Oudtshoorn	39 851 194	15%	43%
Potgietersrus	49 398 967	12%	57%
Standerton	66 450 037	13%	52%

TYPICAL UNITS-LOST FOR VARIOUS TOWNS

TABLE 4.3

Source : The Official South African Municipal yearbook 1983.

The "units-lost-in-distribution" is an average figure based on long term readings. From the above discussion the following can be construed

Consider a town such as Knysna.

The units lost in distribution is 13%

The load factor is 44%

Assume 75% of all losses are load dependant.

Hence the Load dependant Loss is 10% of total units

If the load factor is 44% then it follows from equation (H) that the loss factor is

$$\left(\frac{44}{100}\right)^2 \times 100\% \quad = \quad 19\%$$

From the definition of load factors and loss factors it follows that the maximum loss as a percentage of maximum load must be :

$$\text{maximum loss \%} = \frac{\text{average loss}}{\text{Loss factor}} \times \frac{100}{1}\ \%$$

$$= \frac{10}{19} \times 100\%$$

$$= 52\% \text{ of units}$$

From this result the SRMC curve can readily be constructed. At full load conditions, 52% of all units are dissipated as losses. At three-quarter load conditions, the losses would be $(3/4)^2 \times 52\% = 29\%$. At half load conditions the losses would be $(1/2)^2 \times 52\% = 13\%$ and at quarter load the losses would be $(1/4)^2 \times 52\% = 3\%$.

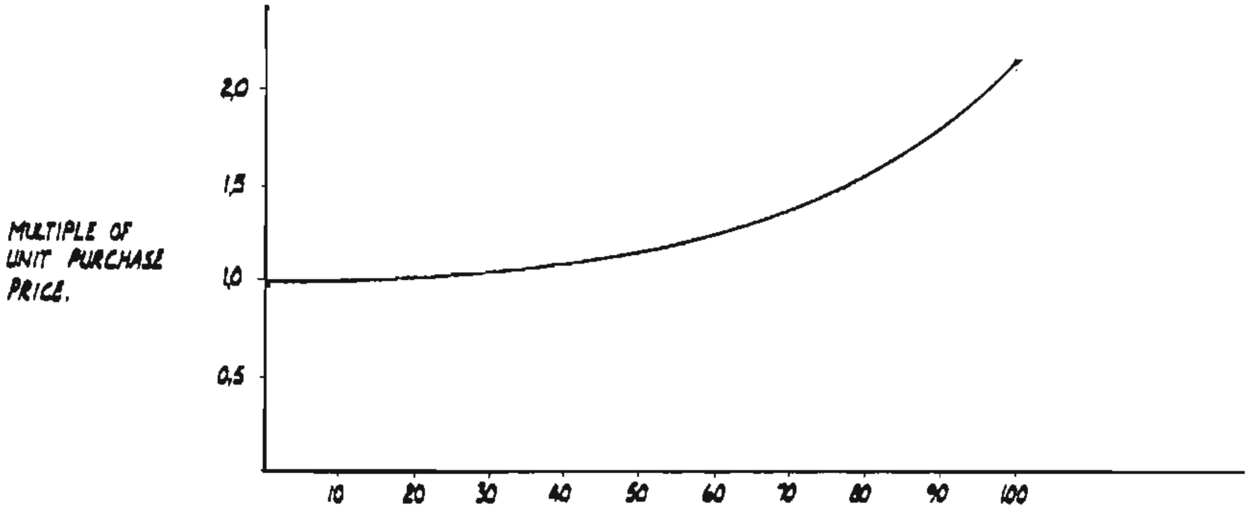
The selling price of units to recover the cost of units lost can be calculated as follows :

$$\text{Selling price of units} = \frac{\text{Purchase price}}{1 - \text{loss}/100} \quad \text{(eq L)}$$

From the above we can calculate the required selling price at the various demand levels as follows :

% of Max Demand	% loss (as calculated above)	Calculation	Selling Price (Multiple of purchase price)
100%	52%	$\frac{1}{1-0,52}$	2,08
75%	29%	$\frac{1}{1-0,29}$	1,40
50%	13%	$\frac{1}{1-0,13}$	1,15
25%	3%	$\frac{1}{1-0,03}$	1,03

The resulting short-run-marginal-cost-curve would then take the following appearance :-



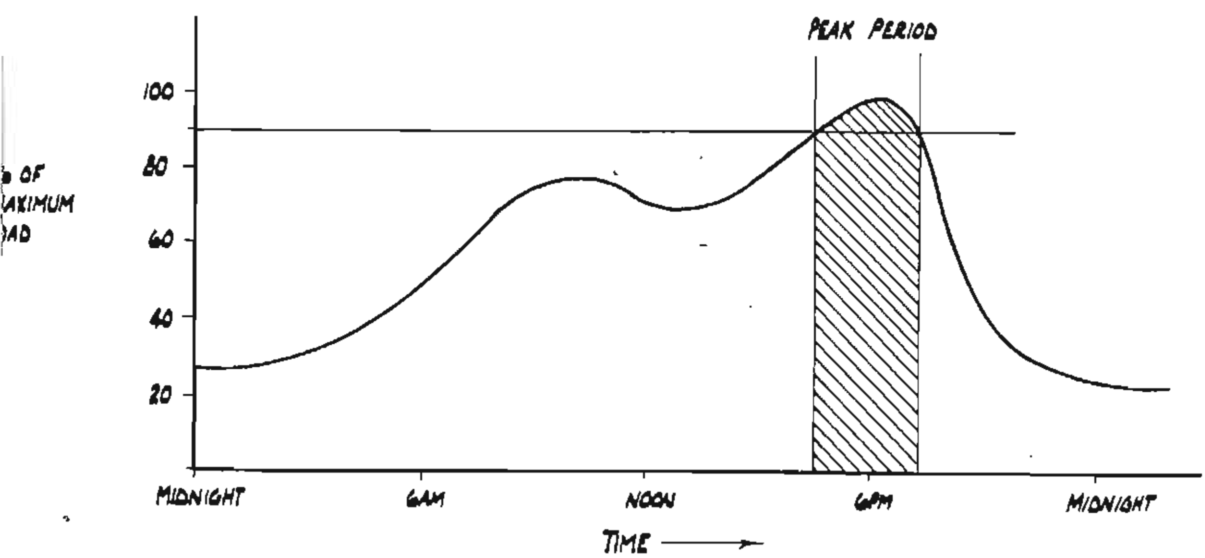
% of highest Maximum Demand
Short run marginal cost curve

FIG. 4.4

The above marginal cost curve reflects the typical upward curving characteristics of increasing marginal costs at higher levels of consumption.

The tariff designer must determine at what level of maximum demand the off-peak tariff ends, and where the on-peak tariff starts.

Consider the following typical load curve :



TYPICAL LOAD CURVE FOR UNDERTAKING

FIG. 4.5

The overall shape of the load curve and the relative sharpness of the peak will determine at what percentage of peak load the off-peak period ends and when the on-peak period starts. It must be borne in mind that any price discrimination between on-peak and off-peak periods will invariably cause some of the peak loads to be shifted to periods immediately adjacent to the peak period. If one considers that the on-peak period is around 2 1/2 hours then it becomes obvious that if too many consumers shift short duration loads into the half hour period immediately prior to the peak period, that it could result in a new and higher peak occuring at this earlier time. This is referred to as the shifting peak phenomenon, and it means that a lower threshold has to be set as the start to the peak period, with corresponding widening of the peak period time.

4.2 MARGINAL COST TARIFF AND AVERAGE COST TARIFF FOR ENERGY CONSUMED DURING OFF-PEAK PERIODS

Having determined the portion of the load curve which will be considered as constituting the off-peak load conditions, then the tariff for the off-peak energy component can be calculated as follows :

Assume that the load curve permits the peak period to be defined as loads exceeding 90% of the peak load. Hence the marginal cost curve for energy will be that portion of Fig 4.4 from zero load to 90% of maximum load. The two alternative energy tariffs will then be :

4.2.1 Tariff based on marginal cost :

Since only one time period is considered for the off peak period, the tariff based on marginal cost must be equal to the marginal cost at the 90% peak load position in Fig. 4.5.

4.2.2 Tariff based on average cost :

It is necesary to determine the weighted average cost of all units sold during the off-peak period.

Since the area under the load curve represents the total units consumed it follows that the weighted average can be calculated as follows:

1) Determine the total units sold during the off peak period by determining the total area under the load curve excluding the peak period. This area can be determined by using the sum of squares or another suitable method.

2) From the load curve, determine the proportions of the area which correspond to different levels of maximum demand as indicated by the load curve.

3) Determine the total cost of the units by multiplying the number of units corresponding to the various levels of maximum demand by the marginal cost of those units as determined from the marginal cost curve, and summating all such products.

4) Determine the weighted average by dividing the total cost by the total units.

The energy tariff for the on-peak period can be determined in a similar manner.

4.3 MAXIMUM DEMAND TARIFF IN OFF-PEAK PERIODS FOR EVERY MUNICIPAL UNDERTAKING.

ESCOM measures the energy consumed and the maximum demand (KVA). It is obvious that consumption during off-peak periods will not add to the recorded maximum demand. Hence, to recover actual running costs, the municipality need only recover from its consumers, the energy costs, plus system losses. This can be either the marginal cost or average cost for energy as discussed before. In addition, it must be decided if the off-peak consumer should contribute towards KVA charges and/or capital charges.

4.3.1 CAPITAL COSTS

The municipal undertaking receives its electricity from ESCOM at its "Intake Substation", and has to distribute it to its numerous consumers, via a complex reticulation network involving various reducing levels of voltages (typically 33kV, 11kV, 400v and 231 volts) to reach every consumer. Such reticulation systems and distribution networks consist of various grades of high voltage cables, transformers and switchgear which require a great deal of capital investment.

It is now widely accepted that peak-period users should bear all marginal capital costs. As stated by Wenders "The traditional theory of peak-load pricing argues that peak period users should bear marginal operating costs and all of the marginal capital costs, and off-peak users should be charged prices which cover only marginal operating costs. These results appear prominently in the Berlin, Cicchetti, and Gillen report (1974, especially Chapter 3) to the Energy Policy Project of the Ford Foundation, and have recently been emphasized by the well-known economist-regulator, Alfred E. Kahn (1985 p 32)".[1.]

The foregoing discussions clearly indicate that it costs more to deliver electricity to the consumer during peak periods. To give the consumer the correct signals it is therefore necessary to design tariff structures which take peak period times into account.

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1. WENDERS John T. "Peak load pricing in the electric utility industry" The Bell Journal of Economics. p. 232.

4.4 ESCOM's New tariff structure : An incentive for Load Management

Table 5.5 shows that the purchase of electricity from ESCOM forms around 65% of the total costs of the electricity undertaking. It is obvious that a thorough understanding of the components of this cost is essential.

Several far reaching changes are to be introduced by ESCOM on 1st January, 1986, and these are discussed below.

4.4.1 Summary of proposed changes in ESCOM tariffs

As stated above, purchases from ESCOM form a very large part of the total costs of the undertaking. For this reason it is considered prudent to include a comprehensive appendix of explanatory notes as well as the full schedule of standard prices as issued by ESCOM, as Appendix A.

The major changes proposed by ESCOM are :- [2.]

a) The concept of undertakings. Undertakings refer to the five areas where ESCOM has been licenced by the Electricity Control Board to supply electricity in South Africa. Before 1960 the undertakings were not only legally but also physically separate entities. The national network is now sufficiently extended to allow the merging of these undertakings.

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2. ESCOM : DATA : Consumer Information 1 August 1985.

This enables ESCOM to introduce a national equalization of tariffs regardless of the geographical location of the consumer.

b) Fixed transmission costs to agreed reference points. Transmission costs reflect the loss of energy involved when electricity is transmitted over long distances from the major generating areas on the coalfields. These costs will now be fixed in increasing percentages from 0% - 3% according to four distinct zones, each with a radius of 300km departing from the central reference point of Johannesburg.

c) Pooling of costs. Costs for like groups of consumers will be pooled throughout the country, enabling ESCOM to recover the costs of supply in a more equitable manner.

d) Introduction of a tariff structure to satisfy load management requirements. Large Power Users may opt for a new tariff designed to encourage off-peak use of power.

This makes the existing load management incentive available not only to consumers who operate on a 24-hour basis but also those who can alter part of their activities to operate during off-peak periods. By introducing a more efficient pattern of use, consumers can gain financially while reducing their demand during ESCOM's peak period of load.

4.4.2 ESCOM's New Tariff Structure

Full details of the new ESCOM tariffs are contained in Appendix A. The two alternative tariffs which will be of interest to Municipal Undertakings are Tariff(A) and Tariff(E). The relevant important sections of these tariffs are discussed below :-

Tariff(A): Large Power Users : General

i) A basic charge for each point of supply of R45.00 (forty-five rands) per month.

ii) A demand charge for each kilovolt ampere (KVA) of the maximum demand supplied in the month of R9.75 (nine rand seventy-five cents) when the supply is furnished at a nominal phase-to-phase voltage between 380 volts and 66 000 volts.

iii) An energy charge of 1,87c (one comma eight seven cents) per KWh supplied in the month.

iv) The sum of the amounts stated above shall be subject to a transmission percentage charge as follows :

a) Nil for points within 300 km of Johannesburg.
b) 1% for points between 300 and 600 km of Johannesburg.
c) 2% for points between 600 and 900 km of Johannesburg
d) 3% for points exceeding 900 km from Johannesburg.

v) The total as determined above shall be subject to the general surcharge ruling at the time.

Tariff (E) : Large Power Users : Off Peak

The tariff charges are identical to that described under tariff(A) above except that

i) The basic charge is R100.00 per month
ii) The demand charge for each Kilovlt Ampere (KVA) of the maximum demand applies only to that supplied during the peak hours

iii) A minimum overall charge of 3,3c (three comma three cents) per kWh supplied in the month.

iv) The off-peak periods (in which there is no charge for KVA demand) is as follows :

Off-Peak Periods

Monday 23h00 to Tuesday 07h00
Tuesday 23h00 to Wednesday 07h00
Wednesday 23h00 to Thursday 07h00
Thursday 23h00 to Friday 07h00
Friday 23h00 to Monday 07h00

Public holidays to be negotiated.
Minimum agreement period of one year.

4.4.3 Selection of Perferred Tariff

The intention of tariff(E) is to encourage certain large-power-users, who use power continually over the 24-hour period, to switch off some of their load during the 16 hour "peak period" from 7h00 to 23h00 daily, and to run this load in the remaining 8 hour off-peak period.

Several examples of suitable application for this tariff come to mind. Large electric machines, such as electric arc furnaces at ISCOR, and at Alusaf would be ideal for this purpose provided the furnaces can be cycled in this time. Pumped-storage schemes will also benefit from this tariff, as only energy will have to be paid for if pumping is done in the off-peak period.

Nevertheless it is unlikely that tariff(E) will be of any benefit to Municipal Undertakings.

The reason is the large domestic component in the daily load curve. The daily load curve of a typical town such as Tongaat as shown in Fig 3.6 indicates that the maximum demand in the peak period is around 30 000 KVA, whereas it is less than 23 000 KVA in the ESCOM off-peak period, from 23h00 to 7h00. Since the municipality has its own "free capacity" it does not require to contract to ESCOM to meter the two periods separately, since this will cost the undertaking the difference in the two basic charges, i.e. R100.00 less R45.00 = R55.00 per month.

CHAPTER FIVE

CAPITAL EXPENDITURE AND ITS EFFECT ON THE ELECTRICITY TARIFF

5.1 The economics of System Reliability

Reliability is a relative measure. As Munasinghe points out "An ideal electric power system that unfailingly supplies power to consumers is by definition a perfectly reliable one, and conversely a system that is never able to deliver electricity to users could be termed totally unreliable. All real systems lie between these extremes."[1.]

As the system's reliability level is improved, a trade-off occurs between increased costs of supply and reduced inconvenience and costs to consumers from fewer power shortages.

As discussed by Munasinghe,[2.] various indexes are used to express the system's inability to meet the predicted load. Familiar reliability indexes such as the loss-of-load-probability (LOLP) and loss-of-energy-expectation (LOEE) are based on combinatorial (probablistic) methods. His descriptive definitions of some of these terms are summarised below.

The LOLP criterior is commonly used in generation planning. System failure is often defined in terms of inability to meet the daily peak load, and may be expressed as the average number of days over a long period, during which the daily peak demand is expected to exceed the available generating capacity.

The LOEE is the expected amount of energy not supplied because of outages in the long run, and may be expressed as a fraction of total energy demanded during a certain period.

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1. MUNASINGHE Mohan, "The Economics of Power System Reliability ad Planning" John Hopkins University Press 1979. p. 13.
2. MUNASINGHE Mohan, Ibid. p. 18-27

The expected-loss-of-load (XLOL) indicates the expected magnitude of the unsupplied load, given that a failure has occurred.

It requires the use of numerous indexes such as the above to accurately describe a system. For example, knowing the expected-loss-of-load (XLOL) is not sufficient, one also requires to know how often such loss-of-load is expected, or the frequency-and-duration (FAD) of such losses.

When taken in isolation, it is not easy for an undertaking to economically justify expenditure to improve reliability.

From a societal point of view, an outage represents loss of production for industrial consumers, loss of sales of commercial consumers, and loss of activities for domestic consumers. Yet for the undertaking, the actual loss of energy sales may be minimal.

Frequently therefore, the gains made by society from improved system reliabilty far exceed the cost for the improvements, yet the increased energy sales by the undertaking will not cover the costs involved. It is therefore necessary to develop suitable models to correctly interpret the extent to which society is prepared to pay higher tariffs for improved reliabilty.

An interesting model developed by Mohan Munasinghe [3.] indicates that the total outage cost at low levels of reliability will be higher for those consumers who expected better reliability.

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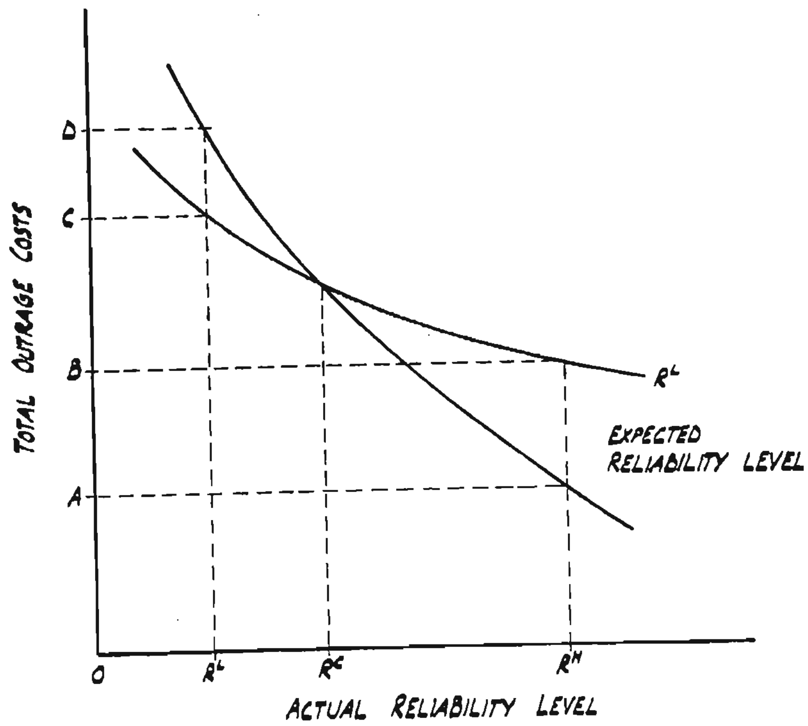
3. Munasinghe, Mohan, Ibid,p. 47

This is indicated graphically in Fig 5.1 below.

Source : Munasinghe Mohan, Ibid. P. 47.



Relation between Total Outage Costs and the Levels of Actual and Expected Reliability

<u>FIG. 5.1</u>

The reasoning as presented by Munasinghe, is that individuals who expect high reliability do little to adjust their behaviour and the cost of the outage is high, whereas consumers who did expect poor reliability would have taken precautionary measures such as having alternative energy sources available, and would experience less outage cost at low levels of reliability. Conversely, if the reliability is high then those Consumers who expect low reliability wil be spending money needlessly on standby facilities and their total cost will be higher than for those consumers who correctly expected high reliability. Overall, total outage costs are likely to be highest with high expected reliability and low actual reliability.

As Munasinghe points out, There are two methods used to estimate Outage Costs." One approach is to estimate them on the basis of observed or estimated willingness-to-pay for planned electricity consumption. The other approach estimates outage costs by the effects of outages on the production of various goods and services".[4.]

Some of the observations made by Munasinghe regarding outage costs for different types of consumers is summarised below.[5.]

The outage cost for residential consumers is not straightforward, since most of the "outputs", such as leisure are consumed within the household and are not valued in the market. It is possible to reschedule household chores, thereby minimizing outage costs. Also, non-housekeeping activities may be substituted for those involving housekeeping activities. For example, if a power outage occurs while ironing is being done, the householder may decide to do the weekly shopping while waiting for power to be restored.

For industrial consumers, the effects and direct costs of outages during working hours can be classified into two main categories: (a) Spoiled material in the process of being produced or in storage, and (b) reduced production during the outage and the following restart period.

For Commercial Consumers, the outage cost will depend on the extent that the consumers rely on electricity-using equipment. For example, offices where only lighting is affected may be able to function normally.

If electricity-dependent facilities such as reproducing machines, desk calculators, and computer systems are used extensively, work is more likely to be interrupted.

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4. MUNASINGHE Mohan, Ibid p. 49.

5. MUNASINGHE Mohan, Ibid p. 62-64, 72-73, 80-81

It is obvious that the cost of an outage depends on numerous factors, such as the time of day, the duration of the outage, the type of consumer involved, etc, as well as on the consumers' expectation regarding reliability (i.e. the extent to which he prepares for outages).

5.2 THE DISTINCTION BETWEEN CAPITAL WORK AND MAINTENANCE/REPAIR WORK

For private trading companies, there is a definite need to clearly distinguish between Capital Work and Repairs-and-Maintenance, since the latter can be deducted as an Expense in the Income Statement to determine the Taxable Income, whereas work of a Capital nature is not tax deductible, and does not appear in the Income Statement.

Since Municipal Undertakings are not taxed, such a clear distinction is not necessary and it is common to see both capital costs and other costs entered as expenses on the Income Statement. Similarly, whereas private companies are only permitted to deduct interest paid as an expense, the municipal undertaking normally deducts the entire instalment paid on capital loans, to determine the Operating Surplus.

Some Treasurers are very strict in their interpretation of what constitutes Capital Work. They insist that a Capital project must result in an identifiable additional asset, for example, a new substation, or additional street lighting, or new underground cables in a new township area etc. Repairs and maintenance to them is also easy to distinguish, since it is performed on an existing asset, for example, changing the oil in an existing transformer, replacing damaged insulators etc.

The matter is, however, not so simple. If, for example, an overhead line has a useful life of, say, 25 years, and if it is decided in the 20th Year to extend its life by a further 10 years, it may require quite a lot of improvement, e.g. some poles may have to be replaced, conductors in an area which had previously suffered flashovers may be replaced etc. In this instance some Treasurers regard the extension of useful life as sufficient proof that this is a project of a capital nature. Other Treasurers insist that regular, good maintenance on an overhead line prolongs its life indefinitely, and that merely abstaining from doing maintenance work until it forms a large volume of work does not convert it from maintenance to capital in nature.

The distinction is somewhat arbitrary, and since "profits" are not taxed, it does not seem to make much difference anyway.

But what is very important is the effect that the method of financing can have on tariffs. If a large amount of maintenance becomes necessary in a particular year, and is to be financed only from revenue then it may require tariffs to be increased dramatically to cover the cost. On the other hand if the same amount of work were to be financed from a long term loan, say over 10 years, then the repayments per year will be very much less, with correspondingly less upward pressure on tariffs.

5.3 GENERALIZED OPERATING STATEMENT

The typical Income Statement of a Municipal Electrical Undertaking is shown in Table 5.1.

Several interesting and important facts can be seen from the Income Statement.

These are :

1. The municipal undertaking does not pay Income Tax. Since true "Income Earned" is therefore not important, it allows the parties to mix revenue amounts with capital amounts in what would be a very confusing arrangement for normal Trading Companies.

2. In normal Trading Companies, only the interest to be paid is considered to be an expense, while repaying the capital is a Balance Sheet adjustment which does not affect the Income Statement. The Municipal Undertaking, as shown above, writes off all instalments made against loans, including the capital and interest portions.

3. Payments into the Capital Development Fund and the Renewals Fund, both obligatory in terms of the Local Ordinance, are actually balance sheet adjustments, whereas here it is shown as an expense. This is offset by the fact that Depreciation is not claimed as an expense. There is therefore a difference between the "net profit" of a Trading Company, and the "Operating Surplus" of the undertaking.

TABLE 5.1

GENERALISED INCOME STATEMENT

TYPICAL ANNUAL INCOME STATEMENT OF MUNICIPAL ELECTRICITY UNDERTAKING

INCOME :			
From Sale of electricity			4 505 000
From availability charges			24 000
Total Income			4 329 000
EXPENDITURE :			
Escom purchases		1 864 000	
Electrical Staff Engineer	27 000		
Electricians	45 000		
Foreman	18 750		
Labourers	26 500		
Meter Readers	15 850		
Transport	18 000	151 100	
Repair & Maintenance materials		100 000	
Audit fees, insurances & sundries		12 000	
Administration contribution		95 000	
Renewals Fund		25 000	
Capital Development Fund @ 3%		133 160	
Loan charges : internal	280 000		
Loan charges : external	310 000	590 000	
Total Expenses			2 970 260
Operating Surplus			1 358 740

USE OF THE OPERATING SURPLUS

Table 5.2 shows the relative magnitude of the portion of the operating surplus generated by typical cities and towns, used by the municipalities for the relief of rates.

TABLE 5.2

OPERATING SURPLUS USED TOWARDS RELIEF OF RATES

Town	Surplus transfered to relief of Rates (Rands)	Rates Fund (Rands)	Percentage contributed by Surplus to rates
A. Large Towns			
Alberton	1 811 958	15 948 396	29.7%
Benoni	1 287 440	79 236 197	10.9%
Bloemfontein	2 535 052	108 139 820	15.9%
Cape Town	7 840 000	21 998 460	9.9%
Durban	5 090 521	130 843 578	4.7%
Germiston	2 053 198	6 725 000	9.3%
Johannesburg	5 716 414	14 741 973	4.3%
Krugersdorp	1 239 219	31 951 037	18.4%
Pietermaritzburg	1 822 364	53 992 779	12.3%
Port Elizabeth	2 275 000	31 951 037	7.1%
Pretoria	8 836 700	53 992 779	16.3%
Springs	2 714 493	8 070 958	31.4%
Welkom	2 797 894	8 906 992	31.4%
B. Smaller Towns			
Dewetsdorp	21 895	52 845	40,0%
Ermelo	747 758	1 880 148	39,7%
Heidelberg	233 084	977 286	23,8%
Kimberly	560 000	1 375 955	40,7%
Louis Trichardt	191 301	885 119	21,5%
Warmbaths	687 216	594 907	115,6%

SOURCE : Official South African Municipal Year Book, 1983 Sextion X1, Table B.

It is interesting to note that there may be two reasons that an undertaking may wish to increase its revenue and its operating surplus. Firstly, the salaries of all municipal employees, from the Town Clerk down, are determined by the revenue handled by the Local Authority.

Secondly, there are typically thousands of consumers of the undertaking who are not rate-payers. (i.e. they fall outside the municipal area). By increasing the operating surplus, and transfering it to the relief of rates, these authorities are in fact employing a system in which the outside consumers are subsidizing the rates of the parent local authority.

For example, Durban Corporation Electricity Department reported an operating surplus of R12 503 207.00 in 1982/3 of which R5 090 521.00 was allocated to the relief of rates for Durban ratepayers. Yet, where is this surplus generated? This undertaking supplies numerous other Local Authorities, such as Westville, Queensburg, Pinetown, New Germany, Kloof, Hillcrest, Amanzimtoti, and many others such as Verulam, Clairmont etc. Is the flow of funds in the right direction? Table 5.2 shows the extent to which the rates of the operating Local Authority is augmented by the operating surplus of the electricity undertaking.

Since it is the people outside the municipal areas that the government wants to involve in the proposed constitutional reforms, it becomes obvious that a more equitable method of sharing the operating surplus will have to be found, and this will further support the move towards the regional electricity services as discussed in Section 7.4.

The inadequacies inherent in the Generalised Income Statement, (such as not showing depreciation as an expense and of not valuing the assets at replacement value) means that electricity tariffs may be unrealistically low, yet may show an operating profit. The problem only manifests itself many years ahead when a large portion of the reticulation network may need to be replaced, and it is then found that insufficient allowance has been made for this eventually. ESCOM uses a similar approach in its Income Statement, and is drawing attention to this problem.

The Income Statement for ESCOM for year ended 31 December 1981 is shown below :_

TABLE 5.3

ESCOM Income Statement for year ended 31 December 1981

	R000	
Electricity Sold :		2 140 689
Operating Expenditure	1 061 051	
Loan Charges	720 634	
Contribution Reserve Fund	900	1 782 585
Operating surplus for the year		358 104

Source : ESCOM Annual Report and Financial Statements 31 December 1981 p. 40.

ESCOM's annual report draws attention to the inaccuracies in this form of reporting, and the following excerpt appeared in the report:

"The tariff applications of ESCOM having to acquire its assets, in their actual condition of being partly used, at current prices and having to finance this operation at the ruling rate of interest have been calculated. To do this the following assumptions have been made :

- The average useful life of assets in use is 30 years after which time they have negligible residual value.

- The current (1981) total capital cost (generation, transmission and distribution) of installing 1 kW of capacity is R815.

- The average cost of finance, raised in 1981 was 13%. It is assumed that the interest burden would therefore have been 13% of the replacement value of the assets in service in their present condition.

- Straight line depreciation is a reasonable measure of the cost of using the assets in the production of electricity. The income statement would then have been as follows :-

TABLE 5.4

Revised ESCOM Income Statement

	R000
Sales of electricity	2 140 689
Less operating costs	1 061 051
	1 079 638
Less depreciation	524 969
Less interest	1 325 259
Loss for year	770 590

If the above "loss" of R771 Million were to have been avoided ESCOM would have had to raise its tariffs to a level of 36% above those actually charged in 1981."[6]

5.4 THE COMPONENTS OF COST

The costs of the Undertaking can conveniently be divided into four groups, namely :

5.4.1 Consumer related costs

5.4.2 Demand or capacity related costs

5.4.3 Energy related costs

5.4.4 Joint costs

The purpose of correctly identifying the components of costs is to ensure that the resultant tariff recovers the correct revenue from each sector of consumers.

There is, needless to say, some difficulty in drawing precise boundaries around financial expenditure. For example, if a small substation is to be constructed to serve a group of consumers, then it is clear that the actual position of the substation is somewhat arbitrary, and affects the distance to each consumer. There is no justification for penalizing those consumers who happen to be situated further from the substation. It is therefore generally accepted that all costs, to get power up to the consumer's boundary should be regarded

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6. ESCOM's 59th Annual Report, 1981, page 20, 21.

as joint costs, which should be averaged out over all similar consumers in that class.

5.4.1 CONSUMER RELATED COSTS

Consumer related costs can be grouped as follows :

a) Joint costs that can be attributed directly to the number of consumers supplied.

b) Costs that can be attributed to individual consumers.

Joint costs include shared capital costs as described above, as well as such costs as meter reading, billing, collection, public relations etc.

When many similar consumers have to be connected onto the system, it may be more economical for the undertaking to average out all costs relating to similar consumers. As Herrmann points out, "A utility may have a very large number of domestic consumers, and may connect many consumers of the same class annually. Each consumer will have a meter, a protective device and a length of cable which will be different for each connection. In such a situation the undertaking may find that it is not realistic to attribute cost differences to each consumer, in which case the costs will be averaged over all consumers in that class.

Invariably there are some consumers where the cost of the connection differs materially from the average, either because of the size of the consumer's requirements or because of the length of the connection required. Such costs will then be attributed directly to the consumer or group of consumers concerned." [7.]

5.4.2 DEMAND OR CAPACITY RELATED COSTS

Most of the fixed costs of the undertaking relate to the ability of the undertaking to meet the demand for electricity by the various consumers, and can therefore be regarded as Demand related costs.

They are made up largely of the annual capital costs of the undertakings' assets used in the distribution of electricity and they tend to make up an increasingly larger portion of total costs.[8.] These costs include those which do not vary directly with output, such as costs of administration, salaries, wages, cost of vehicles etc.

Table 5.5 shows the proportion of fixed costs and variable costs for typical towns.

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7 & 8 HERRMANN G.F.K., Ibid p. 4.3

	Variable Cost	Fixed Costs			Total
Town	Cost of electricity purchased from ESCOM.	Working Expenses including provision for renewals	Administration and General	Loan Charges	Total
Benoni	3 656 947	550 321	289 200	998 997	5 495 465
Brits	314 092	483 970	30 718	115 548	944 329
Estcourt	754,182	53 136	48 702	112 470	968 490
Potchefstroom	1 249 977	135 346	124 418	362 339	1 872 080
Springs	2 976 676	499 245	75 310	798 883	4 350 114
Vereeniging	1 949 498	191 912	279 655	474 264	2 895 329
Warmbaths	876 486	255 148	58 627	311 002	1 501 263
Average % of total	65%	12%	5%	18%	100%
		35%			

TABLE 5.5

TABLE SHOWING PROPORTION OF FIXED COSTS AND VARIABLE COSTS FOR TYPICAL TOWNS.

Source : South African Municipal Yearbook, 1977, Section X1, Table B.

From Table 5.5 it can be seen that approximately 65% of the total costs consist of electricity purchased from ESCOM. This purchase consists of two components, namely the energy component, and the Demand component.

The energy component can be measured accurately and easily for each consumer, and each consumer can be charged directly for the energy he uses.

The demand component is more complicated. In the first place the cost of demand metering, particularly for small power consumers, is high. Secondly, the sum total of all demand meters will exceed the total demand as measured by ESCOM, due to the diversity which results from the difference in the time when the various consumers use their power. It therefore follows that certain consumers are more responsible for the system peak than others and it is therefore incorrect to charge all consumers the same tariff for maximum demand, but it is impractical to attempt to distinguish between the consumers. The only alternative is to identify a period in which the peak is likely to occur (refered to as the peak period) and to meter this period separately. Suitable incentives or surcharges can then be applied to consumers who are responsible for the peak.

From the above table it can be seen that some 35% of the costs incurred by the undertaking are fixed costs, of which about half is for loan charges i.e. repayments for capital expenditure which were made to provide the capacity to meet the consumers total requirement

There is no precise method of allocating these fixed costs.

The most satisfactory method would perhaps be to portion the fixed costs amongst the consumers in proportion to their maximum demands at the peak period. There is,however, no method of determining precisely when the system peak occurs, and it is impractical and uneconomical to meter each consumer with such sophisticated equipment as to determine to what extent his load curve corresponds to the system load curve. In this sense present-day metering methods are very inexact and provide only a crude method of sharing the fixed costs.

For many consumers, such as domestic consumers the actual demand per consumer is relatively small and does not warrant the cost of the demand meter. In such cases it is necessary to estimate the portion of fixed costs which can be attributed to that class of consumers and to average this portion out over the number of consumers. If this sum cannot be charged out as a basic charge, then consideration must be given to the "block tariff structure".

In the block tariff structure the necessary basic cost is spread over the average number of units that the consumers use. Since the necessary basic cost is then recovered when the consumer has purchased the average number of units, it follows that subsequent units can be sold cheaper. Also, as a consumer uses more units his load factor improves, which means that less additional KVA is required for additional units, and the result is the typical declining block tariff.

As mentioned previously, although the declining block tariff is based on sound reasoning it receives considerable criticism since it means that the rich consumers purchase additional units at a cheaper rate, making their average cost per unit less than that for the poorer consumer.

5.4.3 ENERGY RELATED COSTS

Energy can be measured accurately and easily for each consumer. The sum total of energy metered for all consumers will be less than that metered by ESCOM, since a small amount of energy is lost in distribution, as discussed in section 3.5

The design of tariffs requires to take into account that energy is more variable than maximum demand. For example, to save money a large factory may run its central air conditioning plant for a few hours less each day. The total demand for power will remain unaltered, whereas the energy consumed will be significantly reduced.

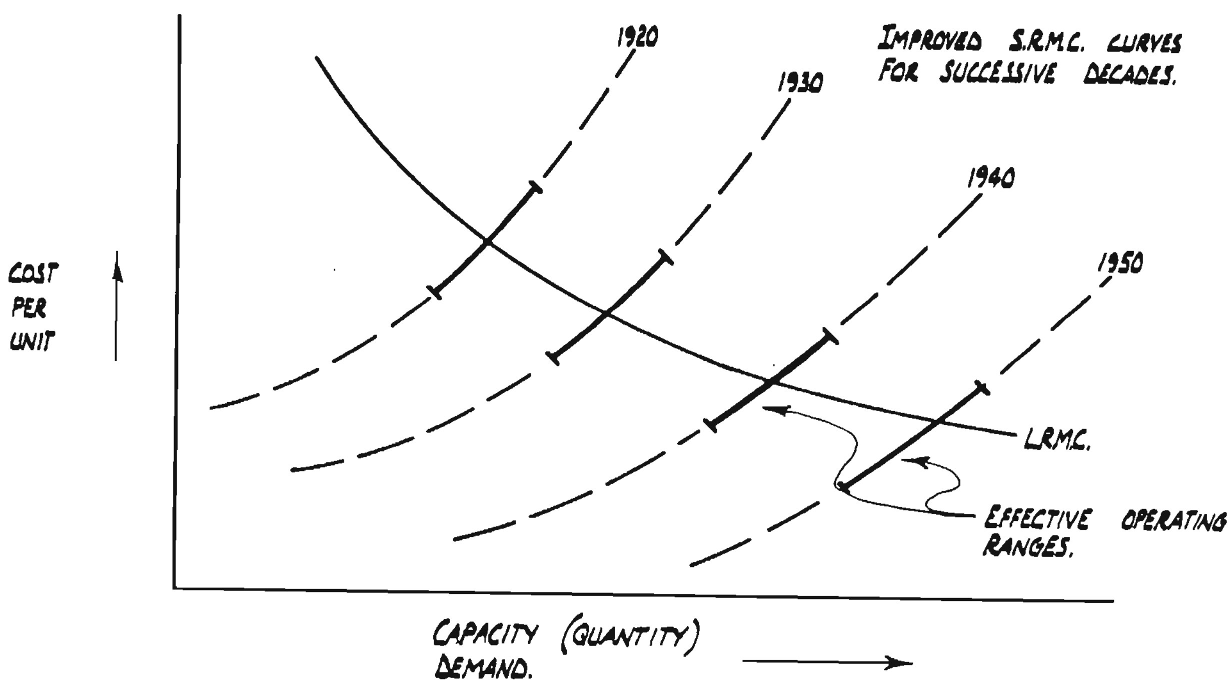
The energy related cost for a power station will vary as the total load increases, since the plant is operated in merit order, and less efficient plant is brought into use as the load increases.

However the municipality is spared this consideration, since ESCOM sells all its energy at a fixed rate.

The short-run-marginal-cost curve for energy is upward sloping as discussed in Section 3.5.

The long-run-marginal-cost curve for energy is downward sloping. That is, the actual cost of electric energy decreases over time. This is due to improved technology, savings due to economies of scale etc.

It must be kept in mind that the L.R.M.C. curve is in fact not a supply curve, but is the locus of the operating range of successive improved upward sloping SRMC curves, as shown in Fig. 5.2.



Source : Adapted from Herrmann G.F.K. Ibid, page 4.11.

Long range Marginal Cost Curve

Fig. 5.2

5.5 SECURITY OF SUPPLY VIEWED AS A CAPITAL COST

The electricity is supplied in bulk by ESCOM to the town's Intake Substation. From this point onward it is the undertaking's responsibility to deliver the electricity to each consumer as safely as possible, as economically as possible, and in a manner designed to minimize power interruptions.

As the head of the department must be a Competent Certificated Engineer in terms of the Factories, Machinery and Building Works Act of 1941, it can be accepted that the purely technical aspects of equipment specification, selection and safety are adequately and correctly attended to. It is the non-engineering considerations that create the largest problems, which will be discussed here.
From the Main Intake Substation the electricity must be reticulated to several major substations situated at strategic points throughout the supply area. These major substations in turn supply local substations which are conveniently situated to supply the final consumers.

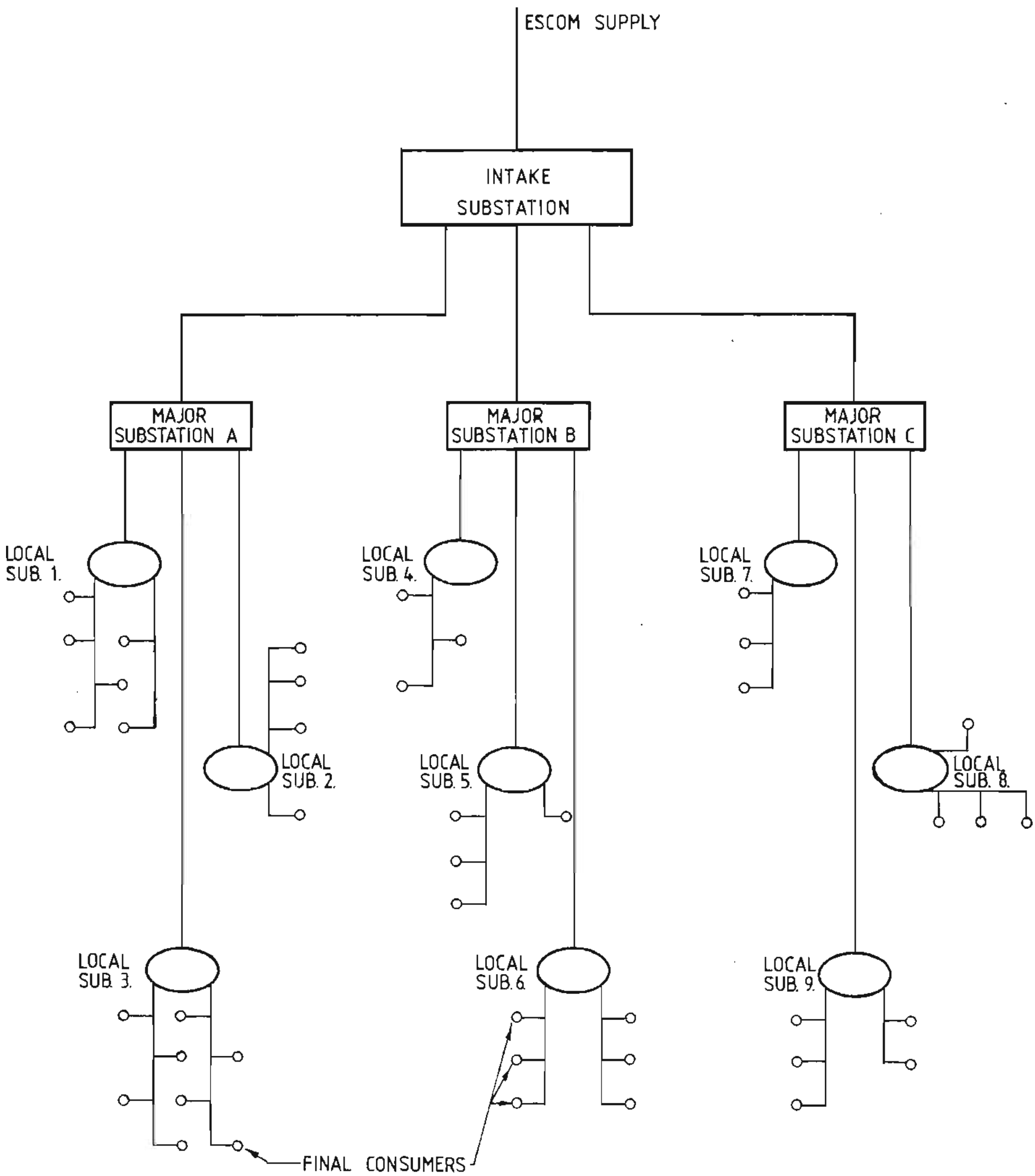
5.5.1 SECURITY OF SUPPLY

This term refers to the ability of the undertaking to maintain a continuous supply of electricity to its consumers. Since all electrical apparatus, cables and overhead lines require some maintenance, or could fail due to storm damage or accidents, it follows that secure supplies can only be made available if at least two separate supplies are provided for.

Fig. 5.3 shows a typical single line system, which is often refered to as a spur system.

FIG. 5.3

FIG. 5.3 SHOWS A TYPICAL SINGLE LINE SYSTEM, WHICH IS OFTEN REFERRED TO AS A SPUR SYSTEM.



It can be seen from Fig 5.3 that the failure of any component or routine maintenance shutdown of any piece of equipment will cut the supply of power to all consumers connected beyond that equipment. Such supplies are not secure, and the final consumers in such systems have to tolerate considerable interruptions in their supplies.

5.5.2 Dual Supplies

The most secure form of supply is generally the "dual supply", whereby a consumer is supplied with two alternative sources of electricity. Typically therefore, most undertakings are supplied from two separate incoming ESCOM feeders, and the main intake substation is then designed in sections, to allow either ESCOM feeder to supply any section of the intake substation. This system firms up the supply considerably since any section can be damaged or switched out for maintenance without disrupting the supply.

Certain major consumers can then be supplied with dual feeders from different sections of the intake substation thereby supplying them with a very firm supply. Such dual supplies are typical of the installation to Mooi River Textiles from Mooi River, David Whitehead from Tongaat, and SAPPI from Stanger.

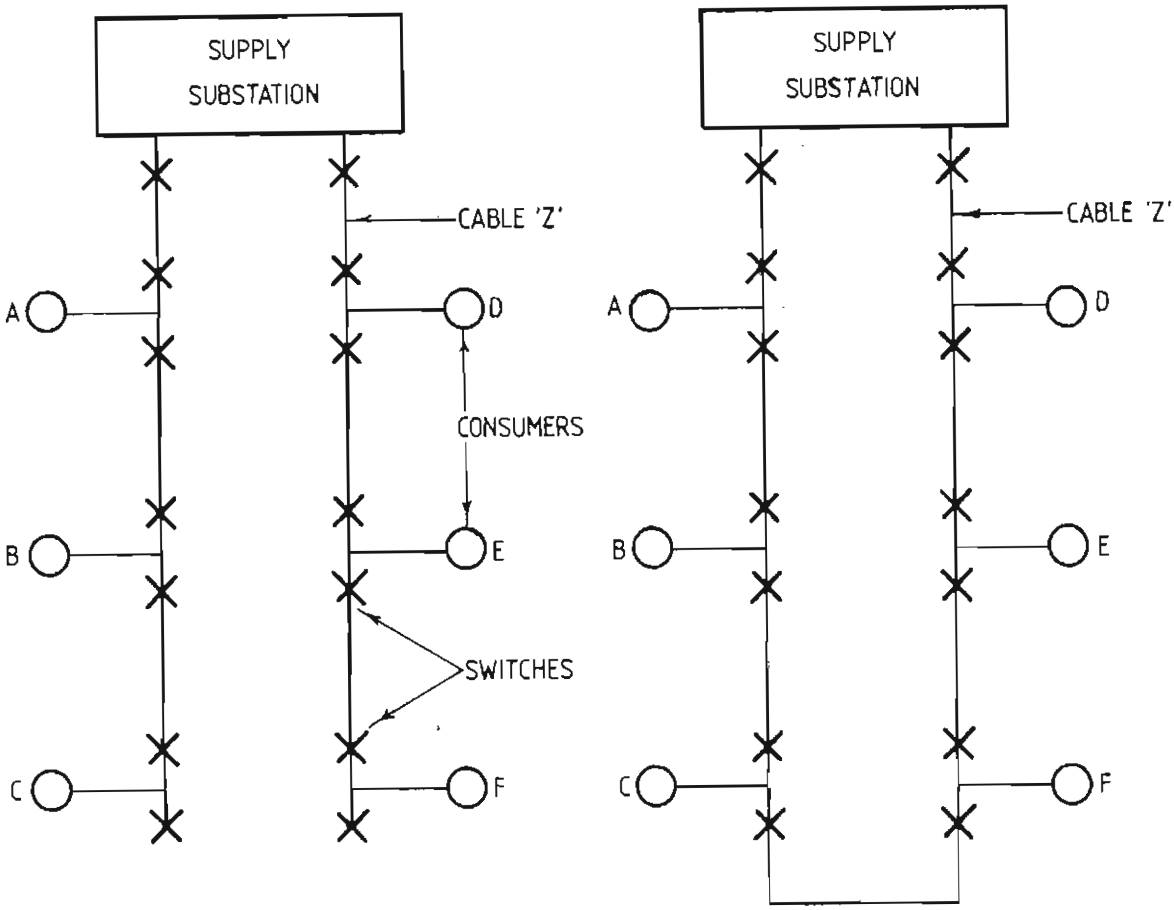
Clearly, each half of the dual supply must be capable of taking the full load, and such installations must cost twice the sum of single line supplies.

5.5.3 Ring Main Supplies

It will be too costly and physically impractical to install dual supplies to each and every consumer. However, the supplies to all consumers can be significantly improved by utilizing ring-main circuits. A ring-main circuit is formed when the far end of one circuit is connected to the far end of another circuit, and suitable swiches installed along its length. The purpose being that any section of the supply cable can be switched out without disrupting supplies to consumers.

Fig 5.4 shows the effective security obtained from ring-main supplies.

If maintenance work had to be done on the section of cable marked "Z" in Fig 5.4.A then all consumers beyond this point would have to be without power for this period. In fig 5.4.B the advantage of the ring main can be seen, since the section of cable "Z" can be switched out on either end, and all consumers can be supplied from around the ring and no consumer will even be aware that maintenance work is being carried out.



A. TWO SPUR FEEDS, EACH SUPPLYING 3 CONSUMERS.

B. RING MAIN FORMED BY CLOSING CIRCUIT BETWEEN CONSUMERS C AND F.

EXAMPLE OF SPUR CIRCUITS AND RING - MAIN CIRCUIT.

FIG. 5.4

Clearly, each half of the ring main must be capable of supplying full power to all consumers. In Fig 5.4.A, each spur only had to feed three consumers. In Fig 5.4B each half of the ring must be able to supply all six consumers. Therefore, the cables in ring main circuits must be rated at twice the current carrying capacity of the spur system, with corresponding increase in the cost of the system.

To overcome this inefficiency, a system of "opposite substations" is widely used.

5.5.4 OPPOSITE SUBSTATIONS

Fig 5.5 shows the typical effectiveness of this system compared to spur feeders and ring main circuits.

Again, as before, repair work on cable "Z" would cause consumers J, K and L to be without power in the spur system shown in Fig 5.5.A. As discussed before, the ring-main system shown in Fig 5.5.B would cope, but all cables have to be 200% the capacity of the spur feeders in Fig 5.5.A.

The opposite substation system works as follows. The spur feeders shown in Fig 5.5.A are taken to the opposite substation, and when cable "Z" is switched out, the three consumers J,

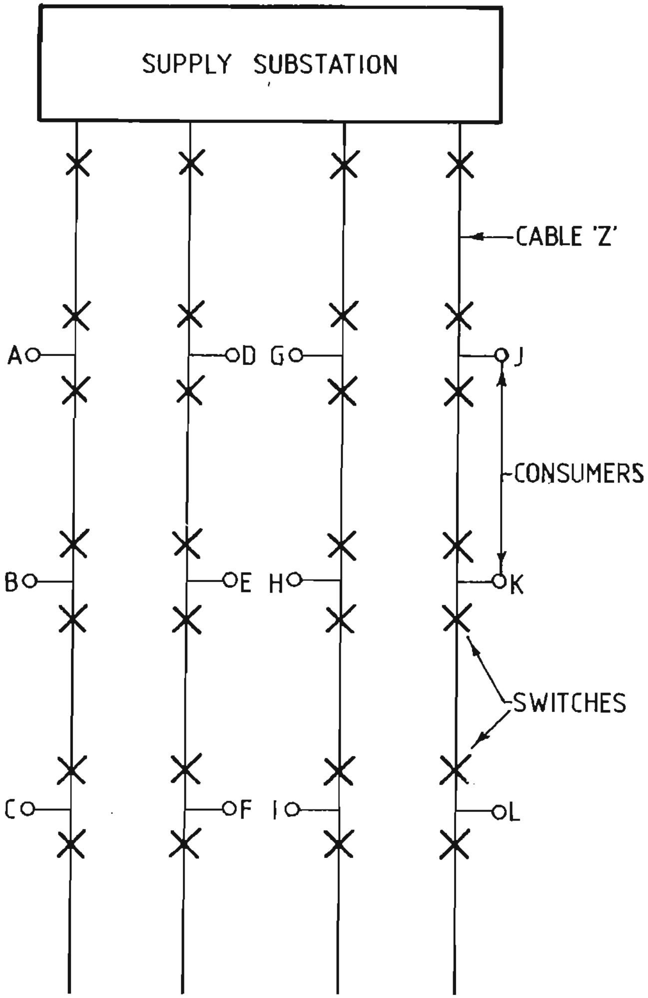
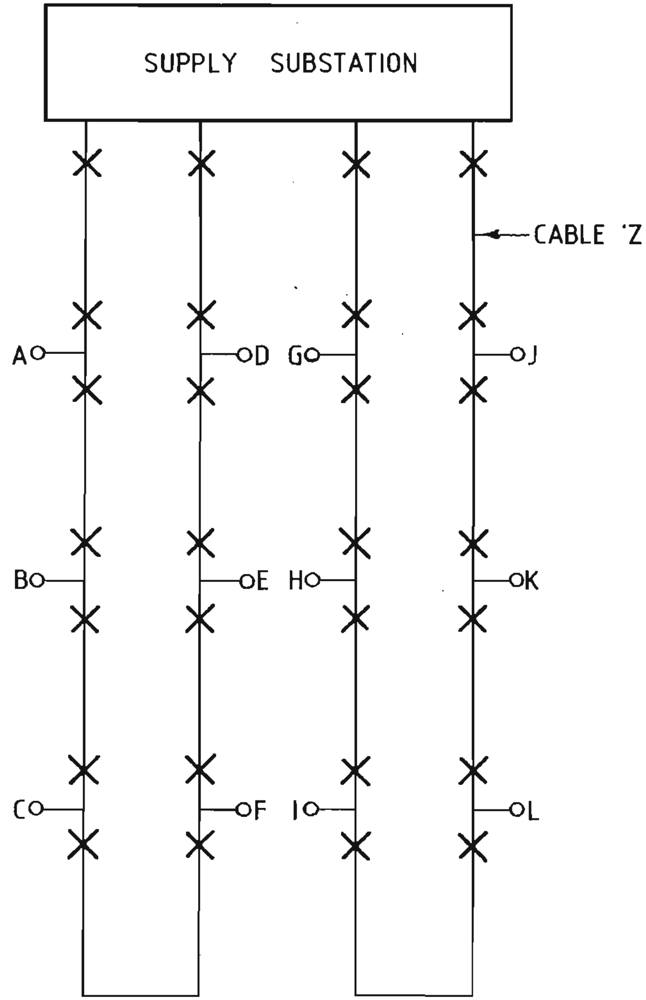


FIG. (A.)

SPUR FEEDS



5.5

FIG. (B.)

RING MAIN FEED

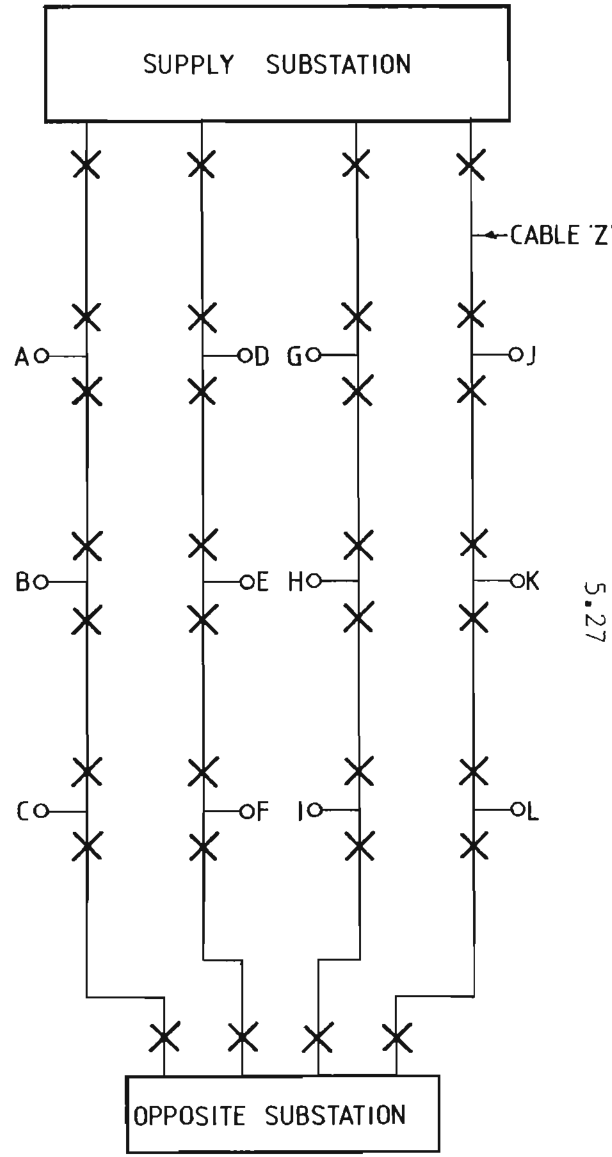


FIG. (C.)

OPPOSITE SUBSTATION SYSTEM

K and L are supplied from the opposite substation, with the three other feeders each supplying 33 1/3% of the load. Hence ring main cables must be 200% of the load capacity and the four cable system to the opposite substation need only be 133% of the load capacity of one spur. This savings of 70% of the capacity can represent a large savings if taken over the entire reticulation system.

If a prefered size of cable is selected for general use in the undertaking, then it follows that this cable may be used to 100% capacity for spur circuits, but only up to 50% capacity for ring main circuits, with the midpoint open, and up to 66% capacity in four circuit opposite-substation systems.

5.5.5, MANAGEMENT OF SWITCHED CIRCUITS

As a town grows, new consumers are continually added, and it is not uncommon to "hook" these new consumers into the network between various ring mains.

The resulting network then resembles the system shown in Fig 5.6 and is very common in smaller undertakings.

The incorrect logic used to substantiate such a maze is that if ring main circuits are so good, then an important consumer can be connected between two adjacent ring main circuits thereby effectively giving him a dual supply. The actual fact of the matter is that such interconnections between ring main circuits effectively bridges out any discriminitive protection, and a fault at any point will invariably cause the entire system to overload and crash, resulting in total blackout. It also completely confuses the electrical staff, who will have almost no hope of speedily isolating the fault. Such massive power failures, due to ring main interconnection is not uncommon, and has occurred at Kokstad in 1981, and New York State in 1977. (The New York power failure took four days to sort out.)

The reason for the bad performance of interconnnected ring main circuits can be illustrated in Fig 5.7 where it can be seen that a fault at Z will pull overload conditions from all other points in the system, causing all protective devices to trip.

Such a system should systematically be improved over time by removing the interconnections and creating distinct and easily managed circuits as illustrated in Fig 5.7. From this Figure it can be clearly seen that a fault at point Z will only trip out the protection device at each end, and thereby only disrupt the supply to a few consumers. Such a limited trip-out allows speedy detection of the faulted area, and rapid restoration of power.

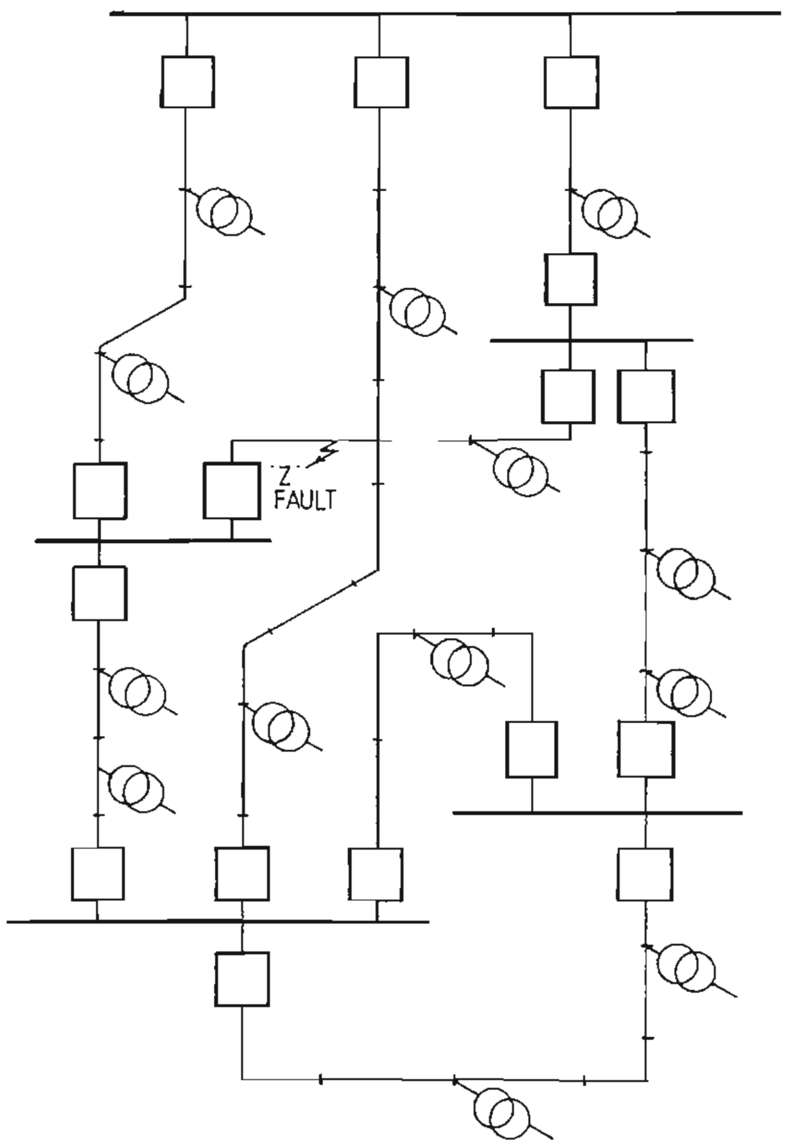


FIG. 5.6 OUTDATED RETICULATION SCHEME.

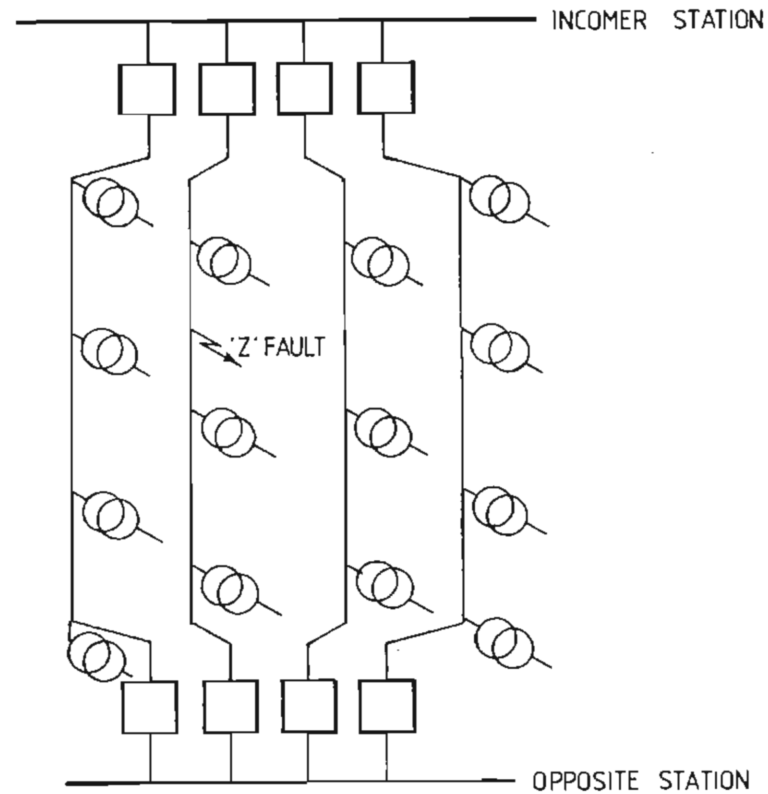


FIG. 5.7 PREFERED SCHEME

5.6 EQUIPMENT SELECTION AND ITS EFFECT ON CAPITAL COSTS AND REVENUE

The previous discussion illustrated some of the technical considerations in determining the correct cable capacity.

One aspect of equipment selection which receives very little attention is the long-term economic effect of such selections.

Two problems which make economic selection very difficult is the varying utilization of the equipment over its useful life, and the difficulty of accurately determining the running costs associated with the selection.

A report issued by IEEE Task Group on Long Range Distribution System Design included the following passage :

"The next 20 years will undoubtedly challenge the capabilities of the electric utility industry. The industry will be summoned to respond to

(1) a growing dependence on electricity as an energy supply medium,

(2) a continuing pressure to reduce oil and gas imports, and

(3) regulating and social pressures to maintain high service reliability and low environmental impact at reasonable cost. Rising energy costs combined with difficulties in acquiring capital necessary for system development and an increasing scarcity of suitable sites and rights of way for new facilities may frustrate the industry. Technological innovation, however, if properly guided will provide the basis for meeting these challenges."

In a developing country such as South Africa, the young and small municipalities can be expected to show continual growth over the next 25 years or so. This is an important consideration since it means that all cables and equipment installed now should be sized suitably to accommodate the anticipated growth.

Although this is an obvious statement it is an extremely difficult one to put into practice, since it is almost impossible to justify the increased cost. This problem arises due to the fact that payments for the equipment cannot be deferred until they are used more fully. They must be paid for now, by the present few consumers. As there is a definite limit on the financial burden that any community can support, it follows that many cables which are now installed may be selected on present day needs and may become overloaded long before their theoretical useful life is over.
It is very difficult to optimise such a situation.

It is evident that load forecasting is of prime importance in the planning of improvements to the system.

As Dr. B.M.A. Rozali[9.] states :

"The importance of still making load projections as

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9. Rozali Dr. B.M.A, Berrie T.W. and Murgatroyd W. "Planning the developement of a power System."
Electrical Review International Vol. 205 No 9 7 September 1979.

accurate as possible cannot be underestimated, for the electricity supply industry's decisions on investment have to be based on accurate predictions of load several years ahead. Few other industries have to place such great reliance upon forecasts so far into the future. The repercussions of errors in forecasting are serious. Overestimating results in a large amount of capital investment, which could otherwise have been gainfully employed in other sectors of the national economy. This is a serious matter for developing countries. On the other hand underestimating can retard social and economic development, which is equally undesirable".

The importance of correct load forecasting is obvious. Throughout the design one deals with a constant planning period. Errors which may enter the load forecast could seriously affect the long term efficiency of the system.

As Willis[10.] puts it :

"Implicit in the analysis is an assumption that the forecast will be used to plan the future system and that any forecast errors could impact design. Lead times on equipment may be such that commitment to location, size and installation is made before any errors are apparent".

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10. Willis H.L., "Load Forecasting for distribution Planning-Error and impact on Design". IEEE Transactions on Power Apparatus and Systems, Vo. PAS.102, No. 3, March 1983.

"Error in a load forecast can be caused by any number of problems in anticipating the character of future growth. An area that has long sustained growth may stop growing as it reaches saturation. A residential area may gradually change to a mixture of both residential and commercial, or all commercial. Areas that were long vacant may suddenly develop growth as, for example, farm land is converted to industrial purposes or subdivided into residential development. Incorrect anticipation or assessment of the degree of such factors leads to errors in the load forecast".

Clearly one cannot install all cables now to meet the anticipated load in 25 years time. Equally, cables which are sized precisely to meet only the present loads may be overloaded within a few years. Several techniques can be used to obtain the maximum life from cable installations.

Assume the average growth in a town is 4% per annum. Therefore within about 15 years the load will have doubled. This implies that main cables must have a current carrying capacity of twice the present day requirement, to be able to still be used in 15 years time. Since cables are designed to have a predictable life of upwards of 25 years, it can be planned that within the first 15 years a second equally sized cable must be installed, parallel with the first cable. Such a combination will then have a life-span of about 28 years.

A second method of extending the useful life of a cable installation is to plan for a future centre feed into the cable. If a cable can transmit, say, 100 Amps, then when this load is reached the cable is fed at its centre point. Each half can then transmit 100 Amps away from its midpoint, effectively doubling the capacity of the installation.

A third (and very effective) alternative technique is to install the cables for the next standard voltage higher than the present system voltage, and to use the cable at the lower voltage initially. As the load increases to the capacity of the cable, the installation is then converted to the higher voltage, effectively doubling or trebling the capacity of the system. Tongaat recently installed a new major overhead line to the ribbon development along Tongaat Beach. This overhead line is designed for 33kV but is being operated at 11 kV. At this lower voltage the line has a capacity of about 5000 KVA, which can be increased to 15 000 KVA, by operating it at the higher voltage.

The selection of equipment on long-term economic grounds produces some very interesting results.

Consider as an example that it is necessary to install a feeder cable to a new industrial township under the following assumed conditions:

1) Distance from major substation to new industrial township : 1000m.

2) Load requirements at 11kV : 270 Amps for 8 hours per day : Unity power factor.

3) Utilization pattern : 21 days per month, 12 month per year

4) Cost of electricity : R10.00 per KVA, 1 cent per kWh

5) Fault level of system : 8,0 kA for 1 sec,

The selection of the feeder cable will be made on the typical technical data as shown in Table 5.6.

TABLE 5.6

TYPICAL TECHNICAL DATA FOR CABLE SECTION

Cross Section mm^2	Current Rating Amps	Max. Short circuit Rating K.Amps	Conductor resistance ohm/km 'r'	Cost of cable R/m
50	185	8,4	0.359	28.56
70	230	11,7	0.256	33.94
95	275	15,8	0.189	41.30
120	315	19,9	0.149	48.11
150	355	24,9	0.120	56.08
185	400	30,6	0.097	68.23
240	460	39,7	0.075	85.96

Source : ASEA PEX Technical Data Publication and Provisional Price List : Scottish Cables.

The cable selection for the above example, could be made as follows

a) The maximum fault level of the system is given as 8,0 kA. The above table shows that all cables from $50mm^2$ upward can handle the fault level.

b) The current rating required is given as 270 Amps. The above table shows that the smallest practical cable to select would be $95mm^2$ which has a current rating of 275 Amps.

c) The total cost of this cable for 1000m would be R41,300.00.

An alternative method of cable selection, based on long-term economic considerations could be done as shown in the following 4 steps :-

1) Kilo watt-hour units lost in cable

$$= \frac{3I^2 \; r \times hours}{1000}$$

where I is in Amps

r is in Ohms/km

For the current (I) of 270 Amps for 8 hours per day, 21 days per month and 12 months per year, the annual cost of losses at R0.01 per unit would be :

Annual cost of losses

$$= \frac{3 \times (270^2) \times r \times 8 \times 21 \times 12 \times 0{,}01}{1000}$$

$= 4408r$

where r is in ohms/km for the various cables.

The values of 'r' for the different cables is given in Table 5.6 and substituting these values we obtain the following :

Conductor cross section	Cost of losses per annum for 270 Amps for 8 hours per day, 21 days per month, 12 months per year at 1 cent per unit.
mm^2	Rands
50	1582
70	1129
95	832
120	656
150	528
185	428
240	331

TABLE 5.7

2) The cost of lost KVA at peak periods at unity powerfactor can be calculated as follows :

$KVA = 3I^2 r/1000$

since at unity power factor 1 kW = 1 KVA

where I is in Amps

r is in ohms/km

The cost of lost KVA, at R10.00 per KVA, for 270 Amps, 12 months per year will be

$$\text{cost of KVA lost} = \frac{3 \times (270)^2 \times r \times 12 \times 10}{1000}$$

$= 26244\ r$ where r is in ohms/km.

The value of 'r' is given in Table 5.6.

Conductor Cross Section	Cost of KVA lost at peak periods for 270 Amps, 12 months per year, at R10.00 per KVA
mm^2	Rands
50	9421
70	6718
95	4954
120	3909
150	3149
185	2545
240	1967

TABLE 5.8

TABLE SHOWING COST OF LOST KVA

3) The cost of the cable can be calculated by multiplying the cost per metre of the cable by the required length, in this case 1000m. The cost per metre is given in Table 5.6 and hence by substitution we get the following results :-

Conductor cross section	Cost of cable	Annual instalments to repay capital & interest @ 15% over 25 years
mm^2	Rands	Rands
50	28 560	4418
70	33 940	5250
95	41 300	6389
120	48 110	7442
150	56 080	8675
180	68 230	10 555
240	85 960	13 298

TABLE 5.9

TABLE SHOWING COST OF VARIOUS CABLES

4) The above figures can be projected for a period, say 15 years, as follows :

a) Assume that capital is borrowed at 15% and that capital and interest is repaid in annual installments over the estimated life of the cable, of say 25 years.

From tables of interest rates it can be established that the annual instalments are 0,15417 of the capital value.

b) Assume that the cost of electricity continues to increase in the future, and the rate of increase is 12 1/2% per annum.

The averge cost for losses per annum over the 15 year period can be determined to be 2,587 times the present day losses.

Determined from $1/15\ \Sigma_{n=o}^{14}(1,125)^{n}$

Using the above figures and combining these with the results previously obtained, we get the results shown in Table 5.10 & 5.11 which can be shown graphically as in Figs. 5.8 & 5.9.

Conductor Cross Section mm^2	50	70	95	120	150	185	240
Cost of kWh losses	1357	968	714	563	453	367	284
Cost of KVA	8077	5706	4252	3351	2700	2182	1687
Total cost of Losses	9434	6674	4966	3915	3153	2549	1971
Annual instalments for cables	4418	5250	6389	7442	8675	10555	13298
Total annual cost	13852	11924	11355	11357	11828	13104	15269

TABLE 5.10

TABLE SHOWING ANNUAL COSTS OF LOSSES AND INSTALMENTS FOR VARIOUS CABLES

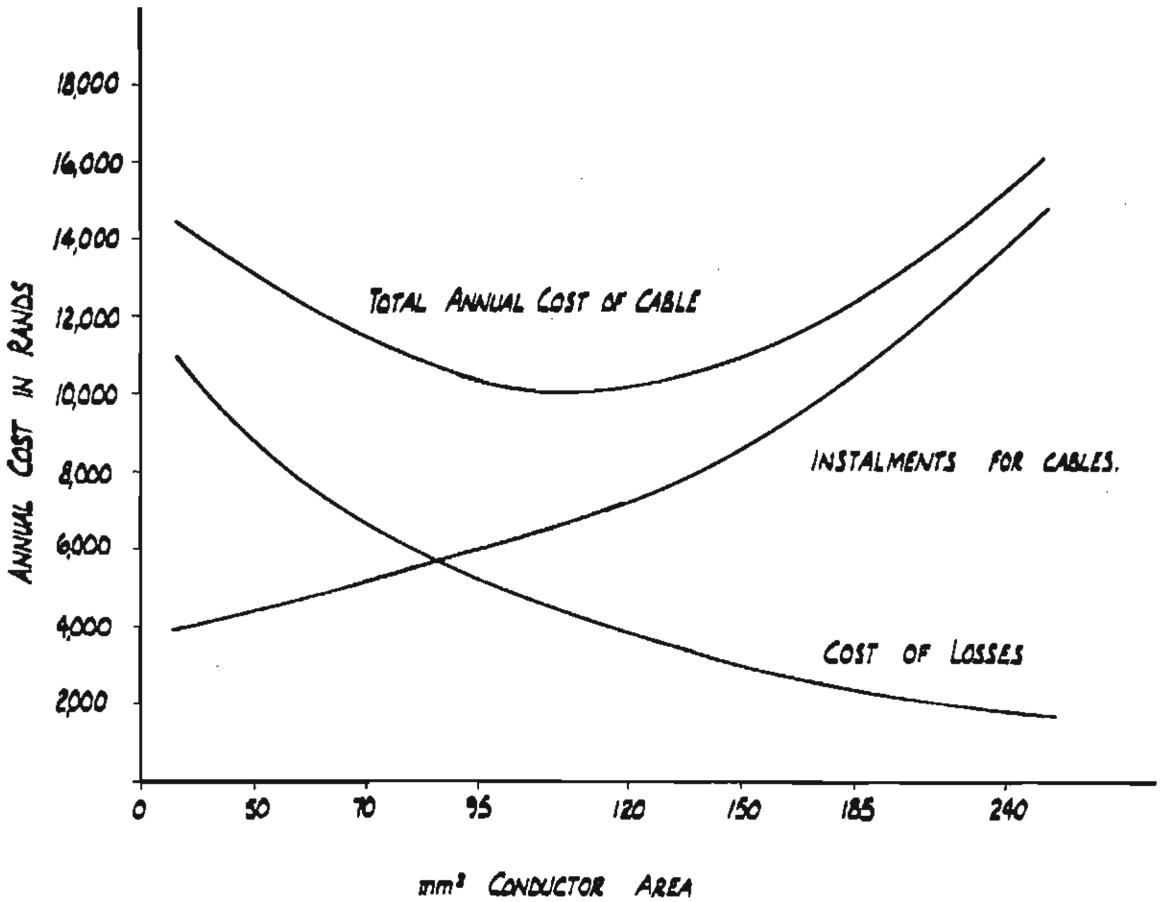

FIG. 5.8

FIG. REPRESENTING ANNUAL LOSSES AND INSTALMENTS FOR VARIOUS CABLES

Conductor Cross Section mm²	50	70	95	120	150	185	240
Average annual cost of losses over 15 years	24405	17265	12847	10128	8156	6594	5098
Annual instalments for cable	4418	5250	6389	7442	8675	10555	13298
Total average annual cost	28823	22515	19236	17570	16831	17149	18396

TABLE 5.11

TABLE SHOWING AVERAGE ANNUAL COST OF LOSSES OVER 15 YEAR PERIOD, TO ALLOW FOR 12 1/2% ANNUAL ESCALATION, AND ANNUAL INSTALMENTS FOR VARIOUS CABLES

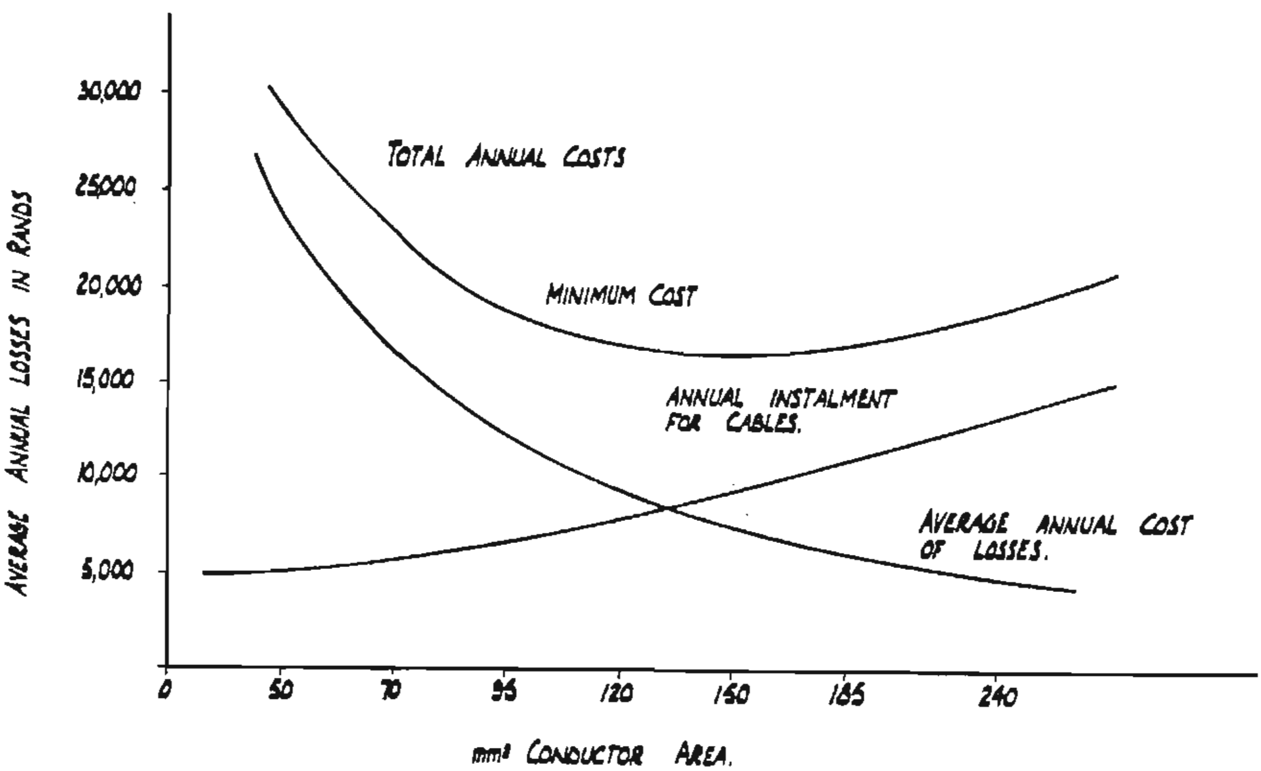

FIG. 5.9

FIG. SHOWING AVERAGE ANNUAL LOSSES AND INSTALMENTS FOR VARIOUS CABLES

The conclusions which can be reached with this analysis illustrates the importance of taking long-term economic considerations into account. From the purely technical requirements the minimum size cable to handle 270 Amps would be a $95mm^2$ cable, which for 1000m would cost R41,300.00.

If, however, one takes into account the annual cost of losses, then the optimum size cable is $150mm^2$, costing R56,080.00.

The average annual cost for this larger cable would be R16,831.00 compared to R19,236.00 for the smaller cable.

It should be obvious that the total annual cost to the undertaking of all its cables etc would be much lower if every cable and other piece of equipment were to be selected on long term economic considerations, rather than on minimum technical requirements.

CHAPTER SIX

EMPLOYEE PRODUCTIVITY AND ITS EFFECT ON THE ELECTRICITY UNDERTAKING

This Chapter deals with employee problems identified in informal discussions with the Town Engineers of Stanger, Tongaat, Kokstad & MooiRiver.

6.1 ORGANIZATIONAL BEHAVIOUR

As in most other enterprizes, the electricity undertaking invariably goes through cycles of high morale, with good planning, low staff turnover, etc to periods of low morale with high staff turnover, poor planning etc.

It is almost as if the effort necessary to correct the poor performance is sufficient motivation for the one or two new key employees to revitalize the organization, and as they introduce new work schedules, attend to grievances etc, the morale of the entire department suddenly increases, with resulting increase in productivity, lower staff turnover etc.

The reasons for these cycles can be explained by behavioral science and a study of organizational behavior.

Firstly, the staff of the electricity department are highly competent electrical artisans, who require an absolute minimum of close supervision. The size of the area to be worked in is vast, typically amounting to hundreds of square kilometers, and direct supervision is impossible. It is necessary to have Theory Y (Mc Gregor) type managers and supervisors who believe that "people can be basically self-directed and creative at work if properly motivated." [1] However, the often-uncoordinated jobs and complete isolation while at work often results in the

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1. HERSEY, Paul, and BLANCHARD, K., "Management of Organizational Behaviour", Third Edition, p. 54.

electrician developing a feeling that his superiors are not interested in his work (because they never visit him), and character regression sets in.

As the morale drops, job satisfaction decreases, and more electricians resign.

After the department has reached its low point, the head of the department (or some other superior) suddenly takes renewed interest in the employees. To increase productivity the condition of their vehicles and tools are checked, and better work schedules are prepared by the superiors. Now, as much as the effect of these physical aspects is the "Hawthorn effect"[2.] on the electricians. Now, their superiors are interested in them. Questions are asked and their opinions are sought about various alternatives. This increased involvement is very motivating, and team objectives are developed and strived for.

Again, due to the large distances to the various work places, follow-up is very difficult, and the system again runs out of steam.

Invariably, at the low point, particularly if it is cricically low, someone other than the head of the department has to

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2. HERSEY, P., and BLANCHARD, K, Ibid. p. 52.

undertake a departmental investigation to draw attention to the shortcomings so that the corrective measures may be taken.

Frequently, such reports draw attention to the frequent experiences of power failures, low voltages, T.V. interference etc, and such reports deal increasingly with the symptoms, and not the causes, of the poor performance. In many cases planned maintenance has all but ceased, but it is still not elevated to its correct status in the reports.

This lack of commitment to maintenance work is, in the author's opinion, the root cause for the poor performance of the electricity department.

Frequently the MISSION and PURPOSE of this department is not stated anywhere in the report. Normally, the OBJECTIVES and FUNCTIONS of the department should be established as a starting point. If the function or purpose of the department can be clearly determined it allows a better starting point for determining job specifications, since each job must then be seen to work towards this purpose. It is this lack of department-purpose that results in the typical directionless job specification given to the Town Electrical Engineer : - viz:

- overall control and management of the Electricity Department.
- Responsible Person in terms of the Factories act

This kind of meaningless job description does not give direction to the position nor does it allow any method to evaluate the effectiveness of the employee.

A far better approach to the whole problem will be :

1. Establish a clear definition of the purpose and function of this department.

2. Define the various jobs so that as each person performs his tasks the objectives of the department are automatically achieved.

The funtion of this department should be :-

TO MAINTAIN AND IMPROVE THE SUPPLY OF ELECTRICITY TO CONSUMERS

From this the job description of the Electrical Engineer would take the following form :

- To develop an effective reporting and evaluation system for monitoring the interruptions of supply to consumers.

- To investigate and determine the causes for interruptions of supply, and to plan cost effective methods for improving the system reliability.

- To formulate an effective maintenance programme.

- To identify all obsolete and/or irrepairable equipment and to formulate a suitable programme to replace/upgrade same.

- etc

- To design and supervise the construction of such Capital Projects which are consistent with the Purpose and Function of the Department.

- etc

Once a clearly defined scope of work for the Electrical Engineer has been determined, the job descriptions of all subordinates can be determined by a method of delegation.

It will be seen that the duties of the Engineer, if he performs his tasks fully, leaves him very little time to get involved in complex new projects. This is particularly true if a large number of electricians are employed on Capital Projects. The reason is that numerous small problems continually develop on new works, which immediately stops further work until the problems are resolved. The maintenance crews are then fobbed off with simple ineffectual instructions to get rid of them, like "go paint some old poles" etc.

To prevent these problems from occurring, a good cut-off point for new work is that only repetitive projects, which have been successfully completed before, should be undertaken departmentally. Also, only such a limited amount, so as not to interfere with the much more important task of maintaining and improving the system, should be undertaken.

It must be realised that the short term gain of undertaking capital work can severely jeopardize the reliability of system (by neglecting maintenance etc) and it becomes increasingly difficult to regain consumer confidence, or to re-establish the importance of planned maintenance.

For various reasons the personnel of electricity undertakings resent work being done by outside contractors. They feel that the more interesting work is being handed out, and tend to exaggerate the poor workmanship of contractors.

The above sentiments presumably reflect earlier bad experiences with Contractors. The truth of the matter is that Contractors have a reserve of highly skilled and experienced artisans, but the entire organization, from the owner to every employee, is motivated by a strong profit motive. The owners, by definition, are risk-takers, and the individual employees were prepared to sacrifice secure jobs and permanent places of employment, in exchange for more challenging work and higher pay. It therefore follows, that in the absence of very tight specifications, close supervision and total control, that the risk-taking ability and strong profit-motives will result in Contractors delivering the lowest standard of workmanship possible, or charging for numerous "extras" when improved standards are enforced. On the other hand there is little doubt that an experienced Architect, working with well prepared plans and tight specifications, can obtain from Contractors a complete building of exceptionally high standards, at costs lower that those which Contractors quote to inexperienced developers, or for what an owner-builder can build for.

The implication is that Contractors will only perform well and economically if accurate plans, sufficient information and tight specification and control is exercised. Under these conditions, Contractors normally outperform any other form of construction gang, since then the very factors which motivate Contractors can come into full play, viz, their skill, experience, initiative and organizational ability.

The decision as to whether to use Contractors or not is usually a policy decision and should be based on clear logic. A widely used criteria which makes a great deal of sense is that only projects which meet the following requirements should be done departmentally :

1. The total construction period should not exceed 6 to 8 weeks. (Larger project can often be broken up into several small projects).

2. Similar projects must occur at least four times a year. This allows costing standards to be developed which allows for more efficient estimating and control, and also allows workmen to become proficient in the standard type of project. This means that any one-off type projects should never be attempted departmentally.

3. The volume of work accepted to be done departmentally must be strictly controlled to prevent the department from becoming swamped with demands, or of big backlogs of projects piling up. It clearly serves no purpose for the estimator to give unrealistically low estimates

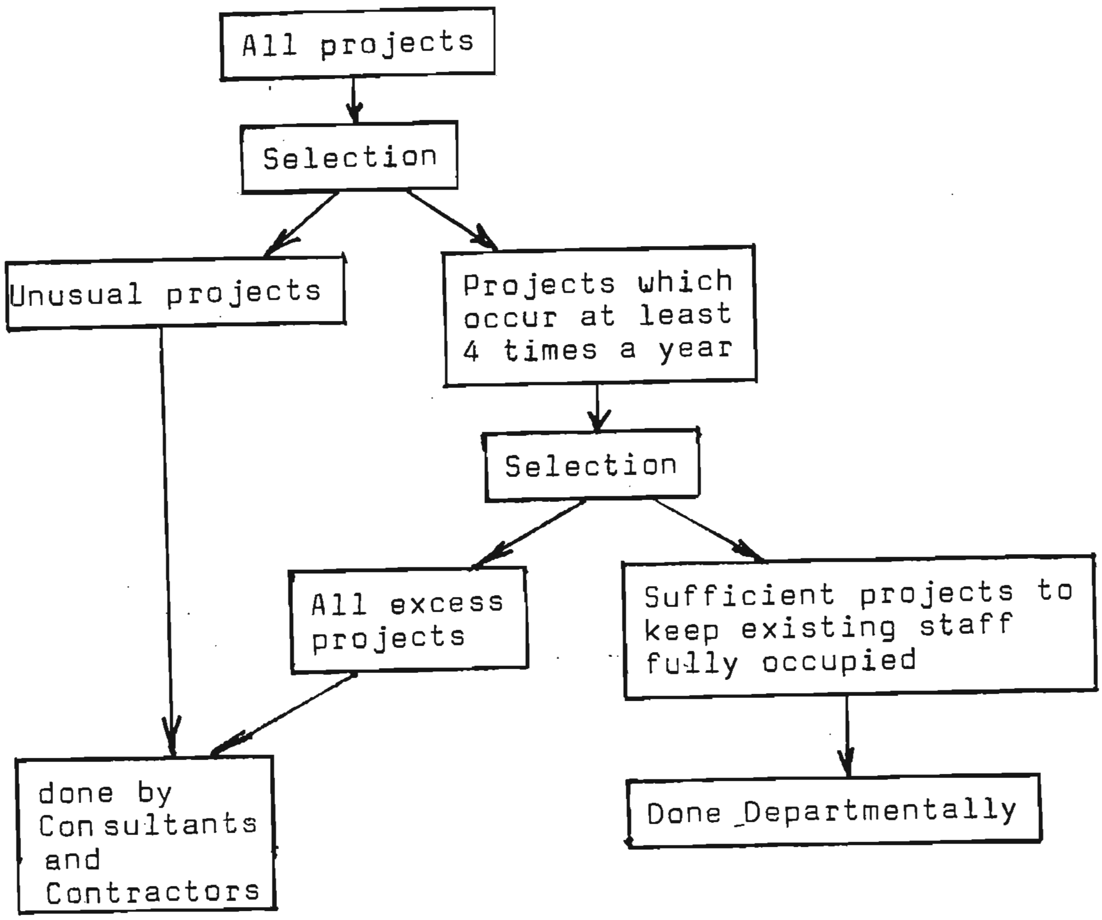
at a tempo which he must know cannot be fulfilled by the department. It will be far better to control the tempo, adjusting the costing system such that all projects can be done within 6 weeks of payment of estimated costs, either by the department or by Contractors.

4. Routine maintenance must be viewed as a project. Hence, if a backlog of maintenance occurs, these should be clearly specified and planned, and outside quotations called for. It is far cheaper, irrespective of the apparently higher cost, to undertake maintenance on Contractors' prices than allow it to go undone. For example it would be very foolish for the owner of a fleet of expensive road vehicles to allow his trucks to be irreparably damaged because his limited staff could not regularly service all his vehicles. It would be far wiser if he arranged for all vehicles not serviced within the recommended period to be sent down the road to the local garage, even if they charged more.

The above criteria have far reaching implications. Firstly, since the same type of projects are repeated several times a year, it follows that standard costs can be developed, which can be tested repeatedly on successive projects, to gain the confidence of the estimators and workmen. Thereafter it can be a powerful management tool for control and incentive schemes. Secondly, the type of work done by a particular artisan becomes much easier to define and to train, making replacement easier. Without doubt one reason for the current stated difficulty of filling all vacancies is the formidable and unsatisfactory job description given to a prospective electrician; that he will be required to lay cables from L.T. to 33 kV install L.T. and H.T. switchgear, be a linesman, maintain major substations, do routine maintenance, attend to breakdowns, etc. Clearly defined workgroups, doing specific tasks, has proved itself to be far superior. Finally, it will be seen that the correct size of the department is such that it just manages to comfortably handle the "base level" of all commonly repeated projects. All extra-ordinary, or rare, projects are done by Contractors, as are all peaks in normal-type work including maintenance. Any other arrangement creates unnecessary problems. The selection process is shown in figure 6.1.

Another advantage of using Contractors for doing standard, recurring work is that it continually sets a market value for the work, and more importantly, departmental work can be judged against it for quality and time.

Also, it allows for a neat method whereby Contractors, who are constantly supervised by Consulting Engineers and Suppliers, can introduce new techniques and materials into the standard project. This cross-pollination aspect allows the standard project to be continually updated. It must be remembered that such contracts require to be done under strict specification and control to achieve the above results.

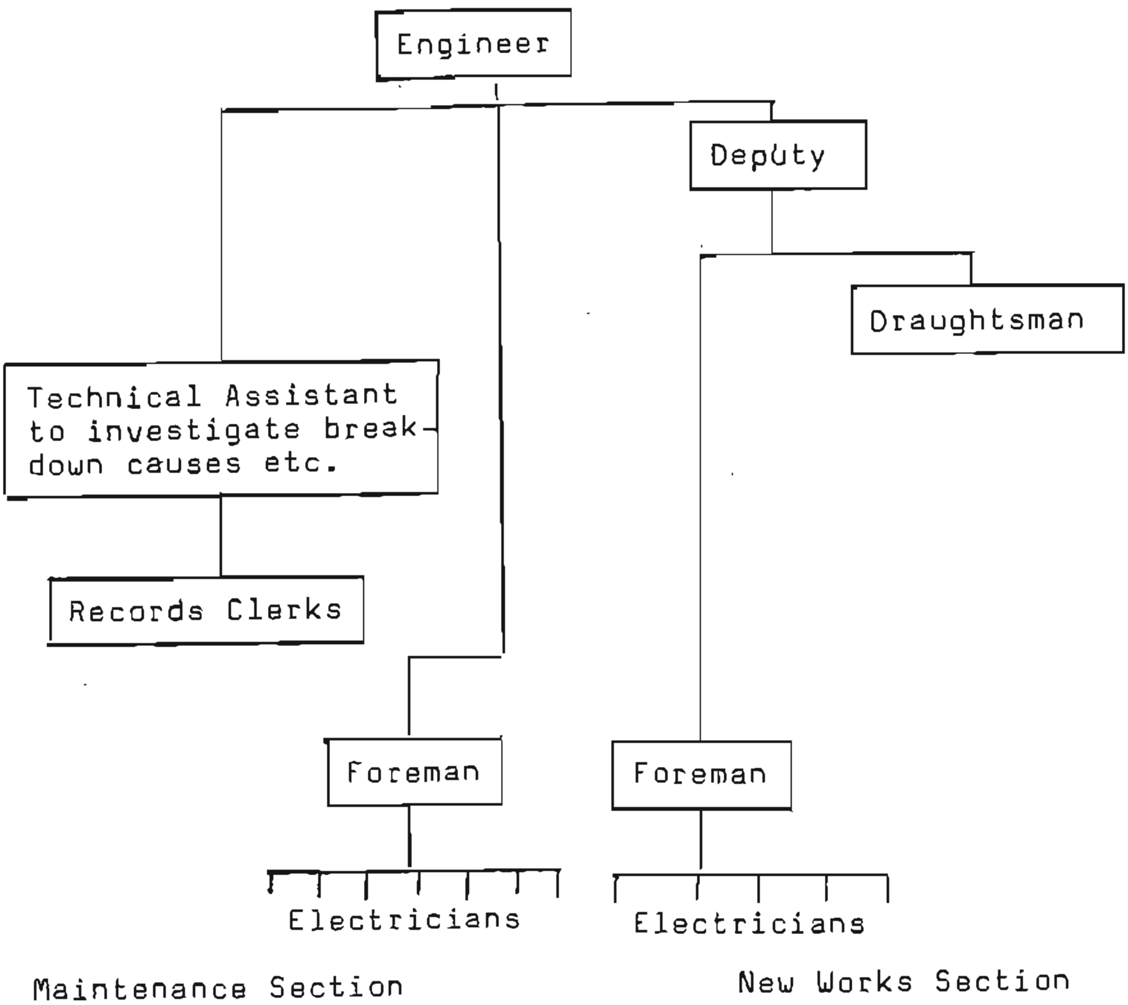


SELECTION OF PROJECTS FOR ELECTRICITY DEPARTMENT

FIGURE 6.1

6.2 ORGANIZATIONAL STRUCTURE

For the reasons stated above, it is better to separate completely the functions of "maintenance" and "new works" from as high as possible in the organization structure. The maintenance section and the new works section should preferably not share the same foreman, unless the new work section is very small. Likewise, these two foremen should not report to the same Engineer. The Town Electrical Engineer should control one section, and his Deputy should control the other. New Works will require more input from the Draughtsman, Estimator etc, and this clearly dictates their position in the organization structure. The Organizational Structure will then appear as shown in Figure 6.2.



ORGANIZATIONAL STRUCTURE

FIG 6.2

To emphasise the importance of the maintenance section it is recommended that this foreman be designated Distribution Superintendent. One or more working chargehands may assist him, depending on the total number of maintenance electricians and area to be covered.

Certain large maintenance schemes may entail the complete replacement of certain sections of overhead lines, etc. These can form a New Works project, undertaken by the Deputy. The two sections therefore work quite closely together.

If the function of maintenance is upgraded to its rightful position, then the amount of investigations into power outages together with detailed planning of system improvements and maintenance will be too much for the Engineer and his foreman to handle alone. This may require a Technical Assistant of some sort to monitor system voltage recordings, etc, so as to guide the planning of maintenance and improvements. An electrician with a bent towards administration and planning will perform better here than an administrative supervisor.

If the functions of maintenance and new work are separated, then care must be taken to select a Foreman suitable for the section he is to head since there is some difference between running a maintenance division, and a new-work division.

6.3 THE NEED FOR EMPLOYEE MOTIVATION

As stated before, the employees of the undertaking are competent, highly qualified artisans who do not require close supervision, and who cannot be closely supervised, as they work in the municipal area of supply which typically covers several hundred square kilometers.

There are several factors which could cause undertakings to have relatively high staff turnovers. These factors are :

a) The salaries of municipal employees may fall to below that of comparable employees in private enterprises (particularly in times of rapid salary adjustments) and municipal electricians risk being syphoned off as they come into daily contact with numerous potential employers in the course of their daily duties.

b) The municipal electricity network consists of a sparse, thin network spread over a very large area. It therefore does not have the appeal to the technically minded as would a densely equipped factory, such as a paper mill or oil refinery. The sense of achievement in keeping a major factory running smoothly is completely absent in municipal electricity work. If this desire to be part of the scene is not catered for in some way, the lure to "get to where the action is" invariably draws the better electricians back to industry.

c) Many municipal undertakings actually expect high staff turnovers. They therefore maintain an infantile attitude towards their employees since the majority of them will be new recruits. As the older employees grow out of this phase, which was well catered for by way of orientation courses, first aid courses, etc, they find a complete vacuum. They are "excused" from having to attend further orientation lectures but there is a total absence of other work-team activity. Finally, the electrician decides that to further improve himself he will have to get back into industry. This step "proves" to the undertaking that it was correct in assuming a high staff turnover, and the undertaking probably decides to spend even more time on new employees, and less time on older employees.

d) As the undertaking does not actually produce anything, and since no measurable changes are evidently dependant on any one electrician's efforts, the job satisfaction can fall to very low levels.

e) The typical undertaking has several thousand electricity consumers. It is inevitable that almost daily some electrician must disrupt some consumer's supply so that work can be done on the system. Such interruptions to electricity supplies invariably result in complaints from the consumer, including complaints about where the electrician parked his truck, the damage the labourers did to the hedge or sidewalk, the refuse and pieces of cable which was left lying around etc. Such continual complaints can easily demoralize most electricians into thinking that their work is not worthwhile or appreciated.

It is therefore very necessary to be fully aware of the negative forces at play and to design an organizational environment to completely counter these forces, and to create circumstances which would inspire and motivate the employees.

6.4 Motivational Techniques

A successful motivational environment can be created if the following can be accomplished :

a) The Hygiene Factors (Herzberg) must be attended to.

b) Measurable results must be developed into a reporting system to provide rapid feedback to each electrician.

c) A combination of the two above results can be used to create the correct climate for the application of Management-By-Objectives.

6.4.1 THE HYGIENE FACTORS

According to Hersey and Blanchard "Hygiene factors produce no growth in worker output capacity : they only prevent losses in worker performance due to work restriction. This is why more recently Herzberg has been calling these Maintenance Factors".[3.]

In this particular application the most important Maintenance Factor can be obtained by developing a better departmental public relations officer. He could be the foreman or the estimator. His task would be to visit the work-site some days before the work commences. He should issue the necessary "power-interruption" forms to the consumers and establish a direct route for complaints to the department, via the correct telephone numbers etc. He should also determine where the trucks should park (or where they should not park) and this information can be included on the usual job sheet, thus creating an atmosphere for customer satisfaction from the outset. Electricians correctly consider themselves to be expensive employees, and fail to see how they could be expected to spend their valuable time tidying up after they have completed their work. It is sometimes far better for the undertaking

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3. HERSEY, P, and BLANCHARD, K, Ibid. p. 66.

to employ a driver and a few labourers whose sole task is to visit the various work sites and to remove all refuse and reinstate grass verges etc.

These efforts will undoubtedly divert the usual complaints away from the electrician to the department, where they can be attended to, (if necessary). It requires the creation of a standard "complaints form" which the telephonist should have at hand. It is very important that every complaint be acknowledged.

A second very important hygiene factor which must be attended to is to establish (or re-establish) the sense of purpose in being an electrician. At some previous time in his life the electrician must have considered various career paths, and had then selected electrical engineering. After many years, many people develop feelings of doubt about whether they made the correct choice. It is therefore of tremendous "maintenance value" if the electricians can be reassured that their profession is of considerable importance to the community, and that they are playing a vital part in developing the area to the benefit of the entire community. Such reassurances can be contained in various forms in the body of discussions held at regular intervals to discuss other feedback reports. It should be remembered that sales managers hold regular feedback and motivational meetings, and are very aware of the rapid decline of performance if such "pep-talks" are delayed. Electricians will respond equally to the additional attention.

6.4.2 FEEDBACK REPORTING

Possibly the greatest shortcoming that undertakings have in this aspect of personnel motivation is the total absence of feedback reporting. This is largely due to the extreme pressures that the department works under.

The fact that no comparative statistics exists for the electrician to measure his performance against can be very demoralizing. Is his effort not worth commenting on? Obviously not if there is no report back. Personal effort is also not encouraged since he has no way of knowing whether a different approach or alternative style produces better results. This reporting apathy breeds job apathy.

Feedback reporting requires quite a considerable effort, since each undertaking, and each section of the undertaking, have large differences.

Statistical reporting as well as subjective reporting is necessary in such a case.

For example, the area can be divided into several sections and each section can be allocated to a work team. Statistics can then be established for each section to indicate the more usual problems, such as consumer-hour outages, line-down reports, number of low voltage complaints etc.

Each month these reports could reflect the past month's record with the previous year's corresponding month statistic, to indicate whether an improvement is noticeable. If such feedback reporting is coupled with an incentive scheme, for example, if a bonus is paid for a particular reduction in lost consumer-hours for each section, then the electrician will definitely begin to take more note of damaged insulators and loose crossarms etc, to everyone's advantage.

6.4.3 MANAGEMENT BY OBJECTIVES

Although this concept was developed in the 1950's, it is still very relevant and effective.

According to the Hersey & Blanchard, Management by Objective is basically "A process whereby the superior and the subordinate managers of the enterprise jointly identify its common goals, define each individual's major areas of responsibility in terms of the results expected of him, and use these measures as guides for operating the unit and assessing the contribution of each of its members.[4.]

The Department should develop an accurate statistically based reporting system, which can aid in identifying weak areas in the system, identified by the relatively high level of consumer-hours of power outage, or high number of complaints. At the same time, electricians can be given short, motivating seminars, highlighting the causes of the reported power outages. The area should be sectionalised, and the electricians can be divided into teams.

Attainable improvements in the statistics can then be set, with the acceptance of all concerned, and the reporting system will become meaningful and important to the electricians, with visual results of their efforts.

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4. HERSEY, P, and BLANCHARD, K, Ibid. p. 127.

CHAPTER SEVEN

THE ELECTRICITY UNDERTAKING AND ITS ENVIRONMENT

7.1 EVALUATION OF THE ENVIRONMENT

The environment in which the Electricity Undertaking finds itself is relatively simple, very stable and allows for accurate analysis.

The characteristics are

7.1.1 Only a single commodity (electricity) is handled.

7.1.2 The quality of the commodity (permitted variations in voltage etc) is fixed as it is set down in various agreements, codes of practice and Acts.

7.1.3 The staff, by necessity, must be technically trained, but need not be highly specialised or specifically skilled. There is therefore a large pool of general qualified electricians available to the Undertaking.

7.1.4 The Undertaking, by definition, exists in a developed town and it will therefore not have the staff problems faced by remote and isolated industrial and mining organizations.

7.1.5 The undertaking operates under conditions of a monopoly. There are no competitors in the environment.

7.1.6 The Undertaking is a division of the Local Authority, and as such its actions and the method of executing its functions are largely controlled by statutory requirements, such as the Local Authorities Ordinance, and this makes it possible, to a very large degree, to define the decision making process.

The above analysis indicates that the environment is extremely stable (since Acts and Ordinances are normally very slowly altered, if at all). It also shows the environment to be free of competitors, only a single product is handled, which has no substitution threat, a relatively abundant pool of skilled labour is available, to which the town surroundings offer congenial working conditions. To proponents of Strategic Management, this anaylsis shows the Undertaking to exist in a very low-risk environment. This low risk factor permits the Undertaking to undertake major capital works at marginal returns, financed over very long periods, without having to discount in any way for unforseen risk factors.

These factors must contribute towards reducing the cost of providing electricity to its lowest possible level, if used correctly.

7.2 THE MUNICIPAL ELECTRICAL UNDERTAKING AND THE LOCAL GOVERNMENT ENVIRONMENT

It is imperative that the Engineer fully appreciates his Department's role in local government affairs, and thoroughly understands the competition for funds at municipal level, as well as appreciate the absolute right of democratic vote in Council on whether or not to proceed with a proposal submitted by his Department.

One problem that Engineers frequently face when they submit their proposals to the Town Council for approval, is the competition for funds amongst numerous other capital projects being discussed in Council. As J.W. Cowden[1.] puts it,

"There has been an extraordinary growth of public expenditure in the twentieth century. Experts in many fields have been very persuasive in directing expenditure along certain lines. The problems of democratic government have been aggravated by the fact that elected representatives have been hard-pressed in the area of choice. They are told that if they do not spend more on roads there will be chaos, more on health there will be epidemics, more on electricity there will be industrial shutdowns, more on parks the people will move away."

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1. COWDEN, J.W., "Problems of Choice in Municipal Budgeting", The Institute of Municipal Treasurers and Accountants, S.A., 1974, p.l.

It is important therefore, that the Engineer presents his proposal to Council as comprehensively and thoroughly as possible. It should clearly and concisely state the problem, indicate the various alternatives which were examined, summarize these results and draw logical conclusions and recommendations. With prior assistance of the Town Treasurer, the proposal-report can also indicate the method of financing, its effect on tariffs etc.

From his previous, regular attendance at the Town Council meetings, the Engineer can develop a clear understanding of the number and type of other capital projects being discussed at Council, and the competition which may or may not exist for funds.

One important consideration which is frequently overlooked by the Engineer when Council discusses his particular capital vote is their concern for the marginal effect that it may have on other socially necessary, but economically unjustifiable capital projects. In terms of the Local Authorities Ordinance No 25 of 1974, the borrowing powers of the Local Authority is limited to four times the annual revenue earned by it, less all existing loan commitments. This can mean that the introduction of a very necessary electrical project, which is easily justified on technical grounds, could push some other project, very necessary on social or political grounds, out of the running. The Council may then decide that it may be politically expedient to reject the Engineer's capital project and to rather undertake the other project, a project which they may feel would be difficult to justify if special Provincial approval for additional expenditure had to be sought.

Whereas the Engineer may be willing to delay his projects for a few years, the urgency of his projects increases, until he feels justified in competing for the funds.

It is at this stage that he needs to present his proposals correctly, to put his case as forcefully as necessary, and to understand the decision-making process to ensure that the necessary majority vote is forthcoming.

7.3 THE DECISION MAKING PROCESS

As in many similar environments the decision making process is diffused along various lines of authority, and an understanding of this decision making process enables the Engineer to present his proposals to Council in the best possible format to facilitate a favourable decision.

Many Engineers fail to realize that numerous decisions have already been taken by his department by the time the proposal is submitted to Council. It is as much a case of having to obtain ratification for all these previous decisions as for obtaining the present go/no-go decision at Council.

Consider, for example, a simple case where growth in an industrial area threatens to overload the existing supply network. The engineering planners will examine the situation to determine the technically optimum solution. Numerous, on-going and inter-related decisions have to be made; e.g. Can the supplies be met from substation A or should more power be brought in from substation B? Should underground cables be used or can overhead lines be constructed? On which side of roads? At what voltage should it be transmitted? What excess capacity should be allowed for growth? etc. etc. The final solution will be determined by these numerous decisions, sometimes taken at very low levels. As the final plan emerges, it can be costed out and presented to Council for approval.

There is always a risk of good schemes being referred back to the Engineer, because of the unacceptable presumption that all decision up to that stage must be correct, and were not disclosed or elaborated on in his proposal.

The better method in such cases is to adopt the following procedure :

7.3.1 The nature of the problem should be clearly set out, and the reasoning used to show that corrective action must be taken should be fully presented. The reason is that electricity is readily and continually measured and read, and measured increases could herald similar overload problems in water supplies, traffic densities etc, and the solution to the problem may well lie in other directions, such as opening new industrial areas. The point is that the Engineer does not have an innate right to decide that increases are continuing. Such decisions should be ratified by Council.

7.3.2 All possible alternatives should be presented to Council, with brief discussions as to why they are discarded, and why the selected one is preferred. Once again, there may be non-engineering factors which Council may wish to introduce into the selection.

7.3.3 The selected plan should be developed sufficiently to establish time programmes, cost estimates, financing arrangements, effects on tariffs etc.

7.3.4 The Engineer has a choice at this stage, to either recommend a definite course of action over a specified period, or else to leave it to Council to decide on these matters. Such a final step is very dependant on the personal interrelationships of the personalities involved on Council, past experiences and preferences.

From the above it can be clearly seen that the presentation of a final plan, with cost estimates, is frequently insufficient for Council.

A question which now arises is whether the elected representatives of the people should make budget decisions rationally or in accordance with the directives and desires of their electors. The choice is often between acting in the public interest or satisfying individual electors for the sake of political survival.

J.W. Cowden,[2.] discussing the Theories of Budgeting and Budgetary Decision-making, indicates that two distinct schools have emerged. The one is described as the comprehensive school,

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2. COWDEN, Ibid, p. 5.

supported generally by proponents of programme budgeting. The other may be described as the incremental school and favour a more pragmatic attitude and has tended to reject the comprehensive approach. The distinction between the two is the approach an administrator adopts in decision making - either he will consider all alternatives and choose that which maximises his value or he will set a principal objective and disregard all social values which are irrelevant. The first decision making model is a "rational comprehensive" one, and the second is based on "successive limited comparisons". Opponents to the comprehensive approach to budgeting believe that it is unsuitable for the complex procedures of a budgetary system. It is beyond the intellectual capacities of decision-makers to come to decisions on this basis. It is not possible to acquire all the knowledge necessary to select alternative proposals. Therefore, he concludes, by the very nature of governmental budgets decision-makers are compelled to adopt an incremental approach, where decisions have to be made at the margin.

As Cowden[3.] points out, any municipal budgetary process will clearly be influenced by the particular institutional framework that exists. Under the multiple committee system of local government the separate committees enjoy varying powers to prepare estimates and it is then usual to have a finance committee or policy committee to bring these into general review.

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3. COWDEN, Ibid, p. 10.

He points out that under the management committee system the committee considers finance and policy simultaneously but the decline in democratic participation under this system has been frequently questioned. It is easy for the management committee to make decisions; the important question is the extent to which these decisions comply with the norms of rationality and community consensus.[4.] Nevertheless there has been a strong movement towards policy formulation and resource allocation by a central committee, which streamlines decision-making.

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4. COWDEN, Ibid, p. 10.

7.4 THE CHANGING ENVIRONMENT

The environment, as outlined above, has been very stable, and has basically remained unchanged for several decades. Certain structural changes to the environment are now envisaged, which could take place over the next five to ten years, and these changes could affect the planning and financing of municipal undertakings, particularly of those which have large areas of supplies, encompassing other communities and local authorities.

In a determined effort to give a larger portion of the population a say in the affairs that affect them, a proposed new system of "Regional Services", is envisaged as opposed to "Municipal Services" as presently operating, as part of the proposed constitutional reforms.

Under the present system, only actual ratepayers, through their elected representatives, have a direct say in municipal services, yet these services frequently extend well beyond the municipal boundaries and are imposed on numerous outside consumers who have no say in the manner in which the services are operated. To correct this deficiency, the concept of Regional Services has been developed, as envisaged in the new constitutional dispensation. These regional services will be controlled on a joint basis with participation in some form involving all the communities affected.

Regional services are seen to fall into two categories. Soft services are those that can be varied at short notice to take changes into account, such as bus services, fire fighting services, refuse removal etc. Hard services are those which require long planning periods, and are more technical in nature. Electricity, water, sewerage etc are such hard services. It is obvious that there are factors in the hard services that can be adjusted at short notice, such as the tariff, quality and type of service, etc which can make joint decision making meaningful.

It is accepted that there is a need for increasing the political participation to a much larger portion of the populace. It is at local government level that the effect of participation can be most evident and meaningful, and the government has made it clear that these structural changes will take place.[5.]

Professor W.B. Vosloo[6.] summed up the present situation as follows :

"Many scholars over the years have insisted that the urban problem is essentially one of "fragmented" government - that is, the proliferation of local authorities in urban areas.

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5. "Komitees - Koodinerende Raad vir Plaaslike Owerheidswese - het belangrike taak, maar moet waak teen persoonlike waardes wat tot nadeel kan strek". Munisipale en Openbare Dienste, April 1984.

6. Professor VOSLOO, W.B., "The Regional Approach to Local Government Re-organization in South Africa". The Institute of Municipal Treasurers and Accountants S.A., 1979, p. 330.

and the lack of co-ordination of public programmes. A common cliche is that the urban problem is one of "big problems and little governments" due to the fact that urban areas (particularly metropolitan areas) are economically and socially integrated to a large degree, but politically divided into many separate units. The objective of reform movements over the last four decades was to rid urban areas of ineffective multiple local jurisdictions and to establish area-wide or regional government arrangements."

Regionalization has two meanings in this political context. The first is an expression of greater decentralization of the machinery of central government and may take the form of either devolution or deconcentration (i.e. either political or administrative decentralization). The second involves a process of scale enlargement on the level of local government in an attempt to rationalize a system. It is this second meaning that interests us here, as it is used as an instrument of local government reform, as a means to improve the quality of local services by means of scale enlargement, but with due consideration to maintaining and fostering close liaison between different interest groups. The creation of the larger units involves to some degree the functional and structural consolidation of a number of neighbouring local authorities.

The various techniques by which regionalization of local government can be achieved range from complete consolidation of functions and structures (total integration) to partial and fragmented functional co-operation (co-operative polycentrism).

Professor Vosloo singles out three main factors in the various obstacles to regionalization. These are firstly the momentum of traditional patterns, secondly, the technical question concerning the relationship between efficiency and size, and thirdly the problems posed by hetrogeneous populations.[7.]

Several committees are presently deliberating the style of regional electricity supplies. These committees report to the Minister of Constitutional Development, the Hon. Chris Heunis.

It is generally accepted that structural changes will be made to the municipal electricity undertakings, and that these will be non-voluntary. These structural changes will fundamentally alter the method of financing capital projects, the controlling authority over the undertaking, and very importantly, it will alter the flow of income to the municipal coffers, as shown in previous chapters.

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7. Professor VOSLOO, Ibid, p. 335.

It is this writer's opinion that as the full effect of the proposed Regional Services becomes clearer, most towns are not going to accept it gracefully, and that tremendous resistance is going to develop against the changes. Already, the first rumblings of discontent, at levels as high as the Natal Provincial Council are becoming evident. Mr. Frank Martin, Natal's Senior M.E.C. commented on a statement made in Parliament on the 25th May 1984, by the Minister of Constitutional Affairs and Planning, Mr. Chris Heunis, that second tier government in the new dispensation would probably deal with "general affairs". Mr. Martin said if this were true the province would lose control of the education department, hospital services and local authorities. He said all indications lately were that the Government was bent on destroying the provincial council system. Mr. Martin said the Government was likely to create metropolitan service boards to handle essential services, such as electricity and sewerage. Local authorities would be left to control minor functions, such as grass cutting.[8]

It is very likely that local authorities will vehemently resist the demotion from running highly technical functions

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8. "Natal Could lose Control : Martin", The Daily News, Saturday, May 26 1984.

to arranging grass cutting. The salaries paid to each municipal employee is directly linked to the annual revenue earned by the local authority, and the exclusion of the electricity undertaking may mean considerable reductions in salaries, if alternative salary structures are not introduced at the same time. Finally, the municipal rates are supplemented to a very large degree by the operating surplus generated by the electricity undertaking, and the local authority faces the unenviable task of increasing municipal rates by upwards of 30% if municipal electricity undertakings are phased out. (See Table 5.2) For these reasons it is very likely that local authorities will come out strongly against these changes, but equally, the central government is committed and decided that such reform will take place. (See "Munisipale en Openbare Dienste April 1984 : Komitees-Koördinerende Raad vir Plaaslike Owerheidswese - het belangrike taak, maar moet waak teen persoonlike waardes wat tot nadeel kan strek.")

Boundaries of the Regional Services Councils are not yet finalised and the functions, financing and composition of the R.S.C.'s are still sketchy.

On the 23rd August, 1985 a major document detailing the functions and financing of a Greater Durban Regional Services Council was revealed.[9] It listed for the first time the authorities to be included in the council and breaks down the voting position, which is based on electricity consumption. Based on recent consumption, with legal adjustment,the following voting position was proposed:[10] (approximately)

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9 & 10. "Big Blueprint for all races to run Durban", The Daily New Saturday August 24, 1985, p. 7.

General Durban	50%
Chatsworth	9%
Northern Indian Areas	6%
Phoenix	5%
Pinetown	4%
Umlazi	4%
Westville	3%
Coloured Areas	2%
Various other areas	1% each.

The philosophy behind the development of R.S.C.'s is that all communities should have a say in the services which affect them, via their elected representatives on these councils.

There are a great number of problems which this philosophy does not address.

Firstly, it must be accepted that these R.C.C.'s are being created to satisfy the political desires of large numbers of previously disenfranchised South Africans. Bearing in mind that White South Africans have traditionally held municipal elections in very low esteem, it is unlikely that non-white will view it any better and the creation of R.S.C.'s (which will be controlled by the various local authorities) will be very unlikely to satisfy the desire of the masses for full political expression at the highest level.

Secondly, the long planning periods and long lead times for delivery of very expensive imported switchgear and other equipment means that typically the various projects undertaken by the

R.S.C. will exceed the average council-members term of office. Also, the decisions to be taken are extremely technical in nature, and are well outside the scope of competency of typical politically elected public representatives. As the subject matter is outside his field of understanding, and since its duration of construction will exceed his stay in office it is difficult to see how he can contribute to the running of the R.S.C. Indeed, to many of the elected representatives who for many years have been deprived of political expression, this experience of attempting to manage a purely technical function may be demoralizing and counter-productive.

As stated by Mr. Ray Swart (P.F.P. Natal leader) "The proposed regional services councils are based on such shaky and flawed foundations such as group areas and ethnic local authorities that their implementation will create more problems than they promise to solve."[11.]

The R.S.C. for Durban and other areas were initally scheduled for January 1, 1986, but the Department of Constitutional Development announced on the 8th October 1985 that there would be a three month delay.[11.]

Although these R.S.C.'s are viewed with a great deal of suspician, they will no doubt assist in releasing the firm grip which White-run municipalities have over all urban areas. Indeed, it is perhaps as a result of the indifference to Black Consumers that R.S.C.'s are going to be forced onto the municipalities.

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11. "P.F.P. warns on danger to future Natal" The Daily News, October 9, 1985 p. 4.

7.5 THE SUPPLY OF ELECTRICITY TO BLACK AREAS

Throughout the world the electricity utility industry tends to hide behind a veil of indifference to the inequalities in society, and in most instances assists in perpetuating the inequalities.

This strange situation is given a cloak of respectability by numerous utility economists such as Bonbright who says "public utility rates are ineffective instruments by which to minimise inequalties on income distribution ....",[12.] and Wiseman who states "... it is not the function of the management of the public utilities to redistribute income nor should they have the power to do so".[13.]

The extent to which the inequalities are perpetuated is clearly demonstrated by the total apathy that most (perhaps all) municipal electricity undertakings have towards their black townships.

Clearly there are problems associated with reticulating electricity in these black townships. There is the high capital cost of the distribution network, the cost of the electrical installation in each house and the cost of the electrical appliances. It is generally

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12. BONBRIGHT, J.C., "Two partly conflicting Standards of Reasonable Public Utility Rates" AER V 47 (1957) p 30

13. WISEMAN, J. "The Theory of Public Utility Price - An Empty Box" OEP V9 (1957) p 61

accepted that the poorly paid black residents can not afford such luxuries, so the white towns continue to get an ever-improving electricity supply, while their black dormitory township residents have to continue using parafin stoves, candles and coal.

The Kwa Zulu authorities have recently electrified portion of Umlazi which is a Black township outside Durban. The extent of their installation includes streetlighting, the main distribution network and terminates at kerb-boundary pillar-boxes. The householder is responsible for the cost of the cable from the pillar-box to his house, as well as the cost of the electrical installation in his house.

It was established during interviews with the Kwa Zulu Development Corporation officials that the cost of the reticulation installation was approximately R587,000.00 for 800 houses, which is approximately R734.00 per house (in 1982)

Private contractors are required to wire up each house, at the householders expense, and a typical installation comprising incoming cable, distribution board, 5 socket outlets and 5 light points costs approximately R990.00 (in 1982) which included the connection fee of R315.00.

The author undertook a survey amongst some 65 householders in Umlazi in an area which had had electricity for about six years.

Questionaires will filled in by the householders as shown in Fig. 7.1 and Fig. 7.2.

FIG. 7.1

1

FORM A

SURVEY TO DETERMINE RELATIVE COST OF ELECTRICITY VERSUS OTHER FORMS OF ENERGY FOR BLACK CONSUMERS FOR HOUSES NOT CONNECTED TO ELECTRICITY

a) Number of persons living in house ....
b) Number of persons working full time ....
c) Number of persons going to school ....
d) Do you use parafin? ....
    Do you buy it in a bottle or tin ....
    How much does it cost ....
    How many bottles per month do you buy ....
  What is the Total cost per month for parafin ....
e) Do you use coal? ....
    Do you buy it in a bag or box ....
    How much does it cost ....
    How many times per month do you buy it ....
  What is the Total cost per month for Coal ....
f) Do you use wood ....
    Do you buy it in a bag or box ....
    How much does it cost ....
    How many times per month do you buy it ....
g) Do you use candles ....
    Do you buy them loose or in a packet ....
    How much does it cost ....
    How many do you buy per month ....
  What is the Total cost per month for Candles ....
h) Do you use gas ....
    Do you buy or refil cylinders ....
    How much does it cost ....
    How many times per month do you buy gas ....
  What is the Total cost per month for Gas ....
i) What time do you start cooking supper? ....
j) What time do you eat supper? ....
k) House number and street ....

2

FORM B

SURVEY TO DETEMINE RELATIVE COST OF ELECTRICITY VERSUS OTHER FORMS OF ENERGY FOR BLACK CONSUMERS

FOR HOUSES CONNECTED TO ELECTRICITY

a) Number of persons living in house ....

b) Number of persons working full time ....

c) Number of persons going to school ....

d) What is the approximate cost per month for electricity ....

e) Do you use any parafin, wood, coal or candles
(If yes please also fill in Form A) ....

f) What time do you start cooking supper? ....

g) What time do you eat supper? ....

h) House number and street ....

Of the 65 randomly selected households, 28 were electricity consumers, and the remaining 37 were not.

Bearing in mind that several responses to these questionaires by different respondents are mutually exclusive it is misleading to attempt to arrive at averages, and a better assessment of the answers can be gained by reviewing the responses given by typical householders in each category.

These responses are shown in Table 7.1 and a typical electricity account for a householder is shown in Fig. 7.3

Several interesting and very important conclusions can be reached from this survey. Consider the following :-

A. <u>For householders not connected to electricity</u>

Average cost of fuels for household not connected to electricity : R46.90.

B. <u>For Householder connected to electricity</u>

(i)	Average cost of energy for households connected to electricity	: R18.10
(ii)	Assume householder repays the electrification of his house of R990.00 over 8 years at 15% : monthly repayments :	17.77
(iii)	Assume householder buys a fridge, stove & radio and pays the amount of R400.00 off over 5 years at 15% : monthly repayments	9.51
		R45.38

ELECTRICITY ACCOUNT.

NAME OF CONSUMER: T. M. MAZIBUKO SITE NUMBER: F 143 UNIT NUMBER: 6	OFFICE DATE STAMP	ARREARS R ....

METER NO.	DATE OF READING	METER READINGS UNITS PRESENT	PREVIOUS	K.V.A.	UNITS	CONSUMPTION K.V.A	TARIFFS	SUB-TOTAL	SERVICE CHARGE	TOTAL R	c
	29-1-85	5726	5600	—	126	—	4,5	5-67	2-00	7	67

(1) Payable at the office for Superintendent
Zone F
c/o The Township Manager
Private Bag X 11,
4060 MOBENI.

(2) Cheques to be made payable and to be forwarded to the Township Manager, UMLAZI.

AMOUNT PAYABLE 7 67

N.B. (3) If this account is not paid within 14 days of date of issue, electricity will be disconnected without further notice.

R7-67

....
SUPERINTENDENT.
UMLAZI.
ZONE F..........

FIGURE 7.3.

Houses Not Connected to Electricity

House	A	B	C	D
Number of persons living in house	8	5	8	15
Number of persons working full time	3	1	2	3
Cost of parafin used per month	R15.80	R6.00	R30.00	R50.00
Cost of Coal used per month	8.00	14.00	6.00	Nil
Cost of Wood used per month	9.00	9.00	5.00	10.00
Cost of Candles used per month	12.60	9.00	3.60	6.30
Total cost of fuels :	R45.40	R38.00	R44.60	R66.30

Houses using Electricity

House	E	F	G	H
Number of persons living in house	10	8	6	4
Number of persons working full time	4	4	4	3
Cost of electricity used	R22.00	R30.00	R17.95	R6.50

Average cost of energy consumed

For 37 Households not using electricity	R46.90
For 28 Households using electricity	R18.10

TABLE 7.1

SUMMARY OF RESPONSES TO QUESTIONAIRES

The almost incredible result shown above indicates that the black householders, who are connected to electricity, pay less for their total costs than those who are not electricity consumers, yet their standard of living is markedly higher. There is no comparison between a house which has electric lights in all rooms to one in which candles are carried around, and there is a considerable benefit in owning a refrigerator, as it extends the useful life of many perishables.

It should be clear from the above discussion that the assumption that black consumers are better off without electricity supplies is totally unfounded, and in fact the tremendous improvement in living standards which could be obtained with the money which they already spend on fuels should make it imperative that all black townships should be electrified without delay.

The gross profit made by the undertaking in supplying electricity to a black consumer can be estimated as follows :-

Average Revenue received :		18.10
Cost of electricity consumed :		
Average diversified maximum demand :		
0,6 KVA (from K.D.C. records)		
@ 9.25/KVA :	5.55	
250 units @ 1c/unit	2.50	
TOTAL COST		8.05
GROSS PROFIT :		10.05

At an interest rate of 15% over 25 years this gross profit of R10,05 can support a capital expenditure of R779.00. The actual cost per house for the reticulation system is R734.00 as stated previously.

It is encouraging to note that (perhaps as a result of the impending imposition of R.S.C.'s) the City Council of Durban has unanimously agreed on a joint report by the City Treasurer and City Electrical Engineer that the council be responsible for distributing electricity to those parts in Kwa-Zulu that lie within Durbans' regional electricity supply system. Commenting on the Councils' decision the chairman of Manco, Mrs. Sybil Hotz praised the move as a temendous step in the right direction and said "This has gone a very long way indeed to improve the qualityof black people's lives in outlying areas. I think this is an extremely important decision."[14.]

It is sincerely hoped that other municipalities will follow Durban's lead and adopt similar policies.

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14. "Electricity Boost for Blacks", <u>The Daily News</u> Tuesday September 24, 1985, p. 9.

CHAPTER 8

POLICY FORMULATION AND RECOMMENDATIONS

8.1 The nature of Policies

Steiner and Miner make the following observations about the nature of Policies.[1.]

"Policies are generally considered to be guides to actions or channels to thinking."

"A business policy can be defined as managements' expressed or implied intent to govern action in the achievement of a company's aim".

"Policies are generally expressed in a qualitative, conditional, and general way."

"Policies direct action to the achievement of an objective or goal".

As stated by Steiner and Miner "the strategic planning process proceeds to hammer out basic missions, purposes, long range objectives and policies and strategies to achieve them."[2.]

In order to determine to what extent these principles are utilized by various municipal electricity undertakings, a structured telephonic interview was conducted with senior personnel of the undertakings of Cape Town, Johannesburg, Durban, Pietermaritzburg, Port Elizabeth, Mooi River, Stanger, Tongaat & Bloemfontein.

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1. Steiner George A, and Miner John B., "Management Policy and Strategy" Macmillan Publishing Co., Inc. New York 1977, pages 24, 25.

2. Steiner G.A. and Miner B.M. Ibid, p. 99.

The interview was divided into four sections to determine the following:

a) Whether the undertaking has a written statement of its aims, missions and objectives, and the extent to which these are supported by written objectives and policies in the fields of its customers, finance, etc.

b) To test the importance of five statements which could be used as a comprehensive statement of the main objective of the undertaking.

c) The extent to which sound financial principles are applied to the design of electricity tariffs.

d) The extent to which load management is practiced.

The questionaire and a summary of the responses appears in Appendix 2 (page 10.23)

The results of the survey show that none of these towns or cities have written statements of their mission, purpose, objectives or policies. Most respondents indicated that many of their functions had written procedures which had to be followed, such as switching procedures, procedures to be followed after an accident, etc, but these are not policies as being discussed in this thesis.

Regarding the objectives, all respondents indicated high importance to statements regarding safety, increased relibility etc, but low importance to the design of electricity tariffs. Further discussions in this direction indicated that the interviewees felt that the final say in tariffs is out of their hands and hence they cannot rate it as important.

Of the 9 centres interviewed, only Johannesburg and Durban state that their tariff is carefully designed each year taking many factors into account. All the other centres state that for various reasons they find it more convenient to merely adjust their historical tariffs proportionately without analyzing its components or its relevance to actual costs.

The fourth part of the survey referred to load management. Most centres segmented their markets to some degree, with Durban and Johannesburg segmenting their customers further into those who cause the system peak. Cape Town, Johannesburg and Durban use incentive tarffs to attempt to shift load out of the peak period.

The conclusion which can be drawn from this small survey is that there is a total absence of strategic planning in even the largest undertakings.

Due to the financial benefits which flow from Load Management, it can obviously stand on its own. However, it is possible to extend the benefits of load management to all other functional areas of the undertaking by employing the principles of marketing management and strategic planning, as illustrated hereunder.

The process of strategic planning, as stated earlier, proceeds to hammer out basic missions, purposes, long range objectives and policies and strategies to achieve them.

The basic mission and purpose of the undertaking is clear, as it relates to the safe and efficient supply of electricity to the consumers.
As a starting point, therefore, it is necessary to first identify and state the long range objective of the electricity undertaking.
The policies will then be formulated to attain this objective.

8.2 Identification of the Long range objective of the electricity Undertaking

The free enterprise system derives much of its driving force from the profit motive and from the demand for constant improvements by firms to remain competitive in the market.

These motivating components are not present for the municipal electricity undertaking, since the operating surplus can be obtained by tariff adjustment, and it has an inalienable right to be the sole electricity supplier in the area, which prohibits any competition. Under these conditions it is easy for the undertaking to become extremely lax and inefficient.

It is therefore very necessary to establish real alternatives to these motivating components. Certain ratios, such as the Return on Investment, give a clear indication of the performance of business firms and can be used to judge the effective utilization of scarce resources. For the safe and efficient distribution of electricity it is necessary to install transformers, switchgear and cables which are capable of carrying the peak loads, which means they are underutilised most of the time. The load factor, and modified forms of the load factor, are indicators of the utilization of the equipment employed, and it is clear that this index can be used as a suitable substitute for the R.O.I. and similar ratios.

The load factor is defined as follows :-

$$\text{Load factor} = \frac{\text{Energy Units Consumed}}{\text{Maximum Demand x hours}} \times 100\%$$

The monthly load factor relates to the maximum demand of the month, the hours in that month and the total energy supplied in that month. The annual load factor relates to the highest monthly maximum demand, the hours in the year and the total energy supplied in the year. The Installed Load Factor relates to the designed full load maximum demand capability of the system the hours in the period being considered and the total energy supplied in that period.

Several aspects makes the Load Factor the most suitable indicator of the performance of the undertaking, viz,

a) It is easily calculated directly from the monthly electricity account received from ESCOM.

b) It is strictly objective.

c) It is readily understood by all employees of the undertaking.

d) It is easy for all employees to see how their efforts affect the Load Factor.

e) The aim to improve the Load Factor leads directly to suitable M.B.O. programmes at all levels and in all fields.

f) The resulting actions and improvements in the Load Factor can have a significant impact on employee productivity and can contribute directly towards the reduction in the cost of electricity to consumers.

The identification of the Load Factor as an indicator for which the Undertaking can be held accountable for, presents a simple and effective method of tranforming the undertaking into a goal orientated organization in which all employees can participate and utilize all their skills to the full.

It is therefore recommended that the main objective of the electricity undertaking must be to improve its monthly load factor.

As stated above, the aim to improve the Load Factor can provide a coherent thread throughout the organization for improved performance. This applies to all fields of activities, as shown below, and brings together all the diverse facets of the undertaking which have been covered in this thesis. The following co-ordinated effort is required to gain the maximum improvement in the Load Factor:

a) The maximum demand must be contained or even reduced. This requires the application of load management which entails the analysis and study of the consumer groups, development of improved tariff structures etc. These components were discussed in Chapters 2,3 & 4.

b) Energy losses in distribution becomes more important since a reduction in the losses can bring about a worthwhile reduction in Maximum Demand with corresponding improvement in Load Factor. This was discussed in Chapter 5.

c) The need to maintain continuity of supply now becomes meaningful, since power outages due to poor maintenance will result in reduced energy sales which will reduce the Load Factor. It must be remembered that a power failure does not reduce the maximum demand but significantly reduces the energy units sold.

It is obvious that the need to maintain high sales of energy by ensuring good continuity of supply introduces a much-needed stimulus to planned maintenance, and to individual initiative and pride of workmanship on the part of the electricians. These matters were covered in Chapters 5 and 6.

The results which can be achieved by improving the Load Factor can be very encouraging.

The following table illustrates the improvement in the monthly Load Factor achieved by Somerset West following the implementation of a comprehensive load management programme based on hard load management of geysers.

SOMERSET WEST

MONTHLY LOAD FACTORS

Month	Before Load Management 1981 Percentage	After Load Management 1985 Percentage
January	59	69
February	61	77
March	46	72
April	55	68
May	49	61
June	47	55
July	54	60
August	56	60
September	48	58
October	53	62
November	64	72

TABLE SHOWING IMPROVEMENT IN LOAD FACTOR

Source : Town Electrical Engineer : Somerset West

TABLE 8.1

8.3 The need for suitable Guidelines

The foregoing discussions indicated that the policy of "abundantly available electrical energy" results in consumption patterns which create very sharp peaks in the daily load curve with a correspondingly low utilization of the capital equipment involved.

As discussed in section 2.2, the continual development of energy-intensive and labour-saving appliances for domestic use allows domestic consumers to concentrate more activities into an even shorter time, and it can therefore be expected that the peaks will become more pronounced which can threaten to overload the existing reticulation networks during these peak periods.

This is further reason why policies must be developed which will improve the load factor, by either remotely controlling some of the consumer's loads (hard load management) or by inducing the consumers to shift portion of their load out of the peak period (soft load management).

The foregoing chapters indicated that a variety of methods are employed by different undertakings in an attempt to control the shape of the daily load curve. These methods include reduction of system voltage during peak periods, remote control of geyser loads, load shedding devices which cut out the geyser while the stove is used, current limiting main switches, incentive off-peak tariffs, restricted period maximum demand tariffs, pumped storage schemes and so on.

Some undertakings report excellent results using one method of load management while other undertakings report poor results when using the same method.

In other cases, the policies differ widely even under very similar conditions. For example, one town fits restricting current limiters on its domestic supplies while an adjacent town does not.

Such diverse policy decisions can only be due to inconsistent objectives or deficiencies in the data base, while the poor results obtained from a load management method clearly indicates that the incorrect choice of load management was made.

It is obvious that incorrect policies can be very expensive and/or can cause needless inconvenience to consumers. Furthermore, the lack of suitable guidelines causes numerous municipal undertakings to indefinitely postpone altering their existing policies for fear of selecting an incorrect and costly alternative.

There are many undertakings which collectively could save their consumers millions of rands per year if the correct form of load management was applied, and conversely millions of rands could be saved if ineffectual remotely operated load control installations could be obviated.

The situation could be significantly improved with considerable benefit to the national economy as well as to all consumers if the guidelines for the development of comprehensive marketing policies, as proposed in this section were applied by all undertakings.

8.4 Guidelines for selection of Load Management Policies

As stated previously, many of the load management techniques are mutually excluding. For example, it was shown that the domestic peak, of a few hours wide could be considerably flattened with a remotely operated geyser control system, to form a flat load curve with a plateau which can extend up to eight hours. It was also shown that there is already a problem in accommodating the payback demand of the controlled geysers and clearly therefore, there cannot also be incentive off-peak tariffs to shift more load into the period following the original peak period.

It has also been stated previously, that if correctly applied, geyser load management produces no inconvenience to the consumers, it does not require them to modify their consumption patterns and it can produce the required reduction in the peak demand. Since other forms of load management invariably require a sacrifice on the part of the consumer, (which has to be bought by way of incentive tariffs, etc) it is recommended that hard load management of consumers' geysers be considered as a first option, and that the feasibility studies as detailed in section 2.11 be applied to the undertaking's load curve.

As determined in section 2.11.5, undertakings whose load curves return a contribution of more than 0,5 kW/geyser toward peak load reduction should seriously consider the installation of a remotely operated geyser control system, whereas those whose load curves respond less favourably should consider alternative forms of load management.

All contributing factors must be taken into account when making this fundamental decision, such as detectable changes in the shape of the daily load curve over many previous years, the historical tariff structures, the present use of current limiting devices, the use of stove/geyser load shedding devices etc.

For undertakings where the contribution is comfortably higher than 0,5 kW/geyser, there is little if any doubt that such an installation will be of benefit.

Where the contribution is less than 0,5kW/geyser, cetain further considerations may be necessary.

Firstly, there may not be other types of loads in the system. It may therefore be a choice between geyser control or nothing. The fact of the matter is that the savings made at less than 0,5 kW/geyser is very risky, as pointed out in section 2.11.5 since changes in the shape of the load curve, improvements in water heating technology and changes in ESCOM's two part tariff could all contribute towards reducing or eliminating the small savings. On the other hand, the total absence of any other forms of load means that the load curve will probably not change, and the continual increases in ESCOM demand tariffs will probably make such an installation a viable proposition in the long term.

If there are other types of loads in the system, for example hotels, factories etc, then further changes in the shape of the load curve cannot be ruled out, and a more conservative approach is warranted.

In such cases detailed attention should be given to the commercial and industrial consumers to determine the form of incentive tariffs which would be of most benefit to them and to the undertaking. Finally, simple tests can be done to determine the peak load reduction which will accompany a 5% voltage reduction to establish whether this form of load control should also be employed.

The guidelines for the selection of Load Management Policies as discussed above are shown in Figure 8.1.

8.5 Guidelines for the development of Comprehensive Marketing Management Policies

The foregoing discussions identified the long range objective to be the continual improvement in the Load Factor. Suitable guidelines were presented which would assist the undertaking in selecting the most approporiate load management policies.

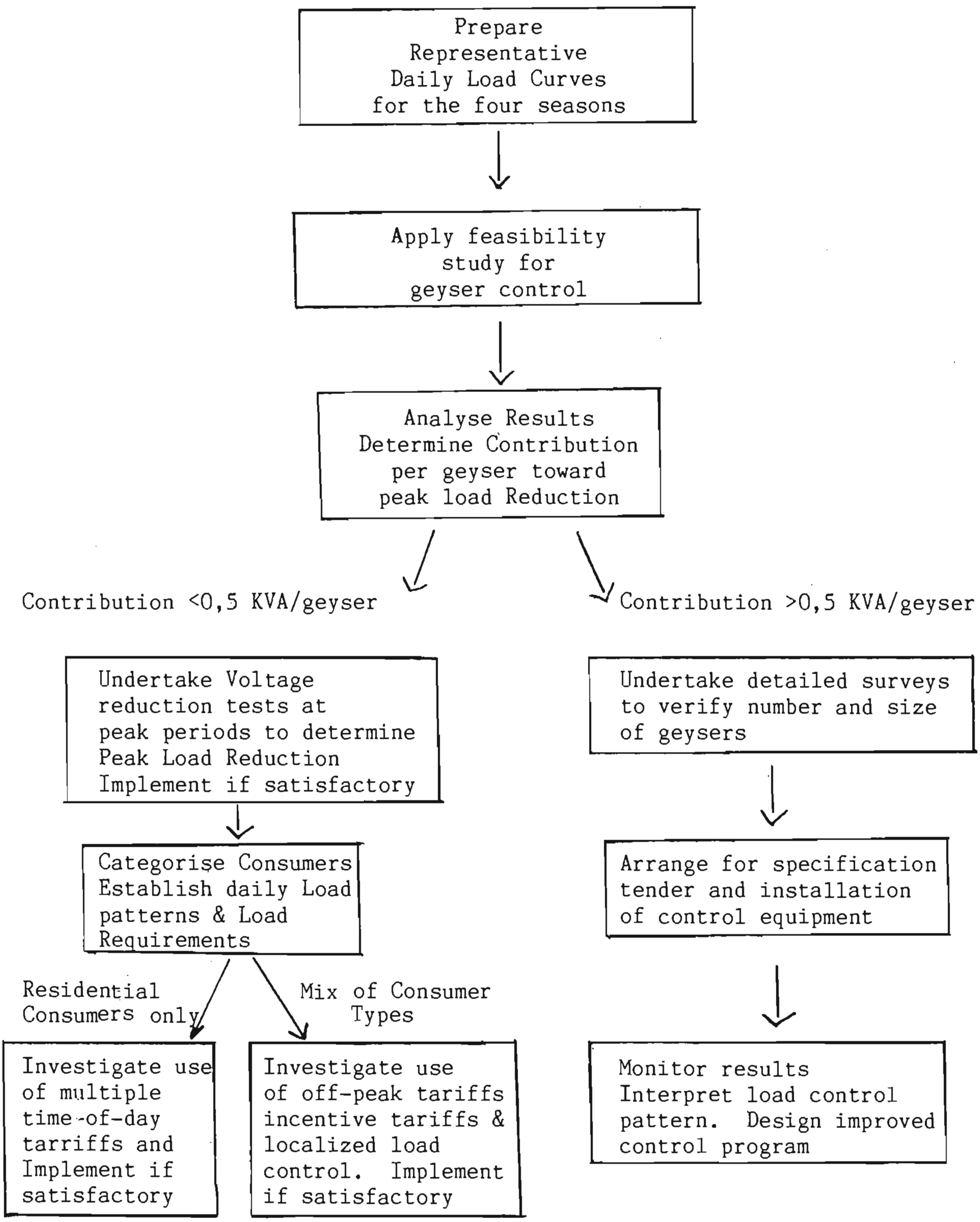
The basic load management policies must be supported by a web of policies in all fields of activities, developed in a logical and co-ordinated manner in order to direct all actions towards the achievement of the objective.

Following on from the stated long term objective it is possible to develop objectives in the fields of consumers, finance, production and personnel which fit in with the main objective and the selected load management policies.

These could be stated as follows, bearing in mind that some of the sub-objectives and resulting policies are mutually excluding, depending on the original selection of load management techniques.

FIGURE 8.1

GUIDELINES FOR THE SELECTION OF LOAD MANAGEMENT POLICIES



8.5.1 Customer Objectives

(i) The customer market will be segmented according to their needs for electricity to ensure that the needs of the different classes of consumers can be identified and catered for.

(ii) The consumption patterns will be monitored and cost effective measures will be used to modify consumer behaviour to reduce the load peak.

8.5.2 Financial Objectives

(i) Market segmentation will be achieved by using differentiated tariff structures.

(ii) Tariff structures will as far as possible be designed to recover actual costs from the relevant market segment, and will be designed to encourage the consumer to shift load out of the peak period.

(iii) Tariffs will be designed for on-peak and off-peak periods, based on the average cost of delivering electricity to consumers in these periods.

8.5.3 Production Objectives

(i) The system's reliability will be improved in accordance with the requirements of the consumers determined largely by their willingness-to-pay for the improved reliability.

(ii) The reticulation system will be improved to facilitate planned maintenance without having to resort to shutdowns.

(iii) The selection of material and equipment will be made on long-term economic considerations.

8.5.4 Personnel Objectives

(i) The objective of the department is to maintain and improve the electrical network for the benefit of the consumers.

(ii) The undertaking will strive to create a stable, reliable work force and will strive to improve productivity.

8.6 Policy Formulation

The above objectives give a clear indication of the policies required, and these can be developed as follows :

8.6.1 Customer Market Policies

a) The market will be segmented according to the needs of the consumers. Based on the discussions contained in Chapter 2, the market will be segmented into the following nine categories.

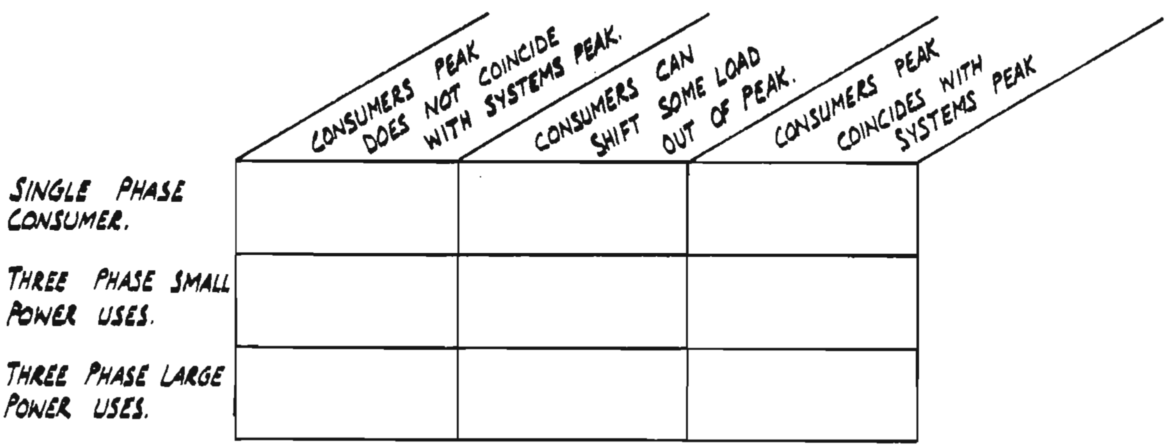


DIAGRAM REPRESENTING MARKET SEGMENTATION

Market segmentation will be achieved by using appropriately worded tariff structures which differentiates between different types of consumers. By carefully selecting the tariff which best suits the customer, he automatically joins the market segment which have similar needs and preferences.

b) The customer load curve must be monitored continually to determine which segment(s) is/are mainly responsible for creating the peak, and to determine which segment(s) can be induced by way of incentive tariffs to shift some of their load out of the peak period.

c) Load forecasting models will be developed as a prelude to full-scale load management. The load forecasting model must be sufficiently accurate to obviate unnecessary voltage reduction or other hard management control on days when the load will not exceed the peak for the month.

d) Soft load Management will be implemented with particular attention being given to the wording of the incentive tariffs to ensure that non-technical users can readily understand the intention and application of the tariff.

e) Hard load management of selected plant such as irrigation pumps will be implemented, taking great care that they are only switched off as the system approaches its peak.

f) Hard load management by means of geyser control and/or system voltage reduction will be implemented, again taking care that the voltage is reduced (by a maximum of 5%) only on those days when the system approaches its peak load value.

8.6.2 Financial Policies.

a) Existing tariffs will be critically examined and improved, while, initially, maintaining the revenue derived from each category.

b) Any disproportionate allocation of costs amongst the various categories of consumers which is identified in the above examination will be corrected by gradual adjustments of the tariffs over several years.

c) The improvements and adjustments made to the tariffs will simultaneously remove all restrictive measures while developing differentiated tariffs with off-peak advantages for the consumers.

The above policies can best be illustrated by way of an example as follows; which is based loosely on Tzaneen.

Consider a town with the following simplified details :

a) Town population : 5000 (Domestic Consumers)
b) Number of commercial consumers : 250
c) Number of industrial consumers : 100
d) Purchase price of electricity from ESCOM : R8.50 per KVA. and 1,5c per kWhr.
e) The ruling tariffs of the town are :

Domestic consumers :	20 Amp circuit breaker	R21.50
	30 Amp circuit breaker	R32.50
	Basic Charge	5.50
	Charge per kWhr	2,9 cents

Commercial Consumers :	Basic charge	R7.00
	First 400 kWhr	20 c
	next 600 kWh	15c
	remaining units	10c
Industrial consumers :	Basic charge	R10.00
	Max. Demand KVA	R9.20
	Charge per kWhr	2,9 c

Discussion

For an initial, and yet very critical, examination of the tariff structure it is not necessary to have details of load curves, load factors etc. as a first approximation.

One can then assume the folllowing :-

a) All loads peak together at some time.

b) The maximum demand and energy purchased from ESCOM must be 10% higher than that sold to consumers to allow for distribution losses.

The following can then be determined :

a) Domestic Consumers

Assume 50% of consumers pay for a 20 Amp circuit breaker, and 50% pay for a 30 Amp circuit breaker.

From the results obtained in Section 2.7 we note that the diversified maximum demand of all consumers is about 2,5 KVA and the consumption of energy is around 650 units per month, irrespective of size circuit breaker installed.

Hence for the 5000 domestic consumers we will have the following :

Power purchased from ESCOM for 5000 consumers :

5000 consumers @ 2,5 KVA : 12 500 KVA

5000 consumers @ 650 units : 3 250 000 units

The cost would be :

12 500 KVA @ R8.50 :	R106,250.00
3 250 000 units @ 1,5c :	48,750.00
	R155,000.00
Add 10% to allow for distribution losses	15,500.00
	R170,500.00
The total income would be :	
5000 consumers : Basic @ R5.50	27,500.00
2500 consumers : (20 Amps) @ R21.50	53,750.00
2500 consumers (30 Amp) @ R32.50	81,250.00
3 250 000 units @ 2,9c	94,250.00
	R256,750.00

This means that a gross profit of R86,250.00 is made on R170,500.00. which represents a mark-up of 50,5% on ESCOM prices.

b) Commercial Consumers

Assume that the average commercial consumer uses 4500 units, and works a 200 hour month using power uniformly over this period. His approximate KVA demand will be :

4500 ÷ 200 hrs = 22,5 KVA

The cost of this electricity from ESCOM would be

22,5 KVA @ R8.50 =	R191.25
4500 units @ 1,5c	67.50
	R258.75
Add 10% to allow for distribution losses :	25.87
	R284.62

The revenue derived by the town would be

Basic charge	7.00
First 400 kWhr @ 20c	80.00
Next 600 kWhr @ 15c	90.00
3500 remaining units @ 10c	350.00
	R527.00

This means that the undertaking makes a gross profit of R242.38 on a cost of R284.62, which is a mark-up of 85,2%.

c) <u>Industrial Consumers</u>

Assume the average industrial consumer works a 200 hour month and draws 100 KVA. The number of units used would therefore be around 100 x 200 = 20 000 units.

The cost of purchases from ESCOM is :

100 KVA @ R8.50	R850.00
20 000 units @ 1,5c	300.00
	R1,150.00
Add 10% to allow for distribution losses	115.00
	R1,265.00

The income derived by the town would be :

Basic charge	10.00
Maximum demand 100 KVA @ R9.20	920.00
20 000 units @ 2,9c	580.00
	R1,510.00

This means the undertaking makes a gross profit of R360.00 on purchases of R1,265.00 which represents a mark-up of 19.4%.

It can therefore be seen that the gross profit derived from different categories of consumers differs markedly. It is necesary to examine the breakdown of previous capital expenditures on each category as well as the portion of time the department spends on each category of consumer to determine whether the recovery of cost is equitable.

Improving the existing tariff structure

The following discussions on the domestic tariff and the Off-peak pumping tariff are presented as examples of the manner by which the existing tariffs can be improved.

a) Domestic Tariffs

The existing restrictive domestic tariff could be replaced with an "open"tariff as follows :-

Assume that "approved installations" can be fitted with a 60 Amp circuit breaker in place of the 20 Amp or 30 Amp circuit breaker at a cost plus finances charges over 3 years of R100.00 or R2.80 p.m. ("Approved installation" means one that has been declared safe by the wiring inspector to be supplied by the larger circuit breaker).

To maintain the revenue income the new tariff must bring in the original R256 750.00 plus 5000 x R2.80 = R14,000.00 or a total of R270 750.00 p.m. Assume that this is to be recovered from consumers by using a simple reducing block tariff, i.e. one that does not contain a basic charge. Assume that all costs are to be recovered in the first 2/3 of the total unit sales, and all sales after that point are sold at only 10% above cost, since all required profit has then been accounted for. We then have

Required income

Original income :	R256,750.00
Cost of circuit breaker conversion	14,000.00
	R270.750.00

Hence for 5000 consumers, the incomer per average consumer must be R270,750.00 : 5000 = R54.15 p.m. (approximately)

This average consumer used 650 units. If we assume he purchases the last one-third at cost of 1,5c + 10% then we get :

Required Income :	R54.15
less 1/3 of 650 units @ 1,65	3.57
Therefore the first 2/3 of 650 units must bring in :	R50.58

A suitable split would be

First 250 units :	15 cents
next 200 units :	7,3 cents
remaining units :	1,65 cents

The average consumer using 650 units would then pay :

First 250 units @ 15 cents	37.50
next 200 units @ 7,3 cents	14.0
remaining 200 units @ 1,65 cents	3.30
	R55.40

Hence to maintain the present revenue income the new domestic tariff structure will be :

First 250 units : 15 cents per unit

next 200 units : 7,3 cents per unit

remaining units : 1,65 cents per unit

Needless to say one must question whether a return of 50,5 on ESCOM purchases is warranted when the mark-up on industrial consumers is only 19,4%.

(b) OFF PEAK PUMPING RATES

If one looks at the above Industrial tariff of R9.20, and compares it to the ESCOM purchase price of R8.50, then it is obvious that the maximum demand mark-up is 8,23%. In actual terms the mark-up is R0,70.
It is obvious that the off-peak tariff could be priced at R0.70 per KVA (to recover the mark-up,) and 2,9 cents per unit to maintain revenue income.

A town such as Tzaneen experiences its peak at around 11.00 a.m., due largely to irrigation consumers.

An irrigation tariff of R1.00 per KVA and 2,9 cents per unit, with a restricted period from 10.00 a.m. to 12 noon would be of mutual benefit to the farmers and the town. The farmers would save R8.20 per KVA while the town increases it's profit from 70 cents per KVA to R1.00 per KVA since it is all sold off-peak. For a typical irrigation consumer using 100 KVA, his savings per annum would amount to R9,840.00, while the towns profit increases by R360,00.

8.6.3 Personnel Policies

Based on the objectives set out earlier, the policies of the undertaking will be formulated to focus attention to the following :

a) To maintain and improve the supply of electricity to consumers.
b) To create a stable and motivated work force.

Suitable policies to meet these objectives would be :

a) Job descriptions will be drawn up for all posts which will emphasise the importance of planned maintenance. The goal of each job description will be to reduce consumer outages.

b) An effective reporting and evaluation system for monitoring the interruptions of supply to consumers will be developed, and positive feed-back reporting to the entire work-force will be implemented. This may take several forms, such as a wall hanging graph on which the consumer-hours outages for each month can be plotted etc.

c) Management-by-objectives and similar techniques will be used, together with the above feedback reporting, to create an atmosphere of involvement for all employees.

d) In order that productivity is maintained at a high level, and to ensure that control and standard costing can be developed, only repetitive type of work will be done departmentally. Any unusual or one-off type of work will be put out for tender by outside contractors.

8.6.4 Production Policies

Following on from the objectives set out above the following policies can be stated for the network.

a) The selection of equipment will be based on long term economic considerations.

b) The network will be subdivided, and badly interconnected ring-mains will be separated. Dedicated feeders will be installed to the different areas to reduce outages.

8.6.5 Environmental Policies

The municipal electricity undertaking is part of the local government, and therefore has a political component. Its policies regarding the environment must reflect the political leanings of the Town Council but at the same time it has a forum in the Council Chamber to influence political thought through debate.

A fact that has to be borne in mind is that each town councillor represents a section of ratepayers and considers himself to be responsible for that section. This means that nobody is specifically looking after the interests of consumers outside the municipal area.

It is therefore very important that the undertaking develops a policy which makes special provision for outside consumers.

The changing environment, particularly the rising aspirations of the black communities makes it imperative that the undertaking must make it its policy to continually investigate alternative methods of electrifying black townships and must frequently undertake responsible surveys in these communities to determine the feasibility of electrifying these townships as soon as possible.

CHAPTER NINE

CONCLUSION AND IMPLEMENTATION

9.1 CONCLUSION

It has been shown that the Municipal Electricity Undertaking is a business organization with unusually difficult managerial problems in all its functional areas. The main reasons for the problems in the various fields are :

Personnel The sparseness of the distribution network makes direct supervision and control very difficult. Job satisfaction for electricians can be very low since much of the work effort seems futile as there seldom appears to be any direct result.

The novelty of working on new projects tends to emphasize the dullness of routine maintenance which consequently reduces the self-esteem and status of maintenance crews, as compared to construction crews. Attention to maintenance can be adversely affected, and the morale of all employees is adversely affected if the reliability of the system is low.

Finance The capital cost of electrical equipment is very high, and there is therefore a tendency to reduce the initial capital cost by understating, or even ignoring the long term costs associated with equipment selection, such as maintenance costs, energy loses, possible premature obsolesence etc. Continual incorrect decisions of this nature can ultimately place very heavy financial burdens on the undertaking.

The determination of an equitable electricity tariff is very difficult, since electricity is not purchased for use in its existing form, but has to be converted by appliances for final use by the customer, be it heating, lighting, cooling, music, etc. A tariff is judged by consumers in relation to the useful output which they derive from their appliances, whereas the undertaking is attempting to give signals to the consumers via its pricing policies in terms of electrical units. This leads to confusion and makes electricity pricing difficult.

Customers There are several difficulties created by the consumption patterns of consumers. The behavioural response of domestic consumers to urbanised lifestyles, in which numerous daily activities such as breakfast, lunch, supper, scheduled T.V. times, bathtimes, etc, occur at almost identical times in all households, results in considerable overlapping of the instantaneous demands of the consumers. The short duration of the resulting peaks results in a very low utilization of the expensive reticulation equipment involved.

Continual improvements to labour saving devices tends to aggravate the situation as consumers continue to crowd more activities into the peak periods.

It has also been shown that the above problems are compounded by the fact that the undertaking is a monopoly, and is not driven by the motivating free-market forces, such as a profit motive and the constant need to improve to meet competition. There is thus no motive to seek the optimum solutions to the many problems.

It has been shown that **Load Management**, if correctly applied, can effectively replace the missing motivating free-market forces, and can provide the undertaking with an excellent basis on which co-ordinated policies in all its functional areas can be developed. The load factor, which is a measurement of the effectiveness of load management provides a suitable alternative to measurements of profitability. In striving to improve its monthly load factor many of the difficulties mentioned above can be resolved. By focusing attention to the main objective, which is to improve the load factor, sub-objectives can be developed in all parts of the organization. This will guide decision-making to seek optimum solutions, which will clearly be to the advantage of all consumers.

It has been shown that in the effort to improve the load factor, the system reliability must be improved and hence maintenance becomes a necessary and worthwhile pursuit. Similarly, long term energy losses will adversely affect the load factor and more care will be given to equipment selection.

Further, the need to improve the load factor requires detailed attention to be given to consumer needs, and to design the electricity tariff so that sufficient incentive exists to induce consumers to shift portion of their load out of the peak period.

It has also been shown that geyser-loads form a very large portion of the system peak load, and the control of these units can form a very important part of the load management system.

The benefit derived from a geyser control scheme depends entirely on the shape of the uncontrolled load curve, and hitherto, it was uncertain as to what the benefits would be in a particular system. The result was that some undertakings, spurred on by the successes achieved by other towns would install geyser control systems at considerable expense which resulted in minimal improvements to their load factors, while other towns, hesitant to repeat the same mistakes, forego the opportunity to save hundreds of thousands of rands in reduced demand charges from ESCOM. (See copy of letter from Motorola on next page)

A suitable method for determining the feasibility of geyser control for a given system, and for estimating the actual reduction in peak demand, is developed, and it is recommended that this should form the basis for the selection of suitable load management.

It was shown that a geyser control scheme is a very viable proposition for those undertakings where the feasibility study shows a contribution of more than 0,5 KVA per geyser toward peak load reduction.

Other forms of load management, such as off-peak tariffs, restricted period tariffs, 5% voltage reduction during peak periods, etc, should be investigated for those undertakings where the contribution is less than 0,5 KVA per geyser.

This forms the basic guidelines for the selection of an appropriate form of load mangement, and guidelines are presented to develop supporting policies in all fields of the undertaking's functions.

MOTOROLA ALCOM SYSTEMS (PTY) LIMITED

5 'HORA CRESCENT
W'NBERG, TVL
2018

39666 BRAMLEY 2018
786-8166/'887-0900
4-22070

mas/ak.
28th August 1984

Mr. C.J. Breytenbach
P O Box 18206
DALBRIDGE
4014

Attention Mr. Chris Breytenbach

Dear Sir

CENTRALISED CONTROL GEYSER LOAD MANAGEMENT SYSTEMS

We are leaders in the field of geyser load management, and our locally manufactured radio switches for geyser control have been installed by numerous municipalities and mines, including Randburg, Bedford View, Umtata, Soweto and President Steyn Gold Mine.

The difficulty in accurately predicting the response of an electrical network to geyser control has always made Municipalities hesitant to invest in geyser control equipment, and it is with considerable interest that we have learnt of your progress in this direction.

We are aware of the tests you have conducted which verify your method of calculation, and wish to offer you any assistance you may need for further field tests.

There will be definite benefits to the municipalities and to the manufacturers of the equipment as a result of your endeavours.

Yours faithfully,
MOTOROLA ALCOM SYSTEMS (PTY) LIMITED

M A SCALCO
Account Executive.

In order to facilitate correct decision-making and to assist in the development of comprehensive policies, a database of concepts and models is presented in the various fields and various misconceptions are discussed.

9.2 IMPLEMENTATION

Load management can make a considerable contribution to the improvement in productivity and job satisfaction of all employees of the undertaking, and even by itself, it can result in significant savings to the undertaking by reducing the ESCOM demand charges.

The application of the principles developed for the feasibility studies for geyser control systems, and the use of the guidelines for the development of supporting policies are demonstrated by the application of the principles to four municipal undertakings as illustrated in the following case studies, for Oudtshoorn, Tongaat, Stanger and Ballito.

9.3 CASE STUDIES

As stated in the topic heading of this thesis, and as indicated in the foregoing discussions, particular emphasis must be placed on load management, as it forms a very solid foundation on which all other sub-objectives and resulting policies can be developed.

For this reason the following case studies places particular emphasis on the selection of the form of load mangement, to indicate various aspects of the feasibility study and to demonstrate the application of the guidelines.

An indication is also given of the development of certain relevant policies to support load management. The more obvious policies which have been discussed elsewhere in this thesis, particularly in Chapter 8, and which are common to all the case studies will not be repeated here.

9.4 SUMMARY OF RESULTS OF CASE STUDIES

OUDTSHOORN MUNICIPALITY (Refer Paragraph 9.5)

Tenders had already been called for the installation of a remotely operated geyser control system for 4000 geysers. Tender prices were around R1-million. The author analysed the representative daily load curves and found that the average contribution per geyser toward peak load reduction was 0,28 KVA and that the installation would operate at a loss of around R17 200.00 per annum. Feasibility studies were done for various numbers of controlled geysers, and it was found that optimum results would be obtained for 1500 controlled geysers which would give a contribution of 0,62 KVA per geyser. The installation cost would be reduced by over R500 000.00, and the system would make a net operating profit of R105 540.00 per annum. The Town Electrical Engineer familiarized himself with the components of the feasibility study, and concurred with the findings. He recommended to his Town Council to adopt the reduced scheme. (See copy of letter on next page)

The result of this application of the guidelines was that it conceivably prevented the expenditure of R1-million on a control system which would have run at an operating loss, and made it possible to select the optimum number of geysers for a reduced scheme, which would be more economical to install, and which would operate at a profit.

9.8

DIE MUNISIPALITEIT THE MUNICIPALITY

Teleks
Telex 576110

Telefoon
Telephone 2221

Klagtes alle ure
Complaints all hours 2233

Posbus
P.O. Box 255

Rig alle korrespondensie
aan die Stadsklerk.

Address all correspondence
to the Town Clerk

OUDTSHOORN Electricity

VERW
REF. ED 1/86

CJG/am

BURGERSENTRUM
CIVIC CENTRE,
OUDTSHOORN
6620

1986-10-02

Mr C J Breytenbach
P O Box 18206
DALBRIDGE
4014

Dear Sir

GEYSER LOAD MANAGEMENT SYSTEM

Thank you for your letters and reports regarding the above.

Your efforts in this regard have saved this municipality a large sum of money. Our Electrical Engineer Mr R Millard studied your method of calculating the results for the geyser controll system and agreed with your calculation that the system would not be viable for the planned 4000 controll units.

We have therefore accepted your recommendation to reduce the number of controlled geysers to 1500.

We also wish to thank you for your assistance in adjucating the tenders for the project.

Yours faithfully

ELECTRICAL ENGINEER

SUMMARY 1

TONGAAT MUNICIPALITY (Refer Paragraph 9.6)

The feasibility study showed that an installation controlling 2100 geysers would result in a peak load reduction of 2100 KVA, which would result in a net annual savings of R282 000.00 in the first year, rising to R501 600.00 within 5 years. The estimated cost of the installation is R493 649.00. It was recommended that the system be installed and that the electricity tariffs be revised to give the consumers the benefit of the savings.

STANGER MUNICIPALITY (Refer Paragraph 9.7)

The present electricity tariff is based on a circuit breaker rating charge. This forces consumers to select 25 or 30 Amp circuit breakers which causes unnecessry inconvenience to the consumers while not improving the load curve.

A feasibility study was done on the Stanger load curve and it was found that an installation involving 2500 geysers would reduce the load peak by 2500 KVA, which would result in a net annual savings of R231 830.00 in the first year, rising to R444 230.00 within 5 years. the estimated cost of the installation is R498 500.00.

It was also recommended that the consumers circuit breakers be replaced by 60 Amp units, and that the tariff be revised to pass the savings on to the consumers.

The Stanger Town Council resolved to implement the above recommendations, as indicated in the copy of the letter on the next page.

MUNISIPALITEIT/BOROUGH OF
STANGER

MUNISIPALE KANTOOR REYNOLD STRAAT
MUNICIPAL OFFICES, REYNOLD STREET
POSBUS/P.O. BOX 72, STANGER 4450
TEL.: (0324) 23091

STANGER

Sy Edele/Dr./Ds./Mnr./Mev./Mej
The Hon/Dr./Rev./Mr./Mrs./Miss

Messrs Elliott, Breytenbach
& Gray
P O Box 18206
DALBRIDGE
4014

Ons Verw. /Our Ref. 5238/E15/05/86(AJG)
U Verw./Your Ref.

1986-08-06

Dear Sirs

APPOINTMENT AS CONSULTING ENGINEERS

You are hereby advised that my Council at its meeting held on 31 July 1986 resolved that you be appointed as its Consulting Engineers to undertake the design, planning, tender specification and overall supervision of the following Capital Project as a matter of urgency :

Load Management Control System.

Kindly contact Mr Milsom, Acting Borough Electrical and Mechanical Engineer, who will supply you with further information and details.

Yours faithfully

W T BYRNES
TOWN CLERK

AJG/kb

NP.

BALLITO (Refer Paragraph 9.8)

A feasibility study for geyser control was done on this Ballito Load Curve, using various numbers of geysers, and using various diversified geyser demands. The results indicated that the load curve is not completely suitable for remotely operated geyser control to reduce the load peak, and it was recommended that alternative forms of load mangement be investigated further, namely off-peak tariffs for pumping, restricted period maximum demand tariffs, incentive rebates for load shedding during the peak period etc.

CASE STUDY 1.

9.5 OUDTSHOORN MUNICIPALITY

Background

Motivated mainly by the successes achieved by other Municipalities using geyser load control the Oudtshoorn Electricity Department called for tenders for the supply of equipment for a system suitable for controlling 4000 geysers. Tenders closed in July 1986, and the tendered prices were around R1-million.

Based on the results achieved by other municipalities, notably Somerset West, and encouraged by optimistic assumptions made by the major suppliers of geyser control equipment, it seemed realistic to expect a savings of an average of around 3000 KVA per month for an installation involving 4000 controlled geysers. This would represent a gross savings in ESCOM demand charges of around R500 000.00 per annum.

The author contacted the Town Clerk immediately after tenders had been received, and offered to examine the daily load curves with a view to determining the feasibility of the system and to determine the optimum number of controlled geysers.

Representative daily load curves for the twelve months are shown in Fig 9.1-9.4. Feasibility studies were conducted on each load curve to determine the maximum possible reduction in peak demand using 4000 geysers while limiting the geyser off periods to around 2,5 hours. Typical worksheets are shown in Figs 9.5-9.9.

The instalments to repay capital and interest at the ruling rate was estimated to be R16 000.00 per month.

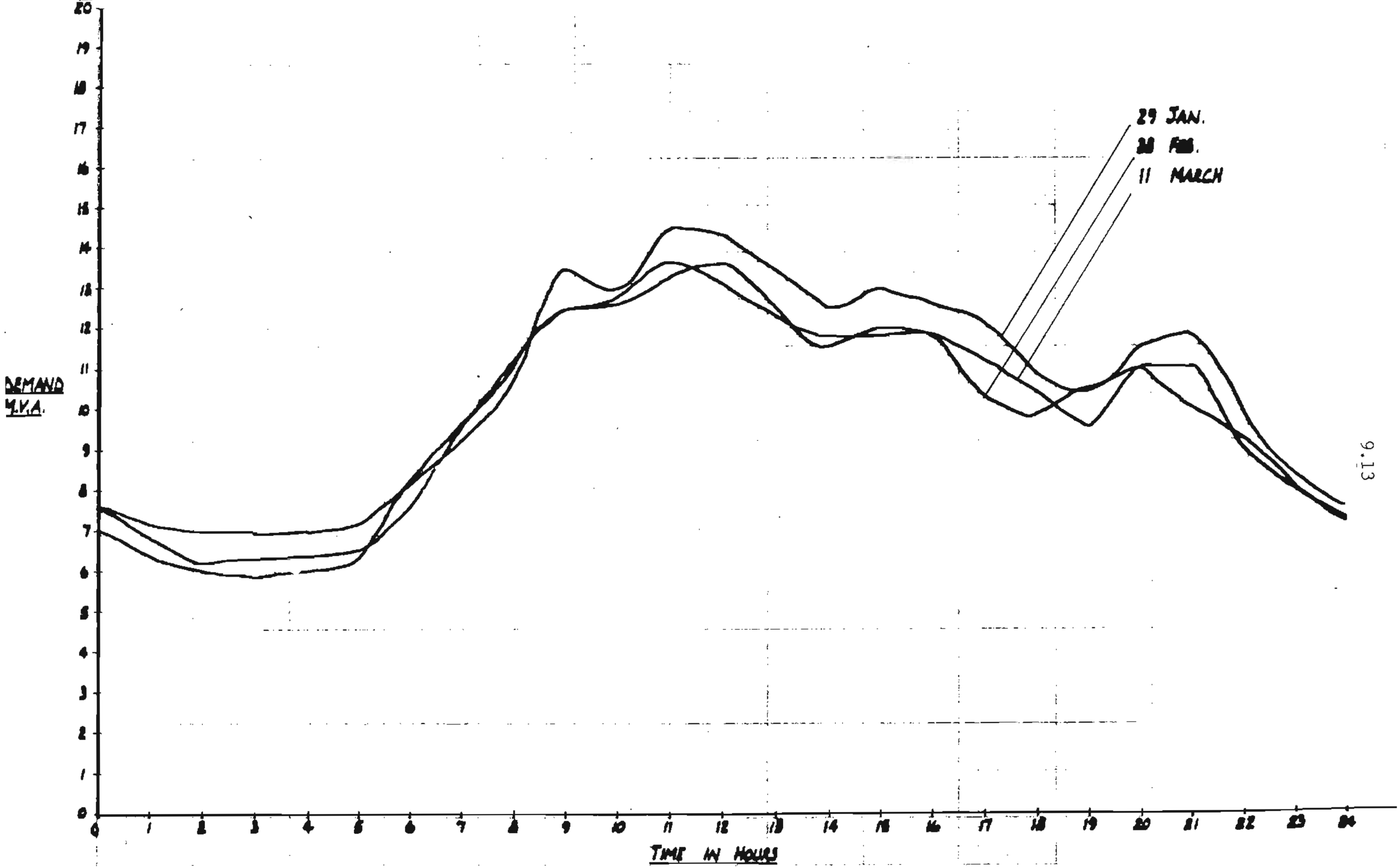

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FIG 9.1

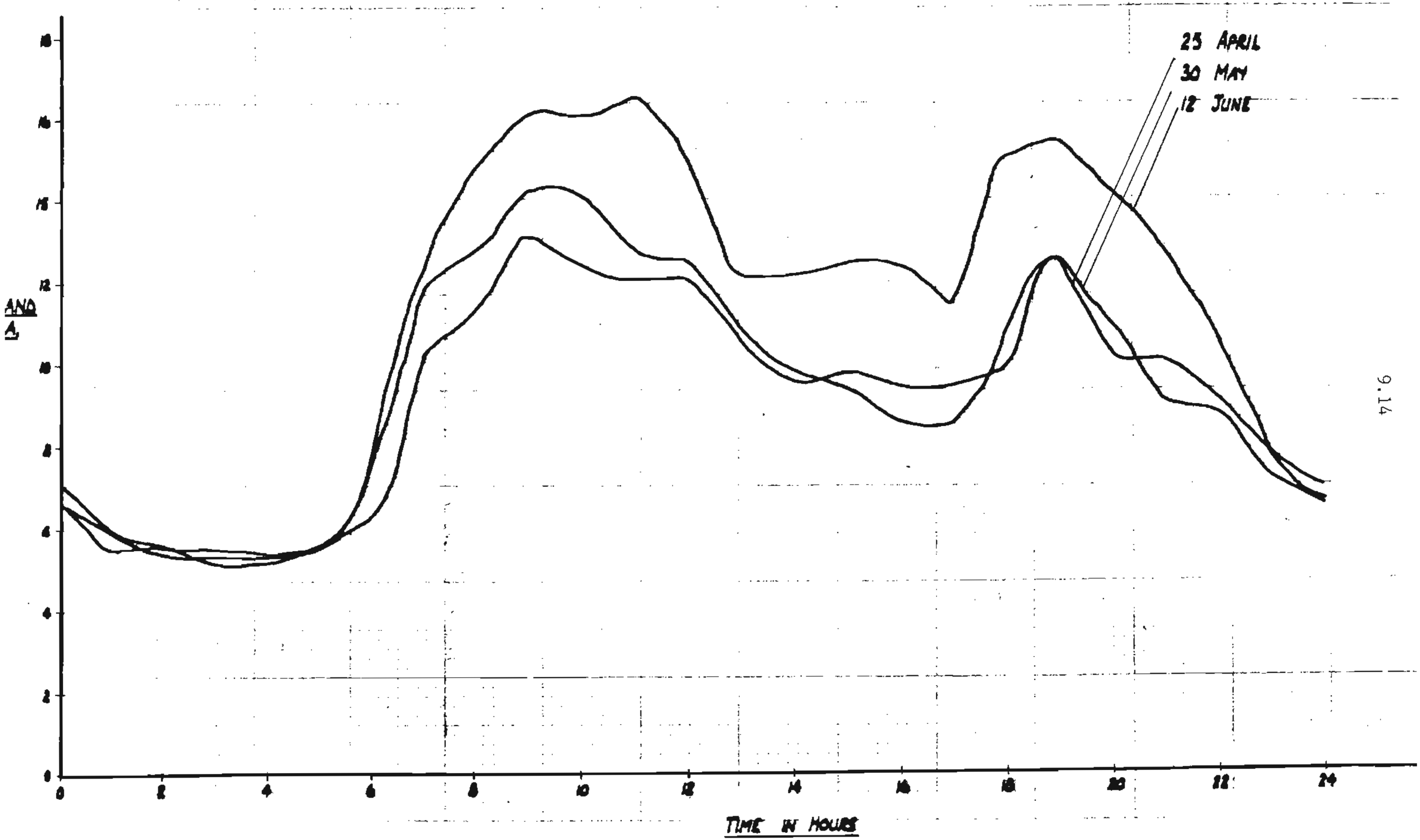
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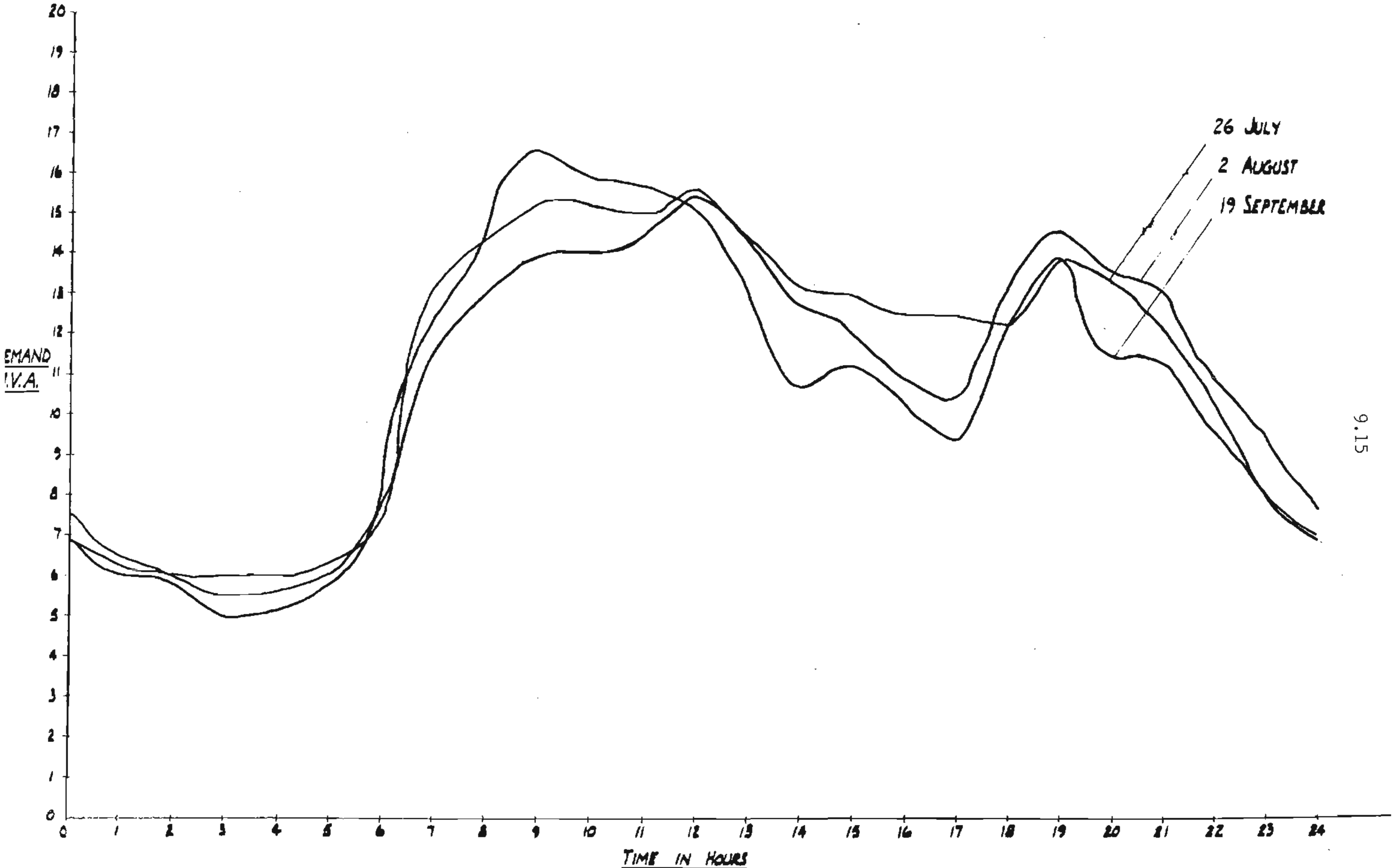
FIG 9.2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26 JULY
2 AUGUST
19 SEPTEMBER

FIG 9.3

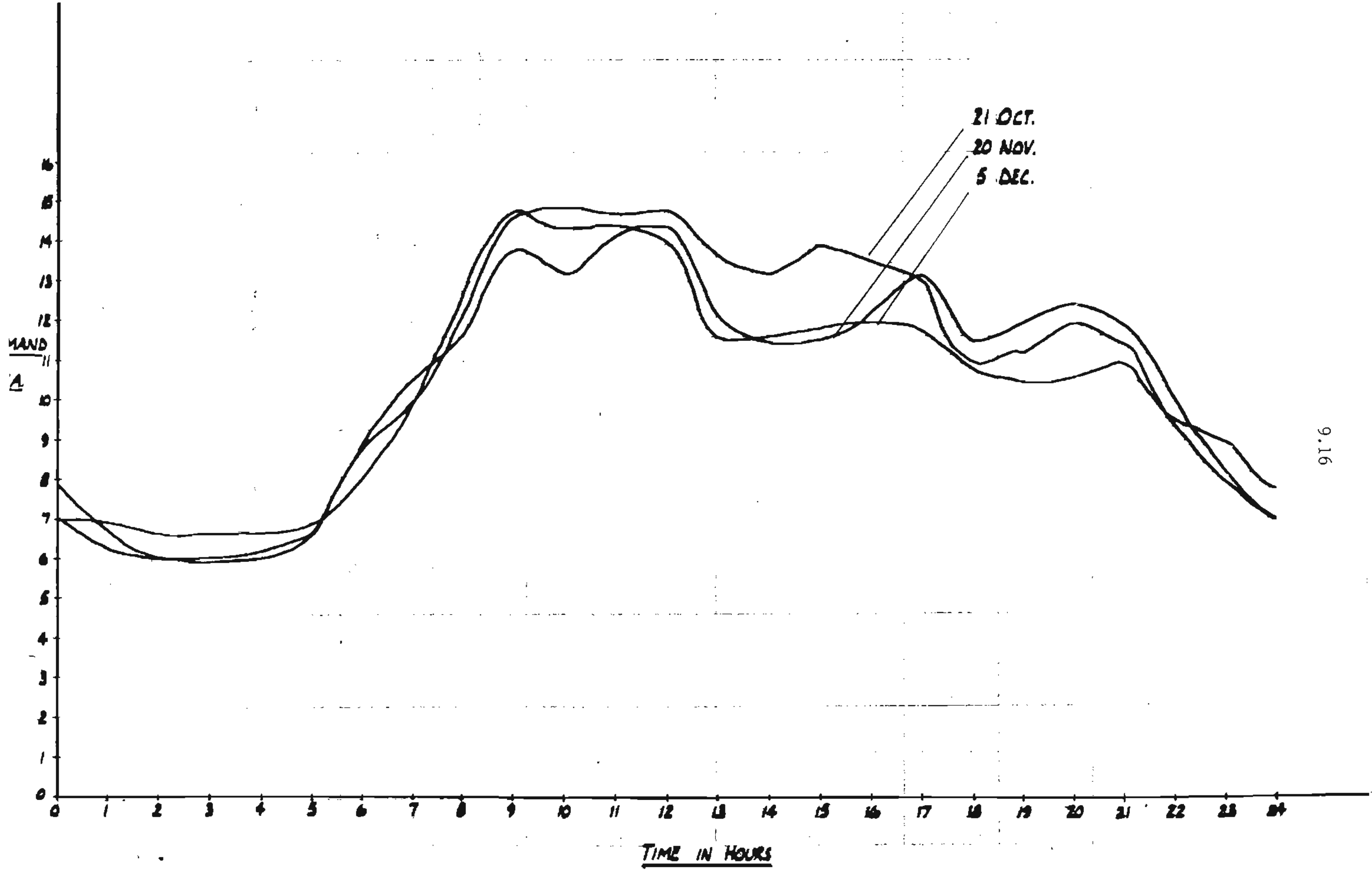

FIG 9.4 .

BOTTOM CURVE: 25 APRIL

AX DEMAND	10500	10900	11600	12750	13200	12500	12250
ARGET MD	12000	12000	12000	12000	12000	12000	12000
IFFERENCE	1500	1100	400	-750	-1200	-500	-250
EYSER kVA	.75	.75	1	1.25	1.5	1.5	1.5
o OF GEYSERS							
500	0	0	0	-625	500	-750	600
500	0	0	0	-625	500	-750	600
500	0	0	0	0	-750	600	-750
500	0	0	0	0	-750	600	-750
500	0	0	0	0	-750	600	-750
500	0	0	0	0	0	-750	600
500	0	0	0	0	0	-750	600
500	0	0	0	0	0	0	-750
	0	0	0	-1250	-1250	-1200	-600
FINAL MD	10500	10900	11600	11500	11950	11300	11650

4000	GEYSERS	
13200	EXIST MD	
12000	NEW MD	
1200	REDUCTION	.3 KVA/GEYSER

12250	12100	12000	12100	11750	11000	10250	9750
12000	12000	12000	12000	12000	12000	12000	12000
-250	-100	0	-100	250	1000	1750	2250
1.5	1.25	1	.75	.75	.75	.75	.75
600	-625	550	-375	-375	600	50	50
600	-625	550	-375	350	-375	350	0
-750	600	-500	500	-375	350	0	0
-750	600	-500	500	-375	350	0	0
-750	600	50	-375	350	-375	350	0
600	-625	550	-375	350	-375	350	0
600	-625	-500	750	-375	350	0	0
-750	600	-500	-375	625	100	0	0
-600	-100	-300	-125	175	625	1100	50
11650	12000	11700	11975	11925	11625	11350	9800

FIG 9.5

TOP CURVE: 21 OCTOBER

AX DEMAND	14500	14.30	14800	14800	14750	14750	14800
ARGET MD	14250	14250	14250	14250	14250	14250	14250
IFFERENCE	-250	-500	-550	-550	-500	-500	-550
EYSER kVA	.75	1	1.25	1.5	1.5	1.25	1
OF GEYSERS							
500	-375	-500	650	100	50	-625	-500
500	0	0	-625	500	-750	-625	850
500	0	0	-625	-750	850	200	100
500	0	0	0	-750	-750	900	250
500	0	0	0	0	0	-625	-500
500	0	0	0	0	0	0	-500
500	0	0	0	0	0	0	-500
500	0	0	0	0	0	0	0
	-375	-500	-600	-900	-600	-775	-800
INAL MD	14125	14250	14200	13900	14150	13975	14000

4000 GEYSERS
14800 EXIST MD
14250 NEW MD
550 REDUCTION .1375 KVA/GEYSER

14500	14000	13500	13250	13500	14000	13900	13750
14250	14250	14250	14250	14250	14250	14250	14250
-250	250	750	1000	750	250	350	500
.75	.75	.75	.75	.75	.75	.75	.75
750	150	50	-375	-375	600	50	50
200	100	50	-375	-375	600	50	50
50	-375	-375	600	50	50	-375	350
100	50	-375	-375	600	50	50	-375
-350	900	250	100	50	-375	350	-375
-375	-375	600	50	50	-375	350	-375
-375	-375	800	200	100	-375	-375	600
-350	-375	-375	750	150	50	-375	350
-350	-300	625	575	250	225	-275	275
14150	13700	14125	13825	13750	14225	13625	14025

FIG 9.6

TOP CURVE : 29 JANUARY

AX DEMAND	13250	14100	14500	14500	14200	13750	13250
ARGET MD	13500	13500	13500	13500	13500	13500	13500
IFFERENCE	250	-600	-1000	-1000	-700	-250	250
EYSER kVA	.75	1.25	1.5	1.5	1.5	1.25	1
O OF GEYSERS							
500	0	-625	-750	850	200	100	50
500	0	0	-750	-750	900	250	100
500	0	0	0	-750	-750	900	250
500	0	0	0	-750	-750	900	250
500	0	0	0	0	-750	-625	850
500	0	0	0	0	0	-625	-500
500	0	0	0	0	0	-625	-500
500	0	0	0	0	0	-625	-500
	0	-625	-1500	-1400	-1150	-350	0
INAL MD	13250	13475	13000	13100	13050	13400	13250

4000 GEYSERS
14500 EXIST MD
13475 NEW MD
1025 REDUCTION .25625 KVA/GEYSER

12750	12600	12800	12900	12750	12500	12300	11900
13500	13500	13500	13500	13500	13500	13500	13500
750	900	700	600	750	1000	1200	1600
.75	.75	.75	.75	.75	.75	.75	.75
0	-375	-375	600	50	50	0	0
50	-375	400	-375	350	0	0	0
100	-375	400	-375	-375	600	50	0
100	-375	-375	600	50	50	0	0
200	100	50	-375	350	0	0	0
-375	900	250	100	50	0	0	0
-375	900	250	100	50	0	0	0
750	150	50	0	0	0	0	0
450	550	650	275	525	700	50	0
13200	13150	13450	13175	13275	13200	12350	11900

FIG 9.7

TOP CURVE : 25 APRIL

AX DEMAND	14000	15000	15750	16200	16000	16000	16250
ARGET MD	15000	15000	15000	15000	15000	15000	15000
IFFERENCE	1000	0	-750	-1200	-1000	-1000	-1250
EYSER KVA	.75	.75	.75	1	1.25	1.5	1.5
O OF GEYSERS							
500	0	0	-375	350	-625	-750	850
500	0	0	-375	-500	650	100	50
500	0	0	0	-500	450	-750	-750
500	0	0	0	-500	450	-750	-750
500	0	0	0	0	-625	-750	850
500	0	0	0	-100	-625	750	0
500	0	0	0	0	-625	500	-750
500	0	0	0	0	-625	500	-750
	0	0	-750	-1250	-1575	-1150	-1250
FINAL MD	14000	15000	15000	14950	14425	14850	15000

4000 GEYSERS
16500 EXIST MD
15000 NEW MD
1500 REDUCTION .375 KVA/GEYSER

16500	15500	14000	12500	12200	12200	12250	2300
15000	15000	15000	15000	15000	15000	15000	15000
-1500	-500	1000	2500	2800	2800	2750	12700
1.5	1.25	1	.75	.75	.75	.75	.75
200	100	-500	450	0	0	0	0
50	-625	-500	750	150	50	0	0
900	250	100	50	0	0	0	0
-750	950	250	100	50	0	0	0
200	100	50	-375	350	0	0	0
-750	-625	-500	950	250	100	50	0
-750	-625	950	250	100	50	0	0
-750	-625	950	250	100	50	0	0
-1650	-1100	800	2425	1000	250	50	0
14850	14400	14800	14925	13200	12450	12300	2300

FIG 9.8

MIDDLE CURVE : 21 OCTOBER

AX DEMAND	12500	13500	14500	14750	14500	14400	14400
ARGET MD	14000	14000	14000	14000	14000	14000	14000
IFFERENCE	1500	500	-500	-750	-500	-400	-400
EYSER kVA	.75	1	1.25	1.5	1.5	1.25	1
o OF GEYSERS							
500	0	0	-625	-750	650	100	50
500	0	0	0	0	-750	-625	850
500	0	0	0	0	-750	-625	850
500	0	0	0	0	0	0	-500
500	0	0	0	0	0	0	-500
500	0	0	0	-450	-450	510	-500
500	0	0	0	0	0	0	-500
500	0	0	0	0	0	0	-500
	0	0	-625	-1200	-1300	-640	-750
INAL MD	12500	13500	13875	13550	13200	13760	13650

4000 GEYSERS
14750 EXIST MD
13875 NEW MD
875 REDUCTION .21875 KVA/GEYSER

14400	14250	13500	12000	11500	11600	11750	11800
14000	14000	14000	14000	14000	14000	14000	14000
-400	-250	500	2000	2500	2400	2250	2200
.75	.75	.75	.75	.75	.75	.75	.75
0	0	-375	350	0	0	0	0
200	100	50	0	0	0	0	0
200	100	-375	-375	600	50	50	0
-375	-375	750	150	50	0	0	0
-375	650	100	50	0	0	0	0
450	-375	-375	600	50	50	0	0
-375	-375	750	150	50	0	0	0
-375	-375	-375	750	150	50	0	0
-650	-650	150	1675	900	150	50	0
13750	13600	13650	13675	12400	11750	11800	11800

FIG 9.9

The load reductions as calculated on the worksheets are shown on Table 9.2 and are extended to determine the viability of the System. It can be seen that the proposed system incorporating 4000 controlled geysers will operate at a loss of R17 205.00 per annum.

The calculations were repeated for various numbers of controlled geysers, ranging from 500 to 4000 as shown in the typical worksheets in Fig 9.10 to Fig 9.15 and the following results were obtained :

	Contribution per Geyser	
No. of Controlled Geysers	Cold Months	Hot Month
500 geysers	1,14 KVA	0,92 KVA
1000 geysers	0,98 KVA	0,69 KVA
2000 geysers	0,80 KVA	0,38 KVA
3000 geysers	0,53 KVA	0,25 KVA
4000 geysers	0,31 KVA	0,22 KVA

Table showing Contribution to the Reduction in the Peak Load for various numbers of controlled geysers.

TABLE 9.1

SCHEDULE 1

TABLE OF RESULTS

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Max Demand KVA	14500	13700	13700	13200	16500	14300	17000	16000	13375	14800	14750	14500
Controlled Demand	13475	12600	12550	12000	15000	12900	15500	14600	12235	14250	14000	13800
Reduction KVA	1025	1100	1150	1200	1500	1400	1500	1400	1140	550	750	750
Savings @R13.00	13325	14300	14950	15600	19500	18200	19500	18200	14820	7150	9750	9100
Repayments R	16000	16000	16000	16000	16000	16000	16000	16000	16000	16000	16000	16000
Profit (Loss) R	(2675)	(1700)	(1050)	(400)	3500	2200	3500	2200	(1180)	(8850)	(6250)	(6900)

Total Loss for year. R17,205.00

Average Contribution : 0,28 KVA/geyser

SCHEDULE 2

PROJECTED RESULTS IF ESCOM INCREASES KVA CHARGES BY 10% P.A.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Savings on 13445 KVA	174795	192274	211501	232652	255917	281509	309660	340626	374688	412159
Less Repayments R	192000	192000	192000	192000	192000	192000	192000	192000	192000	192000
Annual Results R	(17205)	274	19501	40652	63917	89509	117660	148686	182688	220495

TABLE OF RESULTS

TABLE 9.2

MD	12500	13500	14500	14750	14500	14400	14400
T	14250	14250	14250	14250	14250	14250	14250
RENC	1750	750	-250	-500	-250	-150	-150
EYSE /SERS	1	1.25	1.5	1.5	1.5	1.25	1
100	0	0	-150	-150	180	50	20
100	0	0	-150	-150	-150	190	50
100	0	0	0	-150	-150	-125	-100
100	0	0	0	-150	-150	-125	-100
100	0	0	0	0	-150	-125	-100
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
	0	0	-300	-600	-420	-135	-230
	12500	13500	14200	14150	14080	14265	14170

500 GEYSERS
4750 EXIST MD
4290 NEW MD
460 REDUCTION .92 KVA/GEYSER

4400	14250	13500	12000	11500	11600
4250	14250	14250	14250	14250	14250
-150	0	750	2250	2750	2650
.75	.75	.75	.75	.75	.75
-75	-75	120	10	10	0
-75	-75	120	10	10	0
-75	190	50	20	10	0
190	50	20	10	0	0
-75	-75	190	50	20	10
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
-110	15	500	100	50	10
4290	14265	14000	12100	11550	11610

FEASIBILITY STUDY : MIDDLE CURVE 20 NOV

FIG 9.10

EXIST MD	12500	13500	14500	14750	14500	14400	14400
TARGET	13950	13950	13950	13950	13950	13950	13950
DIFFERENC	1450	450	-550	-800	-550	-450	-450
KVA/GEYSE	1	1.25	1.5	1.5	1.5	1.25	1
GEYSERS							
200	0	0	-300	-300	380	-250	-200
200	0	0	-300	-300	-300	380	100
200	0	0	0	-300	-300	-250	-200
200	0	0	0	0	-300	-250	-200
200	0	0	0	0	-300	-250	-200
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
	0	0	-600	-900	-820	-620	-700
	12500	13500	13900	13850	13680	13780	13700

1000 GEYSERS
14750 EXIST MD
14060 NEW MD
690 REDUCTION .69 KVA/GEYSER

14400	14250	13500	12000	11500	11600	11750
13950	13950	13950	13950	13950	13950	13950
-450	-300	450	1950	2450	2350	2200
.75	.75	.75	.75	.75	.75	.75
-150	-150	-150	380	100	50	0
-150	-150	-150	380	100	50	0
-150	380	100	50	20	0	0
-150	-150	380	100	50	0	0
-150	-150	380	100	20	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
-750	-220	560	1010	290	100	0
13650	14030	14060	13010	11790	11700	11750

FEASIBILITY STUDY : MIDDLE CURVE 20 NOV

FIG 9.11

EXIST MD	12500	13500	14500	14750	14500	14400	14400
TARGET	13650	13650	13650	13650	13650	13650	13650
DIFFERENC	1150	150	-850	-1100	-850	-750	-750
KVA/GEYSE	1	1.25	1.5	1.5	1.5	1.25	1
GEYSERS							
375	0	0	-562	-562	712	188	75
375	0	0	-562	-562	712	188	75
375	0	0	0	0	-562	-468	637
375	0	0	0	0	-562	-468	-375
375	0	0	0	0	-562	-468	-375
375	0	0	0	0	-562	450	-375
375	0	0	0	0	-562	-468	-375
0	0	0	0	0	0	0	0
	0	0	-1124	-1124	-1386	-1046	-713
	12500	13500	13376	13626	13114	13354	13687

2625 GEYSERS
14750 EXIST MD
13857 NEW MD
893 REDUCTION .3401905 KVA/GEYSER

14400	14250	13500	12000	11500	11600	11750
13650	13650	13650	13650	13650	13650	13650
-750	-600	150	1650	2150	2050	1900
.75	.75	.75	.75	.75	.75	.75
-281	-281	-281	638	150	75	37
-281	-281	-281	638	150	75	37
150	-281	-281	-281	562	112	37
712	-281	460	75	37	0	0
-281	-281	712	188	75	37	0
-281	-281	-281	712	188	75	37
-281	712	188	-281	500	188	75
0	0	0	0	0	0	0
-543	-974	236	1689	1662	562	223
13857	13276	13736	13689	13162	12162	11973

FEASIBILTY STUDY : MIDDLE CURVE 20 NOV

FIG 9.12

Y DEMAND	10500	10900	11600	12750	13200	13300	12250
RGET MD	12700	12700	12700	12700	12700	12700	12700
FFERENCE	2200	1800	1100	-50	-500	200	450
YSER KVA	.75	1	1.25	1.5	1.5	1.5	1.25
OF GEYSERS							
100	0	0	0	-150	-150	190	50
100	0	0	0	0	-150	120	10
100	0	0	0	0	-150	120	10
100	0	0	0	0	-150	-150	180
100	0	0	0	0	0	-150	120
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
	0	0	0	-150	-600	130	370
FINAL MD	10500	10900	11600	12600	12600	12630	12620

500 GEYSERS
13200 EXIST MD
12630 NEW MD
570 REDUCTION 1.14 KVA/GEYSER

12100	12000	12100	11750	11000	10250	9750	0
12700	12700	12700	12700	12700	12700	12700	12700
600	700	600	950	1700	2450	2950	12700
1	.75	.75	.75	.75	.75	.75	.75
20	10	0	0	0	0	0	0
0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
10	10	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
40	20	0	0	0	0	0	0
12140	12020	12100	11750	11000	10250	9750	0

FEASIBILITY STUDY : BOTTOM CURVE 25 APRIL 30 MAY 12 JUNE

FIG 9.13

EXIST MD	10500	10900	11600	12750	13200	12500	12250
TARGET	12200	12200	12200	12200	12200	12200	12200
DIFFERENC	1700	1300	600	-550	-1000	-300	-50
KVA/GEYSE	.75	1	1.25	1.5	1.5	1.5	1.25
GEYSERS							
200	0	0	0	-300	-300	360	100
200	0	0	0	-300	-300	-300	[illegible]
200	0	0	0	0	-300	-300	-250
200	0	0	0	0	-300	-300	-250
200	0	0	0	0	0	-300	-250
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
	0	0	0	-600	-1200	-840	-270
	10500	10900	11600	12150	12000	11660	11980

1000 GEYSERS
13200 EXIST MD
12220 NEW MD
980 REDUCTION .98 KVA/GEYSER

EXIST MD	10500	10900	11600	12750	13200	12500	12250
TARGET	11600	11600	11600	11600	11600	11600	11600
DIFFERENC	1100	700	0	-1150	-1600	-900	-650
KVA/GEYSE	.75	1	1.25	1.5	1.5	1.5	1.25
GEYSERS							
250	0	0	0	-375	-375	450	125
250	0	0	0	-375	-375	450	125
250	0	0	0	-375	-375	-375	475
250	0	0	0	-375	-375	-375	-312
250	0	0	0	0	-375	-375	-312
250	0	0	0	0	0	-375	-312
250	0	0	0	0	0	-375	-312
250	0	0	0	0	0	-375	-312
	0	0	0	-1500	-1875	-1350	-835
	10500	10900	11600	11250	11325	11150	11415

2000 GEYSERS
13200 EXIST MD
11600 NEW MD
1600 REDUCTION .8 KVA/GEYSER

FEASIBILTY STUDY : BOTOM CURVE 25 APRIL 30 MAY 12 JUNE

FIG 9.14

EXIST MD	10500	10900	11600	12750	13200	12500	12250
TARGET	12000	12000	12000	12000	12000	12000	12000
DIFFERENC	1500	1100	400	-750	-1200	-500	-250
KVA/GEYSE	.75	.75	1	1.25	1.5	1.5	1.5
GEYSERS							
500	0	0	0	-625	500	-750	600
500	0	0	0	-625	500	-750	600
500	0	0	0	0	-750	600	-750
500	0	0	0	0	-750	600	-750
500	0	0	0	0	-750	600	-750
500	0	0	0	0	0	-750	600
500	0	0	0	0	0	-750	600
500	0	0	0	0	0	0	-750
	0	0	0	-1250	-1250	-1200	-600
	10500	10900	11600	11500	11950	11300	11650

4000	GEYSERS	
13200	EXIST MD	
12000	NEW MD	
1200	REDUCTION	.3 KVA/GEYSER

12250	12100	12000	12100	11750	11000	10250	9750
12000	12000	12000	12000	12000	12000	12000	12000
-250	-100	0	-100	250	1000	1750	2250
1.5	1.25	1	.75	.75	.75	.75	.75
600	-625	550	-375	-375	600	50	50
600	-625	550	-375	350	-375	350	0
-750	600	-500	500	-375	350	0	0
-750	600	-500	500	-375	350	0	0
-750	600	50	-375	350	-375	350	0
600	-625	550	-375	350	-375	350	0
600	-625	-500	750	-375	350	0	0
-750	600	-500	-375	625	100	0	0
-600	-100	-300	-125	175	625	1100	50
11650	12000	11700	11925	11925	11625	11350	9900

<u>**FEASBILITY STUDY : BOTTOM CURVE 25 APRIL 30 MAY 12 JUNE**</u>

<u>FIG 9.15</u>

A careful study of the 12 monthly load curves reveals that there are more hot, dry and mild months in the year, and if one assumes that 8 months are "mild to hot", and 4 months are "cool to cold", then one can obtain the average annual functional curve as indicated on Figure 9.16.

From this functional curve the average monthly savings in peak demand can be calculated for various numbers of controlled geysers by simply multiplying the number of controlled geysers by the average contribution for that number. This result is shown graphically in Figure 9.17.

As shown in figure 9.17 it can be seen from the information available and the resulting calculations, that the Oudtshoorn reticulation system saturates at around 1500 controlled geysers, and any further increase in controlled geysers has negligible effect on overal annual savings.

There is no doubt, when studying the load curves for 12 months, that there are more hot, dry and mild months than cold and wet months. Clearly this may change from year to year, but to reduce the risk of capital investment to a minimum, and to maximize profits, it is preferable to use this bias.

It is clear from figure 9.16 and 9.17 that the hot-month curve levels off very rapidly after about 1500 geysers, and it was strongly recommend that this installation be designed initially for 1500 controlled geysers. Once these 1500 geysers are operational, the profitable returns on investment are virtually guaranteed, and extensive real-time tests can be performed on the operational system to determine whether a further 200, or 500, or 1000 geysers could improve the financial gains.

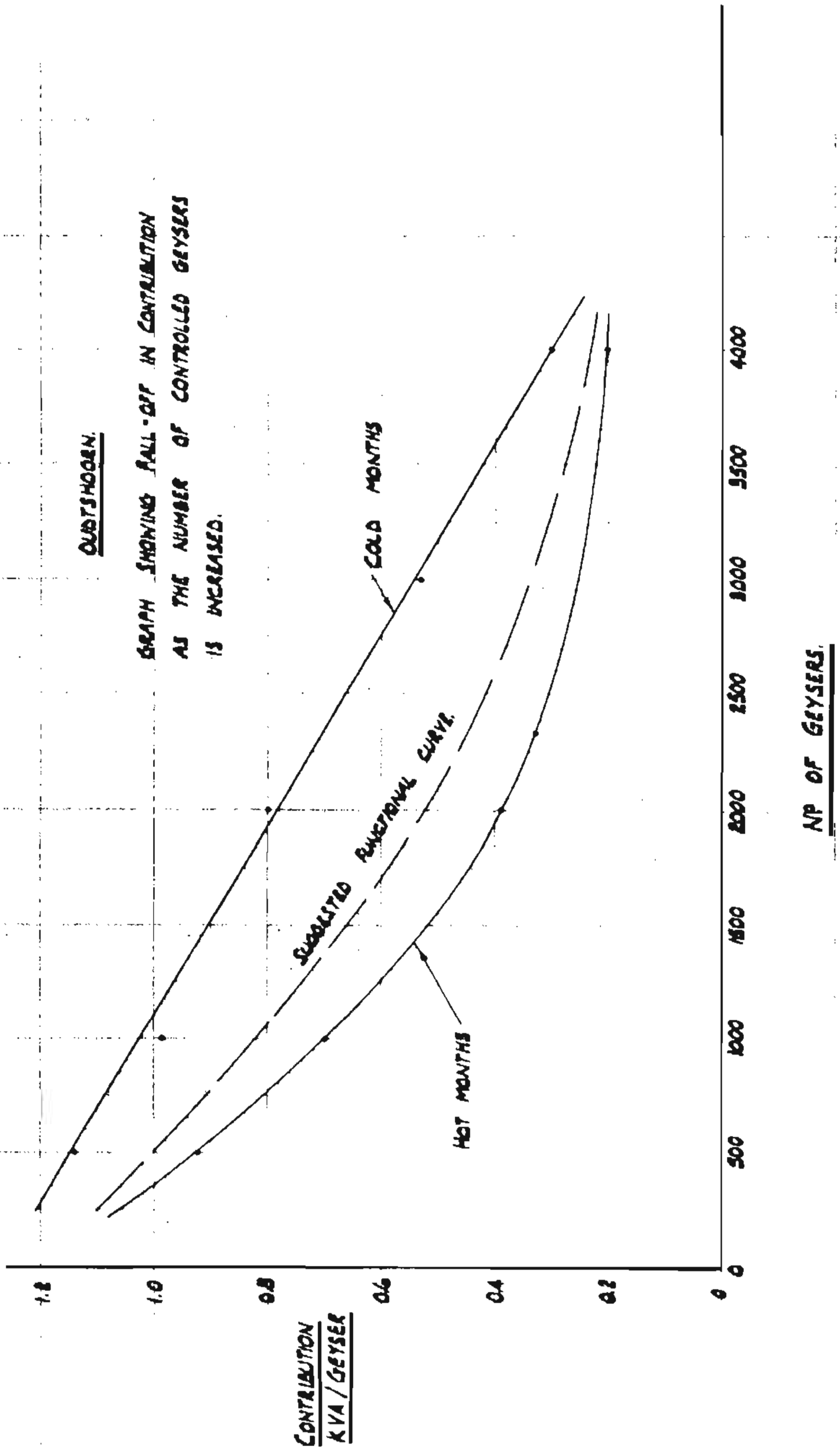
OUDTSHOORN.
GRAPH SHOWING FALL-OFF IN CONTRIBUTION AS THE NUMBER OF CONTROLLED GEYSERS IS INCREASED.
COLD MONTHS
SUGGESTED FUNCTIONAL CURVE
HOT MONTHS
CONTRIBUTION KVA/GEYSER
No OF GEYSERS
0
500
1000
1500
2000
2500
3000
3500
4000
0.2
0.4
0.6
0.8
1.0
1.2

FIG 9.16

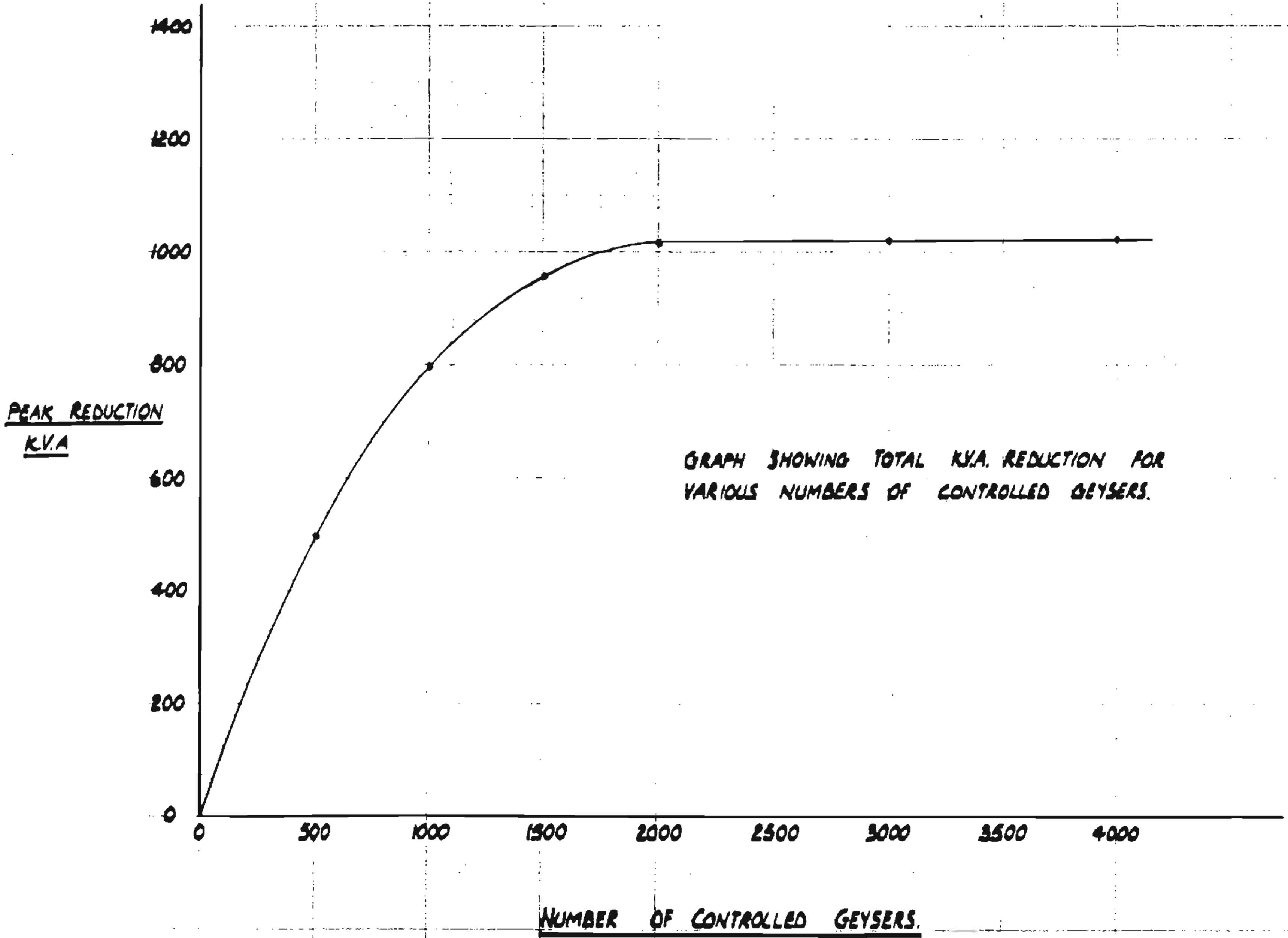
1400
1200
1000
800
600
400
200
0
PEAK REDUCTION
K.V.A
GRAPH SHOWING TOTAL K.V.A. REDUCTION FOR
VARIOUS NUMBERS OF CONTROLLED GEYSERS.
0
500
1000
1500
2000
2500
3000
3500
4000
NUMBER OF CONTROLLED GEYSERS.

FIG 9.17

It must be remembered that additional geyser control units can be installed at any stage, even immediately following the initial installation of the first 1500 control units, but it is almost impossible to pull back from an over-saturated situation.

The financial implications of a control system for 1500 geyser control units will be roughly as follows :

Estimated Capital expenditure for 1500 control unit system

a)	Telemetary equipment from main intake substation to central Control room. This allows for wide coverage of various circuits, display units in control room, status reports from main sub etc.	R43,044.00
b)	Main Control room equipment, including fully extended computer (HP 98580 Series 300 or similar), 12" video display unit, Standard keyboard printer, 1 megabyte RAM card, Data intercommunication unit, General purpose interfaces, Dual disk drives, system software, Interface to Base transmitter and 25 to 100 watt base station transmitter for 92% coverage over 400 km^2 area.	R93,205.00
c)	Installation, commissioning and testing of 1500 geyser control relays.	R255,285.00
	Total Cost :	R391,534.00

The above equipment is overdesigned for the initial installation of 1500 controlled units, but will allow for systematic upgrading for a system controlling over 7000 units over the next 15 years.

The instalments to repay capital with interest at 15% over the next 20 years on the capital sum of R391,534.00, is R5,155.00 per month.

Estimated Peak Load Reduction.

From figure 9.16 and figure 9.17 the estimated peak load reduction for 1500 geyser units can be calculated as follows :

Assume 8 months contribution of 0,58 KVA / geyser

Assume 4 months contribution of 0,7 KVA / geyser

The average monthly contribution to be expected will therefore be:

$$\text{Average contribution} = \frac{(8 \times 0{,}58) + (4 \times 0{,}7)}{12}$$

$$= 0{,}62 \text{ KVA per geyser}$$

Reduction for 1500 geysers : 930 KVA

Assuming that ESCOM increases its demand tariff by 10% per annum over the next 8 years we then have :

	1987	1988	1989	1990	1991	1992	1993	1994
ESCOM Cost per KVA	15.00	16.50	18.15	19.96	21.96	24.15	26.57	29.23
Savings on 930 KVA	13950	15345	16879	18567	20424	22466	24713	27184
Less : Monthly repayments on Capital	5155	5155	5155	5155	5155	5155	5155	5155
Net Monthly Savings	8795	10190	11724	13412	15269	17311	19558	22029
Net annual Savings	105540	121308	140688	160944	183228	207732	234496	264348

Interpretation of Viability Study

1. The above study shows that an installation of 1500 control units is immediately profitable and does not depend on ESCOM increases to make it profitable. Hence there is no risk involved.

2. The off-time required for 1500 geysers is very short, being around one to one and half hours which is perfect, and will never result in cold water complaints.

3. With moderate increases in ESCOM tariffs, the total capital of R391,534.00 can be fully repaid within 3,5 years, which completely eliminates any risk due to load curve changes, ESCOM tariff changes etc.

4. Less than 50% of available geysers are to be controlled. This means bigger and better geysers can be selected, and only easier installations can be selected.

5. The resulting short geyser-off periods and the resulting financial rewards will create an acceptable atmosphere, on which future load management improvements can be developed.

CASE STUDY 2

9.6 TONGAAT MUNICIPALITY

An examination of the load curves taken at various times over the past three years for Tongaat revealed that the load curve had remained unchanged, and it was decided to examine the feasibility of peak load reduction by means of a remotely operated geyser control system.

The procedure adopted, and the results obtained, were as follows.

Daily Load Curve

The load curves were monitored over a one week period to determine the extent of daily variation and the results are shown graphically in Fig 9.18 It will be seen that the load peak is extremely sharp and occurs over a very short period of about 3 hours. This type of load formation is excellent for the proposed geyser control system. A representative daily load curve taken in July 1986 is shown in Fig 9.19.

Seasonal Changes

An examination of the monthly demand records reveals the following maximum demands :

July 85 (Winter) : 21360 KVA

Oct 85 (Spring) : 21980 KVA

Jan 86 (Summer) : 20890 KVA

April 86(Autumn) : 27600 KVA

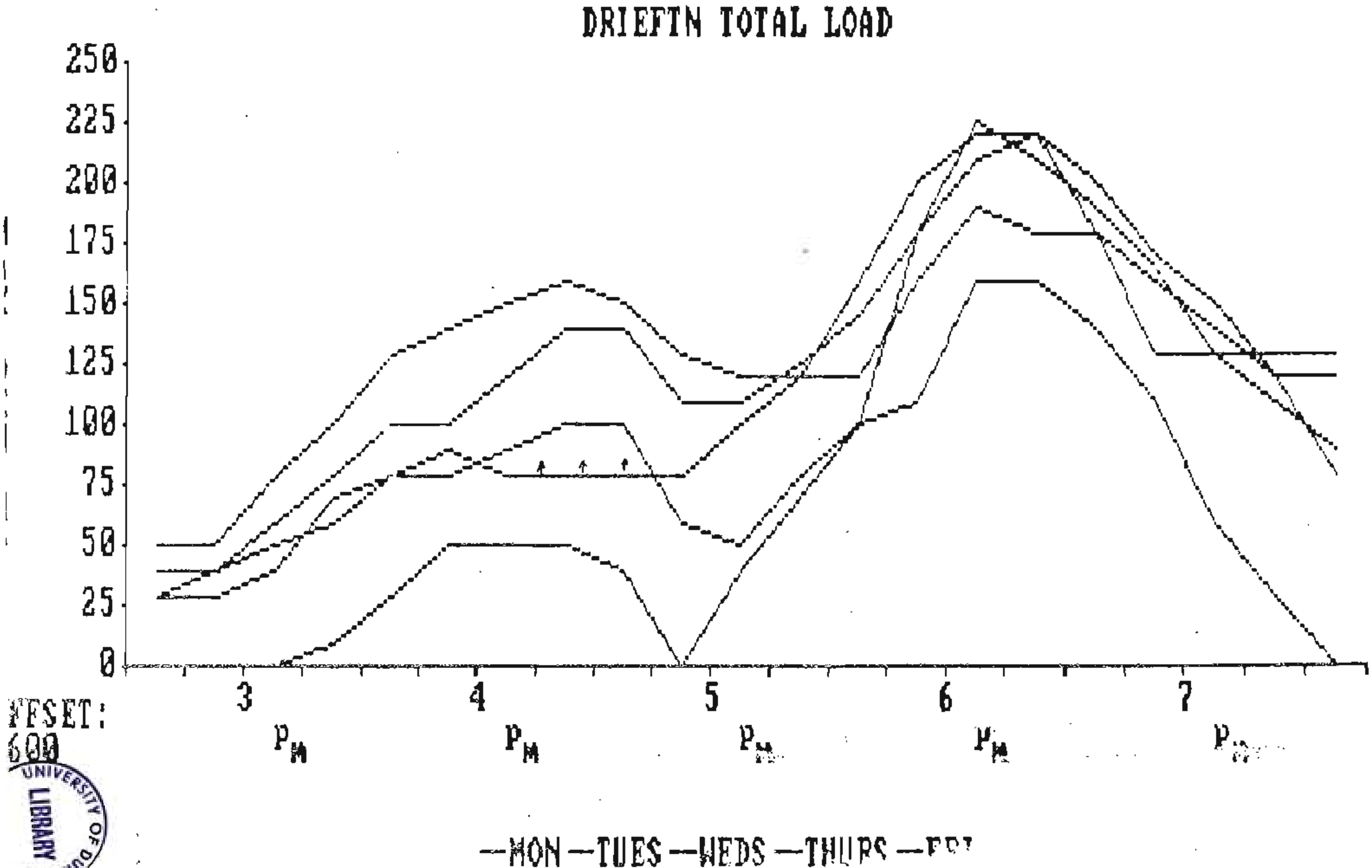
DRIEFIN TOTAL LOAD
250
225
200
175
150
125
100
75
50
25
0
3 PM
4 PM
5 PM
6 PM
7 PM
FFSET:
600
—MON —TUES —WEDS —THURS —FRI

FIG 9.18

9.38

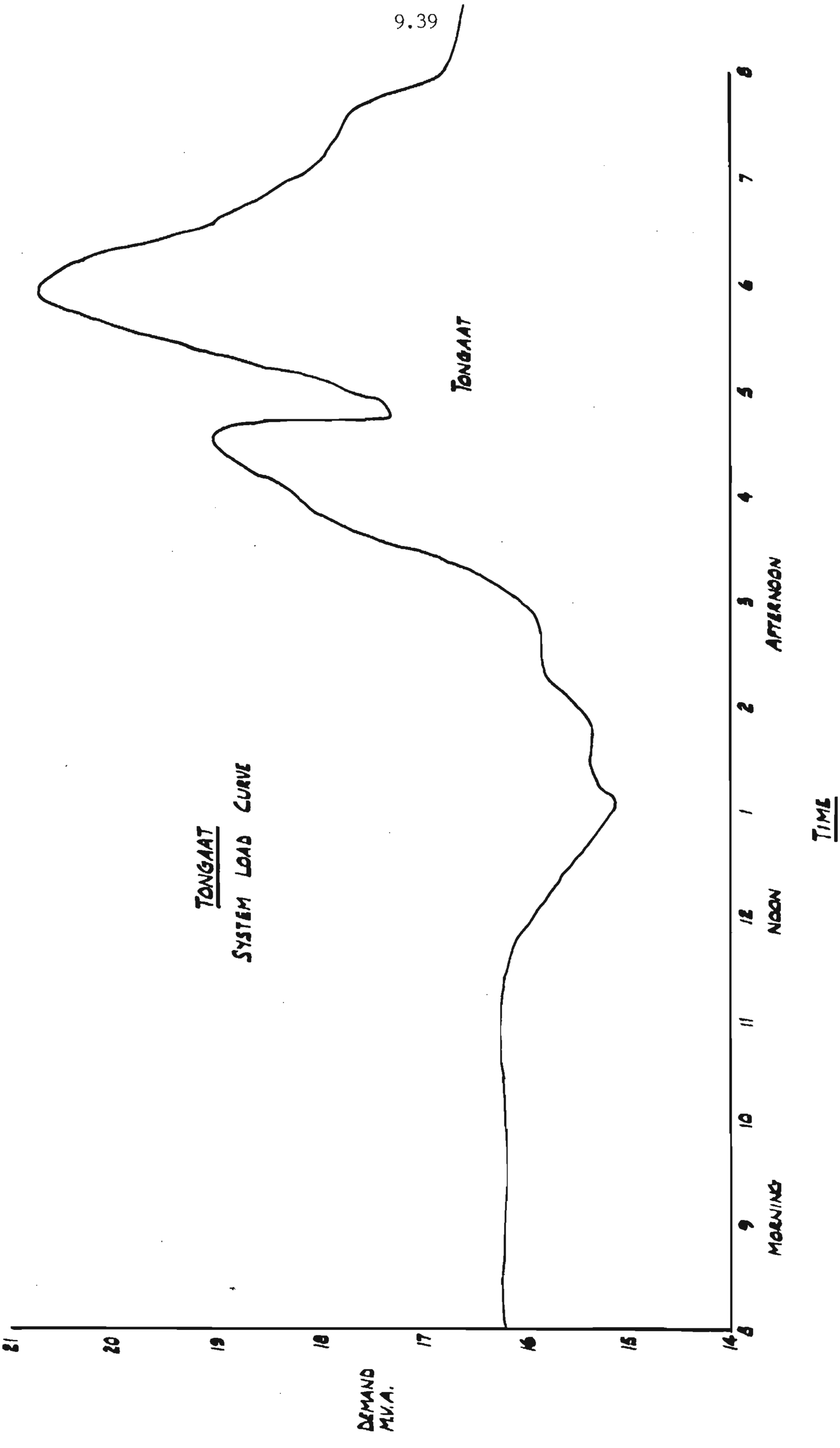
TONGAAT
SYSTEM LOAD CURVE
TONGAAT
DEMAND
M.V.A.
14
15
16
17
18
19
20
21
8
9
MORNING
10
11
12
NOON
1
2
3
AFTERNOON
4
5
6
7
8
TIME

FIG 9.19

It can be seen that the usual large differences between summer and winter demands is absent in Tongaat, due to the mild climatic conditions. The additional load taken by the Tongaat Sugar Mill in April 1986 is measured separately and recovered directly from them.

It can therefore be concluded that the daily load curve taken in July 1986 is representative for the entire year.

Number of geysers in Tongaat

Investigations carried out by the Tongaat Electricity Department revealed that there is a total of 4894 domestic consumers in Tongaat, of which 2582 consumers have geysers.

Optimum number of controlled geysers

Feasibility studies were done for various numbers of controlled geysers ranging from 750 to 2500. The calculations showed that 2100 geysers will result in the optimum predictable savings at this stage. Final tests can be carried out on the completed system ultimately to determine the final requirements.

The calculation showing the response of 2100 controlled geysers is shown in Fig 9.20, and it indicates an excellent return of 1 KVA per controlled geyser, with off-periods of 1 to 1,5 hours which is extemely good.

System Description

The main intake substation for Tongaat Township is Driefontein Substation, which is approximately 12km from Tongaat, and is unmanned.

Water-Heater Load Control

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Interval	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Time	3.45	4.15	4.45	5.15	5.45	6.15	6.45	7.15	7.45	8.15	8.45	9.15	9.45	10.15	10.45	11.15
Row 1	System M.D.	18000	18500	18500	19000	20600	20000	18700	17800	17300	16800	16800	16500	16500	16500		
Row 2	Target M.D.	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600	18600		
Row 3	Change Reqd.	–	–	–	-400	-2000	-1400	-100	+800	+1300	+1800	+1800	+2100				
Row 4	Diversified Geyser Demand	.75	1	1.25	1.5	1.5	1.5	1.25	1	.75	.75	.75	.75				
Row 5 Group A	300				-450	-450	+540	+150	-300	-225	+480	+60	+30				
Row 5 Group B	300					-450	-450	+540	+150	+60	+30	–	–				
Row 5 Group C	300					-450	-450	+540	+150	+60	+30	–	–				
Row 5 Group D	300					-450	-450	-375	+660	+240	+90	+60	–				
Row 5 Group E	300					-450	-450	-375	+660	+240	+90	+60	–				
Row 5 Group F	300						-450	-375	-300	+630	+210	+90	30				
Row 5 Group G	300							-375	-300	-225	+540	+150	60	30			
Row 5 Group H	—																
ow 6	Total Change				-450	-2250	+710	-270	+720	+780	+1470	+420	+120	+30			
ow 7	Final M.D.	18000	18500	18500	18550	18350	18290	18430	18520	18080	18270	17220	16620	16530			

SYSTEM M.D. : 20 600 KVA
CONTROLLED M.D. : 18 550 KVA
REDUCTION : 2 050 KVA

NO. OF GEYSERS 2100
CONTRIBUTION : 1 KVA/GEYSER

FIG. 9.20

The total load demand has to be measured here continuously for input into the programmable controller.

The programmable controller should preferably be at a manned central control room, adjacent to the Town Electrical Engineer's office.

Hence the information must be transmitted from Driefontein substation to the Central Control Room.

The programmable controller will interpret the changes in the actual KVA demand and will select a suitable programme, to determine the groups of geysers which are to be switched off. Within the predetermined time these groups of geysers are switched back on and other groups are switched off to control the total demand.

The Tongaat electricity reticulation system incorporates three widely spaced step-down susbtations, these being Maidstone, Tongaat and Trurolands. There is no advantage to be gained by attempting to inject ripple signals into the neutral circuits at these substations as it will require the information from the programmable controller to be transmitted to the signal injectors at these substations, whereas the same base transmitter could directly activate the geyser control switches with far greater flexibility.

Estimated cost of complete installation

The estimated cost of the complete installation is described in detail in the priced schedules which also indicate the various alternatives which are available. The most flexible system (which has numerous additional features) and the least expensive possible system (which has severe limitations) are summarised below :

	Most Flexible System	Least Flexible System
	R	R
Telemetary from Driefontein	43 044.00	11 740.00
Main Control Centre and Base Station	93 205.00	52 615.00
2100 geyser control Units	357 400.00	357 400.00
	493 649.00	421 755.00
Monthly instalments to repay capital with interest at 15% over 20 years	R6,500.00	R5,544.00

It was recommended that the most expensive system be accepted for the following reasons :

a) It permits a variety of useful information to be displayed continuously at the Central Control Room, which improves supervision and control of the entire electricity department.

b) The software is flexible and can readily be adapted to achieve maximum possible savings from the system.

c) It can readily be modified and extended over the next 10 to 15 years to take into account any changes in the load pattern of the town improvements in water heating technology and improvements in load management.

The cost of the more flexible system is therefore taken into account in the following viability study._

Viability Study

The rate of inflation is of course an unknown quantity, but all indications are that it will remain above 10% for many years. The following table indicates the net annual savings for the system based on 10% annual increases in the ESCOM demand charge, based on a monthly peak reduction of 2000 KVA as determined from Fig 9.20.

	1987	1988	1989	1990	1991	1992	1993
ESCOM cost per KVA	15.00	16.50	18.15	19.96	21.96	24.15	26.57
Savings on 2000 KVA	30000	33000	37000	39920	43920	48300	53100
Less : Monthly repayments on capital	6500	6500	6500	6500	6500	6500	6500
Net monthly savings	23500	26500	30500	33424	37420	41800	46640
Net annual savings	282000	318000	366000	401040	449040	501600	559680

PROJECTED ANNUAL SAVINGS FOR CONTROL SYSTEM

TABLE 9.3

It can be seen that the net annual savings is around R300 000.00 for the first three years and rapidly increases to around R500 000.00 within the first five years under the conditions as stated.

This means that the capital payback period is less than 2 years, and there is therefore almost no risk involved.

It was recommended that the control system be installed and that comprehensive policies be formulated which supported the load management objective of striving to improve the load factor.
It was also recommended that the electricity tariffs be revised to give the consumers the benefit of the savings.

DETAILED COST ESTIMATES

DRIEFONTEIN SUBSTATION

Current transformers to be installed on the three outgoing feeders which feed Maidstone, Tongaat and Trurolands. Information is fed into transducers to determine KVA demand. This is fed to the Expanded Advance Status & Control Unit which permits 16 status inputs, 8 control outputs and 6 Analogue inputs to be transmitted. This information is transmitted to the Central Control Room where the real time situation at Driefontein is continually indicated on instruments and recorded on disc and printer, and the real time information is fed into the computerised controller which is housed at the Central Control Room. This also allows for manual intervention etc.

Instruments at the Control Room will indicate Circuit breaker and bus coupler status at Driefontein, actual KVA demand taken by Maidstone, Tongaat and Truroland Substations, the total demand, and will permit intrusion alarm indication, as well as other similar status information.

ESTIMATED INSTALLATION COST AT DRIEFONTEIN

1. Most Flexible System : Driefontein

a)	Current Transformers, potential transformers, transducers, Limit switches on circuit breakers and isolators etc.	R25 000.00
b)	Out-station transmitter Expanded Advance Status & Control Unit 16 Status input, 8 control output, 6 Analogue inputs.	R12 430.00
c)	Equipment kiosk, installation expenses, Engineering and administrative expenses	5 614.00
		R43 044.00

2. Least Flexible System : Driefontein

a)	Use existing current transformers, potential transformers and obtain M.D. Pulse directly from ESCOM.	No charge
b)	Out-station Transmitter Remote Control Unit transmitter capable of only transmitting 6 analogue signals	9,880.00
c)	Equipment kiosk installation expenses Engineering and Administrative expenses.	1 860.00
		R11 740.00

Information is received from Driefontein. Readout instruments permit general observation and manual intervention. Data supplied to Computerised controller, which determines suitable switching programme, and controls total load curve using real time data continually being received from Driefontein. Converts output into coded format and control of main transmitter.

Estimated installation cost at Central Control Room

1. Most Flexible System : Central Control Room

a)	Hardware : Hulett Packard HP 98580 300 series or equivalent Computer, 12" Video display unit, Standard Keyboard, 120 character per second printer 1 megabyte RAM card. Data intercommunication Unit. General Purpose Interface. Dual 80mm disc drive.	R35 833.00
b)	Software database package	R10 000.00
c)	Communication Interface Unit	R20 000.00
d)	Interface from Controller to Base Station.	7 405.00
e)	25 Watt VHF base station 15-20 km radius. Cabinet, backup batteries, Antenna, lighting protection	R9 337.00
f)	Installation expenses, Engineering and Administrative costs	R10 630.00
		R93,205.00

2. Least Flexible System : Central Control Unit

Hardware

a)	Conlog Microflex 32 Channel load management Controller with standard built in software (or similar):	R20,355.00
b)	Minimal vizual display at Central but with recorded printout and manual intervention facilities :	4,200.00
c)	100 watt Base Station, 40 kM radius with antenna, battery backup, cabinets etc.	21,200.00
d)	Equipping and administrative expenses installation costs	6,860.00
		R52,615.00

Geyser Control Units

In each dwelling where the geyser is to be controlled, a radio controlled Relay unit must be installed. This is normally secured adjacent to the householders distribution board and wired into the geyser circuit at the distribution board.

Estimated cost of installation of Geyser Control Units

a)	2100 radio controlled units @ R139.00 each	R291,900.00
b)	Installation cost on contract :	42,000.00
c)	Engineering and administrative expenses. Testing and Commissioning	23,500.00
		R357,400.00

PRICE SUMMARY

	Most Flexible System	Least Flexible System
Telemetry from Driefontein	43 044.00	11 740.00
Main Control Centre and Base Station	93 205.00	52 615.00
2100 geyser Control Units	357 400.00	357 400.00
	493 649.00	421 755.00

CASE STUDY 3

9.7 STANGER MUNICIPALITY

Many years ago, in an effort to reduce the peak load, a restrictive electricity tariff, based on a relatively expensive circuit breaker charge was introduced. This had the effect of restricting the size of the consumer's circuit breaker. As indicated in Section 2.7 it has no effect on the load peak but creates considerable inconvenience to consumers. The author was requested to investigate the entire matter of electricity tariffs and peak load reduction.

As indicated in these guidelines, improvements in the load factor will result in reduced ESCOM charges and the savings can be passed on to the consumers by way of reduced electricity tariffs. It was therefore recommended that load management should be investigated to determine the correct form of load management, following which all tariffs should be revised as necessary to derive continual improvements to the load factor.

As in the case of Tongaat, the daily load curves had been monitored over many years and their shape had remained unchanged. As in the case of Tongaat, there is almost no variation in the shape of the daily load curve with regards to seasons, due to the mild winters experienced on the Natal Coast.

The attached Stanger Load Curve shown in Figure 9.21 was determined from readings taken at Lavoipierre Substation.

It will be noticed that there is a sizeable peak occurring in the afternoon, followed by a deep valley. This load formation lends iteself to waterheater load management, whereby consumer geysers are remotely controlled during the peak period.

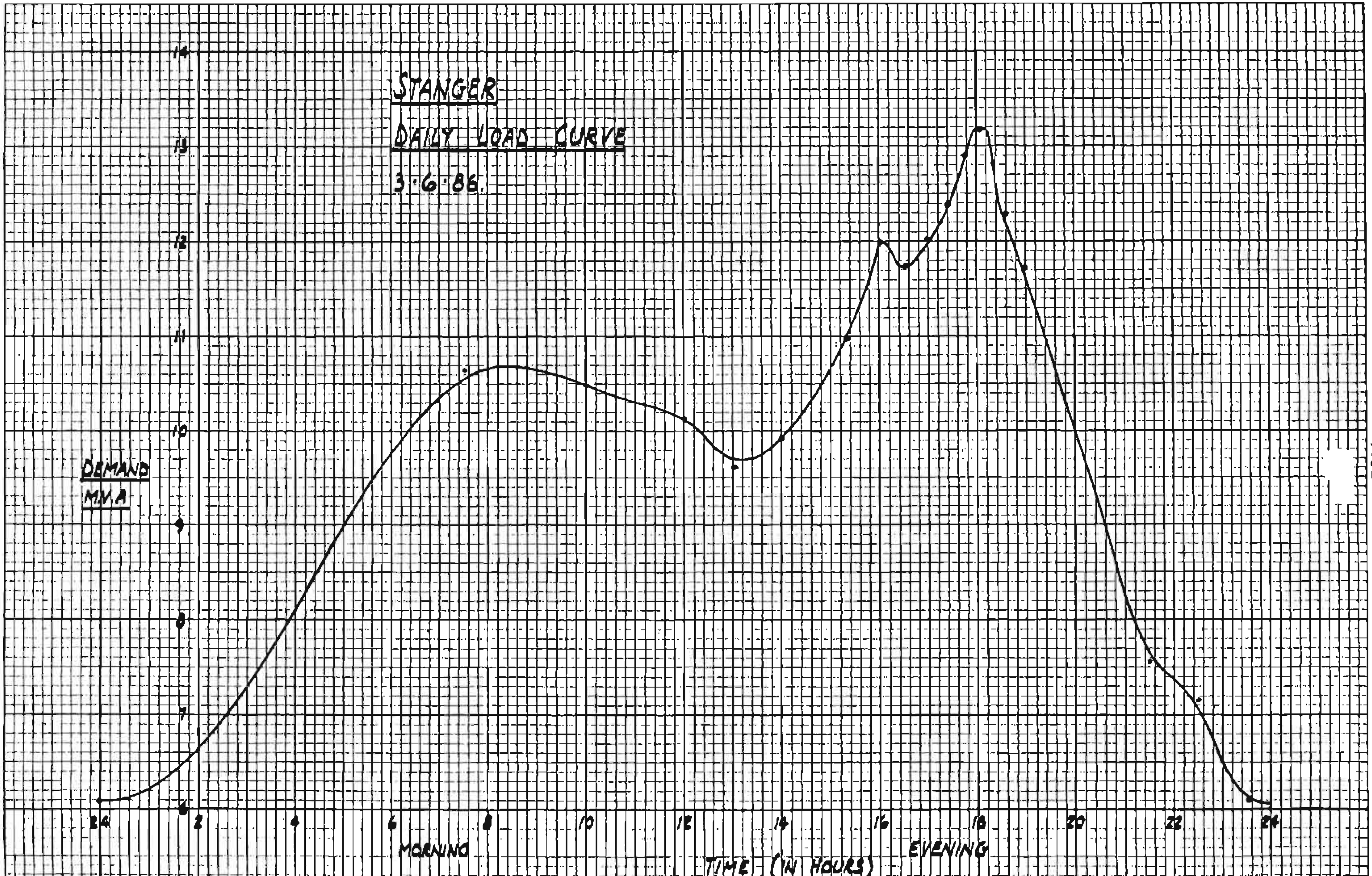
STANGER
DAILY LOAD CURVE
3·6·86.
DEMAND
MVA
14
13
12
11
10
9
8
7
6
24
2
4
6
8
10
12
14
16
18
20
22
24
MORNING
EVENING
TIME (IN HOURS)

FIG.9.21

The shape of the Stanger Load Curve, particularly the steep valley after the peak period, eliminates load payback problems and considerably enhances the effective savings.

The control system comprises metering equipment installed at the main substation which closely monitors the actual electricity demand and feeds the information into the computerised controller. The computer selects from its range of control programmes and decides on which groups of geysers to switch off or on, to attain the optimum load reduction while minimising the off-period for any groups of geysers.

Fig 9.22 shows the worksheet for the feasibility study for the Stanger Load Curve, for 2500 geysers, and indicates a peak load reduction of 2500 KVA.

The savings eminates from reduced KVA purchases from ESCOM. The effective cost per KVA is determined as follows :

Cost per KVA (as at July 86)	R11.80
Add 1% transmission charge	12
	R11.92
Less R2.00 rebate	2.00
	9.92

The estimated annual savings from reduced KVA purchases from ESCOM would then be :

2500 KVA @ R9.92 for 12 months : R297,600.00

ÑTERVAL	1	2	3	4	5	6	7
IME	15.15	15.45	16.15	16.45	17.15	17.45	[illegible]
XIST MD	11000	11750	11750	11800	12500	13000	13200
ARGET	10700	10700	10700	10700	10700	10700	10700
IFFERENC	-300	-1050	-1050	-1100	-1800	-2300	-2500
VA/GEYSE	.75	.75	.75	1	1.25	1.5	1.5
GEYSERS							
400	-300	-300	480	-400	-500	-600	-600
320	-240	-240	-240	480	96	-480	-480
170	0	-127.5	-127.5	-170	-212.5	158.1	192.1
315	0	-236.25	-236.25	223.65	144.9	-472.5	-472.5
305	0	-228.75	-228.75	-305	-381.25	-283.65	344.65
410	0	0	-307.5	-410	-512.5	-615	-615
320	0	0	-240	-320	-400	-480	-480
260	0	0	-195	-260	-325	-390	-390
OTAL CHA	-540	-1132.5	-1095	-1161.35	-2090.35	-2595.75	-2500.75
EW MD	10460	10617.5	10655	10638.65	10409.65	10404.25	10699.25

8	9	10	11	12	13	14	15
18.45	19.15	19.45	20.15	20.45			
11900	11100	10000	9500	8750	8000	0	0
10700	10700	10700	10700	10700	10700	10700	10700
-1200	-400	700	1200	1950	2700	10700	10700
1.5	1.25	1	.75	.75	.75	.75	.75
-600	392	720	340	196	0	0	0
-480	-400	-320	313.6	576	272	0	0
-255	-212.5	-170	158.1	192.1	81.6	0	0
-472.5	-393.75	-315	308.7	497.7	226.8	0	0
-457.5	-381.25	-305	-228.75	701.5	274.5	122	0
401.8	-512.5	1025	196.8	-307.5	287	0	0
313.6	576	-320	-240	-240	262.4	0	0
254.8	468	218.4	124.8	-195	192	0	0
-1294.8	-464	533.4	973.25	1420.8	1586.3	122	0
10605.2	10636	10533.4	10473.25	10170.8	9586.3	122	

GEYSERS	2500
EXIST MD	13200
NEW MD	10699.25
REDUCT	2500.75
CONTRIB	1.0003

TANGER

FEASIBILITY STUDY : STANGER

FIG.9.22

The estimated installed cost for such a scheme is :

a.	Computerised controller	85,000.00
b.	Transmitter	15,000.00
c.	Repeater	20,000.00
d.	2500 Load control relays	337,500.00
e.	Professional fees & disbursements	41,000.00
		R498,500.00

The annual instalments to repay a loan of R498,500.00 over 25 years at 12,5% is R65,770.00.

Thus the net annual savings would be R231,830.00.

This net savings will continue to increase as ESCOM increases its KVA charges. For example within five years, if ESCOM increases its KVA charges by 10% per annum the gross savings will be R510,000.00 and the net annual savings will be R444,230.00.

It was recommended that Stanger should install a geyser control system without delay.

Based on these results and recommendation, Stanger obtained ad hoc approval from the Department of Finance for the additional expenditure in the current financial year.

Arrangements are presently under way for the installation of the equipment, and the control scheme is expected to be commissioned in April 1987.

It was also recommended that the consumer's circuit breaker should be replaced by 60 Amp units and that the load shedding devices be removed. This will be necessary to avoid cold water problems, since it will happen that the controlled off-period could be preceded or followed by a further geyser-shed should the consumer use his stove. The resulting total off-time will then be excessive.

It was also recommended that the circuit breaker charge tariff be scrapped and that a revised tariff be formulated which would pass the resulting savings on to the consumer.

It was also recommended that an agricultural tariff be formulated, which would permit irrigation pumping at very reduced rates during the off peak period.

CASE STUDY 4

9.8 BALLITO MUNICIPALITY

As in the case of Stanger Municipality, Ballito has an outdated tariff structure based on the amp-rating of the circuit breaker. As stated before this results in considerable inconvenience to consumers without deriving any benefit for the undertaking.

In order to determine the correct form of load control to recommend, the feasibility study for peak load reduction by means of remotely controlled geysers was undertaken.

The daily load curves for Ballito had been monitored periodically over the past two years.

In both years, the peaks in the daily load curves for the winter months was about 20% greater than those of the rest of the year. This difference was not apparant in the load curves of the neighbouring towns of Tongaat and Stanger, and the difference was attributed to the fact that Ballito is in many aspects a holiday town, and there is a distinct July holiday season, which is reflected in the daily load curves over this period.

Feasibility studies were done for this load curve with various diversified geyser demands and it was found that the system load curve is not suitable for peak load reduction by means of remotely operated geyser load control.

The attached Fig 9.24 9.25 9.26 indicate that, at best, a contribution of approximately 0,5 kW per controlled geyser can be obtained in

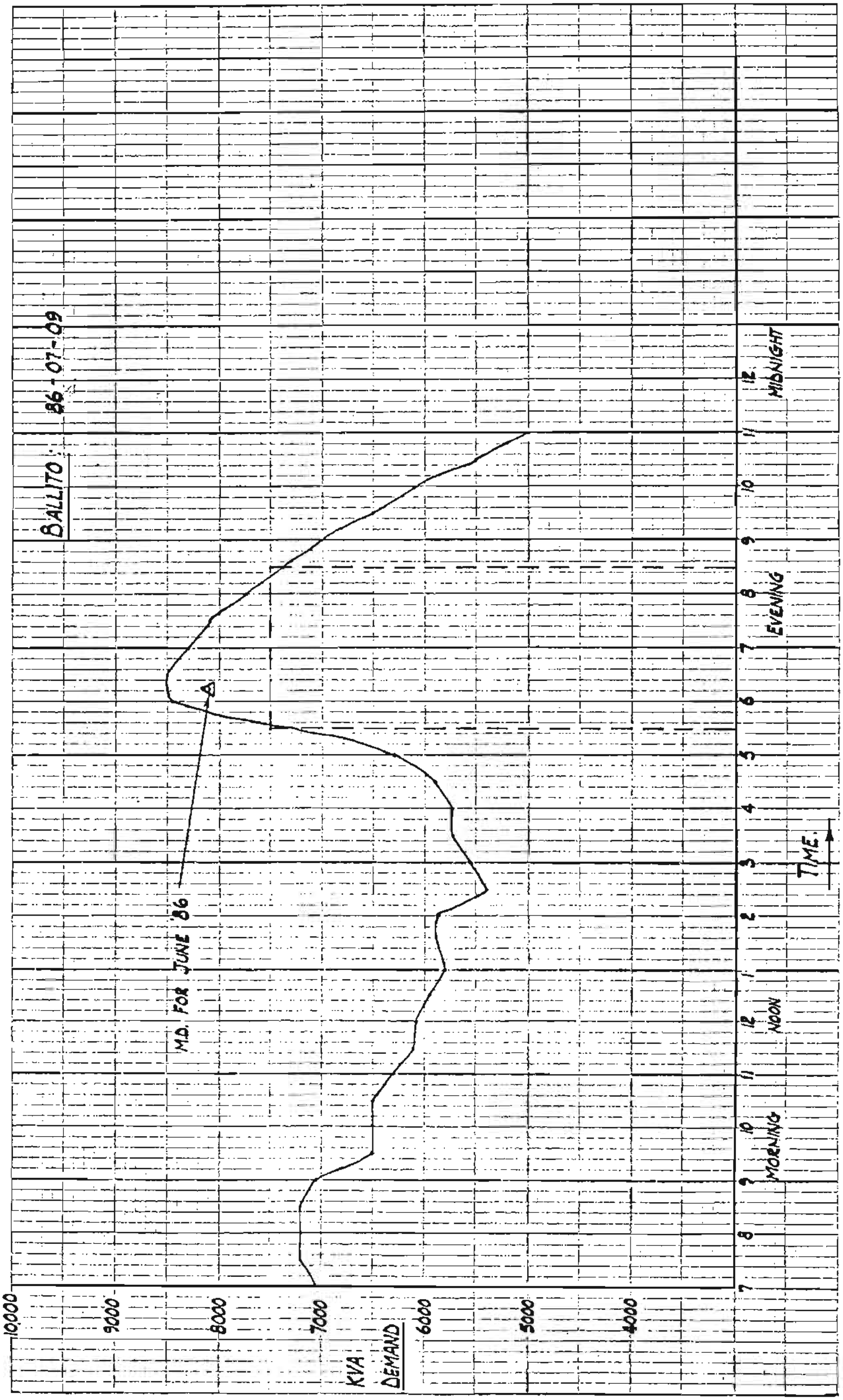
BALLITO: 86-07-09
M.D. FOR JUNE '86
KVA
DEMAND
10,000
9000
8000
7000
6000
5000
4000
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
12
MORNING
NOON
EVENING
MIDNIGHT
TIME

FIG. 9

Water-Heater Load Control **BALLITO**

			D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S.
		Interval	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Time																
Row 1		System M.D.	6700	7800	8500	8400	8200	8000	7600	7200	6700	6300	5800	5200	4800	4200		
Row 2		Target M.D.	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500			
Row 3		Change Reqd.	–	-300	-1000	-900	-700	-500	-100	+300	+800	+1200	+1700	+2300	+2700			
Row 4		Diversified Geyser Demand		1·5	1·5	1·5	1.25	.75	.5	.5	.5	·5	.5	·5	.5			
9	Group A	250		-375	-375	+450	+125	+50	-125	-125	-125	-125	+350	+50	+25			
10	Group B	250			-375	-375	+450	+125	+50	+25	-125	-125	+225	–	–			
11	Group C	250			-375	-375	-312	-188	+575	+225	+100	+50	–	–	–			
Row 12	Group D	250				-375	-312	-188	-125	+525	+175	+75	+50	–	–			
13	Group E	250				-375	-312	-188	-125	-125	+575	+225	+100	+50	–			
14	Group F	250					-312	-188	-125	-125	+450	+125	+50	+25	–			
15	Group G	250					-312	-188	-125	-125	-125	+500	+150	+75	+25			
16	Group H	250							-125	-125	-125	-125	+350	+50	+25			
Row 6		Total Change																
Row 7		Final M.D.	·	-375	-1125	-1050	-985	-765	-125	+150	+800	+600	+1275	+250	+75			
				7425	7375	7350	7215	7235	7475	7350	7500	6900	7075	5450	4875			

SYSTEM M.D. 8500 GEYSERS USED 2000

CONTROLLED M.D. 7500 CONTRIBUTION 0.5 kW/GEYSER.

REDUCTION 1000

FIG 9.24

Water-Heater Load Control **BALLITO**

		Interval	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Time																
Row 1		System M.D.	6700	7800	8500	8400	8200	8000	7600	7200	6700	6300	5800	5200	4800	4200		
Row 2		Target M.D.	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500			
Row 3		Change Reqd.	–	-300	-1000	-900	-700	-500	-100	+300	+800	+1200	+1700	+2300	+2700			
Row 4		Diversified Geyser Demand		1·5	1·5	1·5	1.25	.75	.75	.75	.75	.75	.75	.75	.75			
	Group A	250		-375	-375	+450	+125	+50	+25	-188	-188	-188	-375	+75	+25			
	Group B	250			-375	-375	+450	+125	+50	+25	-188	+130	–	–	–			
	Group C	250			-375	-375	-312	-188	+575	+225	+100	+50	–	–	–			
Row 5	Group D	250				-375	-312	-188	-188	+550	+200	+75	+50	–	–			
	Group E	250				-375	-312	-188	-188	-188	+575	+250	+100	+50	–			
	Group F	250					-312	-188	-188	-188	+500	+150	+75	+25	–			
	Group G	250					-312	-188	-188	-188	-188	+600	+325	+125	+100			
	Group H																	
Row 6		Total Change																
Row 7		Final M.D.		-375	-1125	-1050	-985	-765	-102	+48	+811	+1067	+925	+275	+125			
				7425	7375	7350	7215	7235	7498	7248	7511	7367	6725	5475	4925			

SYSTEM M.D. 8500 GEYSERS USED 1750

CONTROLLED M.D. 7500 CONTRIBUTION 0.57

REDUCTION 1000

FIG 9.35

Water-Heater Load Control   BALLITO

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Interval	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Time																
Row 1	System M.D.	6700	7800	8500	8400	8200	8000	7600	7200	6700	6300	5800	5200	4800	4200		
Row 2	Target M.D.	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500		
Row 3	Change Reqd.	–	-300	-1000	-900	-700	-600	-100	+300	+800	+1200	+1700	+2300	+2700	+3300		
Row 4	Diversified Geyser Demand		1.5	1.5	1.5	1.25	.75	.75	.75	.75	.75	.75	.75	.75	.75		
Group A	300		-450	-450	-450	-375	-225	+720	+390	+150	+120	+90	–				
Group B	300			-450	-450	-375	-225	-225	+720	+360	+150	+90	–				
Group C	300			-450	-450	-375	-225	-225	-225	+720	+390	+150	+120	+90			
ow 5 Group D	300							-225	-225	-225	+450	+90	+30				
Group E	300							-225	-225	-225	+450	+90	+30				
Group F	300								-225	-225	-225	-225	+540	+150	+60	+30	
Group G																	
Group H																	
ow 6	Total Change		-450	-1350	-1350	-1125	-675	-180	+210	+555	+1110	+285	+720	+240	+60	+30	
ow 7	Final M.D.		7350	7150	7050	7050	7325	7420	7410	7255	7410	6085	5920	5040	4260		

1800 GEYSERS
SYSTEM MD. : 8500 kVA
CONTROLLED M.D. 7420 kVA
REDUCTION 1080 kVA

CONTRIBUTION = 0,6 kVA / GEYSER

NOTE: 3 HOUR OFF ON GROUP C.

FIG 9.26

winter using 2000 geysers, which will reduce to approximately 0,35 kW/geyser in summer. Contributions of less than 0,5 kW/geyser are generally not financially attractive, as can be seen from the following discussions.

The estimated capital cost of a geyser control system for 2000 geysers is made up as follows :

Computerised controller	R85,000.00
Transmitter	15,000.00
2000 geyser control relays	270,000.00
Engineering expenses and professional fees	31,000.00
	R401,000.00

The monthly instalments to repay capital and interest at 15% over 20 years on an amount of R401,000.00 is R5,280.00.

For a contribution of 0,375 KVA per geyser for 2000 geysers the monthly operating income statment will then be as follows :

Savings : 750 KVA @ R11.92	R8,940.00
Less	
Monthly repayments on Capital	5,280.00
Gross operating profit	3,660.00

Geyser control systems have to be very profitable before they are considered to be worthwhile, since changes in the load curve, modifications to the ESCOM tariff structure and improvements in water heating technology could all contribute towards eliminating any initial savings. The financial payback period must therefore be short, say 3 or 4 years, to discount these risks.

Another important factor which also suggests that geyser control is not suitable for Ballito is the large number of holiday visitors. During peak seasons it is possible that many houses and flats have more people in them than the existing geysers can actually cater for, and geyser control under such circumstances could result in numerous complaints.

Under the circumstances geyser load control should not be considered as the first alternative for Ballito.

Alternative forms of Load Management

Numerous municipalities, for example Durban, report excellent response to soft load management, whereby incentives are offered to large power users to shift their load out of the peak period.

As discussed above, hard load management of geysers will result in a peak reduction of around 750 KVA on average. It will be seen from the daily laod curve that a 1000 KVA peak reduction requires load to be shifted out of the period 5.30 p.m. to 8.30 p.m.

Incentive tariffs for off-peak industrial heating, water heating and water pumping can show very good results, and the net savings can be as impressive as geyser control. For example, if 8 large hotels each save 100 KVA during the peak period by arranging their own load shifting at an incentive of say R5.00 per KVA saved, then the peak reduction will be 800 KVA, at an expense of R4000.00 per month in incentive rebates, and the gross savings to the town will be 800 KVA @ R11.98 = R9.584.00 per month, or a net annual savings of R71,808.00, with no initial capital outlay.

Soft load management requires a great deal of attention to be paid to a few large consumers whereas geyser control requires about the same total degree of attention but spread over several thousands consumers.

It was therefore recommended that a survey be undertaken of the larger hotels, holiday flats etc to determine the feasibility of load reduction by means of incentive rebates, off-peak tariffs and localized load control.