THE KINGDOM OF THAILAND
FEASIBILITY REPORT
ON
BANGKOK METROPOLITAN AREA
TOWN GAS DISTRIBUTION PROJECT

DECEMBER, 1975

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

The Government of Japan, at the request of the Government of the Kingdom of Thailand, decided to undertake the survey for Town Gas Distribution Project in Bangkok Metropolitan Area, Thailand, and commissioned its task of implementation to the Japan International Cooperation Agency in September, 1974.

Accordingly, the Agency organized a survey team consisting of thirteen experts headed by Mr. Tsuneji Tanabe of the Overseas Planning Division of Tokyo Gas Engineering Co., Ltd., and sent it to Thailand on September 20th, 1974.

During the survey work there for about three months, the team visited National Energy Administration Office of the National Economic and Social Development Board, Bangkok Municipal Office, and discussed with their officials over the project mentioned above. At the same time, it performed a field survey in Bangkok and its vicinity with the cooperation of the Government of the Kingdom of Thailand.

Hereby presented is a report based upon the findings the team has attained in Thailand as well as at home.

Nothing would be more gratifying to us than if this report could be of any help for the social and economic development in Thailand and could contribute to the promotion of friendship between the two nations.

Finally, I take the opportunity to express my hearty gratitude to the Government of the Kingdom of Thailand and other authorities concerned for their kind cooperation and assistance extended to the team, without which the survey work could not be carried out so successfully.

Shinsaku Hogen
President
Japan International Cooperation Agency
Japan

December, 1975

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(SEPARATE COVER)

INTRODUCTION

INTRODUCTION

1. Town Gas

1-1 Town Gas Service in the World

In 1797, William Murudok initiated to use coal-gas for illumination of his house in Britain, and this marked the origin of later development of the town gas industry in Europe and America. However, from the outset of town gas service till the end of the 19th century, the demand for gas came, for the most part, from illumination need.

Since Bunzen invented the so-called 'Bunzen burner' in 1885, town gas has been increasingly used as a heat source, and has brought forth the current prosperity of the town gas industry.

The gas service, featuring efficient delivery of energy in the form of gas through pipelines, holds an important position in energy industries in the world, as shown on Table 0-1-1 'Gas Pipeline by Nation', and Table 0-1-2 'Number of Town Gas Service Concerns and Consumers, by Nation'.

Table 0-1-1 Gas Pipeline by Nation (1970)

	Transit use	Supply use	Extension
USA	413	984	1,397
USSR	79	79	158
Britain			205
West Germany	26	78	104
France	18	70	88
Italy	11	33	33

Table 0-1-2 Number of Town Gas Service Concerns and Gas Consumers, by Nation

	Number of concerns	Number of consumers in thousands
West Germany	600	6,460
Poland	70	3,698
Italy	650	5,122
Australia & New Zealand	58	
Sri Lanka	1	4
Hongkong	1	46
India	2	46
Japan	245	11,711
Pakistan	1	63
Singapore	1	105
USA		42,197
Britain		13,390

1-2 Proposal for Town Gas Service

1-2-1 Comparison of Domestic Fuels

Main domestic fuels today are electricity, charcoal, liquefied petroleum gas, and town gas, the features of which are as follows.

(1) Electricity

Electric power, distributed by wire, and unlike other fuels, its energy not released by combustion, emits no exhaust gas, featuring that it is the cleanest energy in this respect. It is to be noted, however, that electric power, acquaired by thermal power generation, has an overall efficiency of only about 30 per cent as compared with its primary energy sources such as crude oil. For the saving of energy, therefore, use of electric power as a domestic heat source is one of the most inefficient methods of heating. Also, the problem of environmental pollution caused by thermal power plants must be taken into account.

(2) Charcoal

Charcoal, one of the most familiar fuels customarily used from ancient days, may deplete forest resources which have their limitation in supply. Besides, charcoal, unlike other types of fuel, takes time before it has become available as a heat source; namely it is not suitable with respect to one-touch operation.

(3) Liquefied Petroleum Gas (LPG)

Recent development of oil refining and petrochemical industries has enormously accelerated the trend of using more LPG, a light distillate, as a domestic fuel. So convenient because one-touch operation is possible, and so reasonable in price, LPG has been used more in quantities, particularly in such areas where town gas service networks have been undeveloped. Problems for this fuel, however, are that if steel cylinders are used for the purpose of packaging a stock of LPG, they must be replaced whenever the content is used up, that safety and traffic troubles will not be always avoidable in distribution and transit of LPG, and that LPG, heavier than air, will, if leaking, diffuse along the floor surface and, therefore, more liable to explode than town gas. Thus, LPG is not a perfectly ideal fuel for domestic use.

(4) Town Gas

Town gas which can be stably supplied through pipeline requires no consumer's care about whether to run out of its stock, unlike LPG and charcoal. While electric power cannot be stocked, town gas can be stored in gas holders to ensure continuous distribution even when for any reason the production of gas is suspended temporarily. Expedient and simple in use. For all these reasons, town gas has maintained its established reputation as a very useful domestic fuel.

1-2-2 Proposal for Town Gas Service

In addition to the superiority of town gas as outlined in the preceding paragraph, town gas as outlined in the preceding paragraph, town gas, produced at highly rationalized plants, can maintain its calorie, chemical composition, and other properties at stable levels. Its price is the stablest of all other fuels. These conditions are sufficient to meet the requirements for the organization of a public utility service enterprise to supply it. In fact, town gas is one of the most excellent energy sources for domestic use in its safety, stability, cleanness, usefulness and economic efficiency with respect to delivery, distribution and use. It is the domestic utility indispensable for urban life together with electric power and town water.

2. Objective of the Present Feasibility Study

This report is compiled from the site survey which was conducted for the feasibility study on the Bangkok Metropolitan Area Town Gas Distribution Project, at the request of the Thai Government.

Objective of the present feasibility study was to conduct investigations on the specific conditions required to meet this Project, obtain necessary data and information, and based thereon estimate the future town gas demand in this area, then, select from among several alternatives, the most economical and efficient pipeline system, gas producing system, etc., draft a Bangkok Town Gas Distribution Plan and judge whether the Plan has a feasibility for implementation.

3. Development of The Present Feasibility Study

In 1973 the Japanese Government was formally asked by the National Energy Administration (NEA) of the Thai Government of the carrying out of a prefeasibility study on a town gas service in Bangkok Metropolitan Area, for the reasons that follow:

'It is an accepted conservation principle that woods should be utilized for other useful purposes rather than as domestic fuels. The substitution of fire woods and charcoal by other fuels or electricity is always possible, but fuel gas is considered to be the most economical substitute.'

'The remarkable introduction of liquid petroleum gas (LPG) as new domestic fuel in 1964, when the first oil refinery was established in Thailand, has since decreased the consumption of charcoal considerably.

Since then the consumption of fuel gas has been increasing by leaps and bounds, from 2,500 tons in 1964 to 87,000 tons in 1971. Approximately 70% of the total consumption is attributable to Bangkok area.'.

'At present, LPG is distributed or sold to the consumers in cylindrical containers. When consumption increases to a certain level, this method of distribution is not any more economic and efficient, especially in Bangkok area where the traffics are tremendously heavy. This system therefore has its limitation and would impede further expansion of gas consumption.'

'The main purpose of this Project is to develop a gas system in which fuel gas will be produced, processed and safety distributed thorugh pipes to consumers when a where it is required at economical rates.'

The consideration thereof by the Japanese Government concluded that a preliminary survey was necessary before carring out a feasibility study. In pursuance of the instructions of the Japanese Government, Japan Consulting Institute made the pre-feasibility study as part of its 1973 activities, as follows:

Period: From November 12 to December 2, 1973 (21 days)
Number of study group members: 6

Since survey period was too short to carry out satisfactory investigations, a case study was made on the basis of intrepid assumptions for those items for which no investigation could be made and resulted in failure to obtain the results.

In that case study, preconditons were set that the total period for study, preparation and construction would be approximately three years; town gas distribution would be started from 1977; and by the end of the next ten years, approximately 120,000 houses in the major part of Bangkok City would be using the town gas. The maximum share of gas users was presumptively set at approximately 60 percent of the inhabitants. Use of naphtha and refinery-off gas as raw materials for the town gas would be considered recommendable. Investment required over the ten years was calculated to be approximately 1,200 million bahts. At the cost of this amount, it seemed to be possible to establish economical and stable town gas distribution system as an energy source for domestic use from the long-term view. The case study thus concluded that the Project had a considerable feasibility, but, that it would be necessary to further make, in the future, a full-scale feasibility study, complete survey of those items for which sufficient investigation could not be made, hence resulted in failure to obtain the results.

In 1974, Japanese Government decided to pay regard to the above conclusion of the prefeasibility study by carrying out a full-scale feasibility study, and consigned this mission to the Japan International Cooperation Agency (JICA), who in turn consigned the practical work of this mission to the Japan Consulting Institute (JCI).

JCI then organized a study team comprising experts of town gas service and pipeline industry, and dispatched it to Bangkok for a site survey of about three months from the end of September, 1974.

4. Scope of Work

The scope of work designated by the Thai Government to the Japanese Government was as quoted in paragraphs 4-1 through 4-7 of this report.

4-1 Basic Data and Information Studies

The mission of experts shall perform all field investigations, collect analyse and evaluate data and information as follows:

(1) Physical condition of the project area.

(2) Statistical data of import, production and consumption of fuel gas and other competitive fuel such as charcoal, fuel oil, kerosene, etc.

(3) The economics of the city development and marketing survey relating to fuel gas and other competitive fuels in the project area for:
- domestic use
- commercial use
- industrial use

(4) Physical and chemical properties of fuel gas existing in Thailand, LPG, and that of other existing competitive fuels.

(5) Advantages and disadvantages of these existing fuels for:
- domestic use
- commercial use
- industrial use

(6) Rule of safety property and exploitation in Thailand.

(7) Other economic, technical and administrative information, pertaining to the Project.

4-2 Technical and Economic Studies

Based upon data and information obtained in Article 4-1, the mission of experts shall conduct the studies as follows:

(1) A 10-year forecast demand of fuel gas in the project area, by sections.

(2) A finite plan and layout of a modern and most economical town gas system including gas production plant, storages, and distribution networks.
These studies shall include, but not limited to, the followings:-

(a) A comparison between various fuel gases of:
- physical properties
- processes and fuels used for fuel gas production
- advantages and disadvantages

(b) A selection of a best suitable fuel gas for the Project.

(c) Site selections for fuel gas production plants, compressor stations, an operational and maintenance center.

(d) Route selections for high, medium and low pressure pipeline networks and their related facilities.

(e) Cost estimates and comparison between selected pipeline systems.

(f) Comparison of the recommended pipeline system against ohter means of distribution such as bottle-filled LPG.

(3) Formulation of Scheme of Development

Based upon various studies stated in (1) and (2), the mission of experts shall formulate the scheme of development of the project with respect to the practical engineering and economic principles.

4-3 Preliminary Design and Cost Estimates

Design of feasibility grade need not approach the detail of construction designs. However, they shall be in such a sufficient detail that no major deviation from the plan will be necessary when actual construction and development of the project is undertaken. The engineering designs and drawings shall cover, but not limited to, the followings:-

(1) Fuel gas production plants with all equipments including sotrages and material

handling equipments.

(2) Compressor stations with complete piping diagram meterings and safety equipments.

(3) An operational center with operational and maintenance equipments, automation and remote control facilities.

(4) Pipeline networks - high, medium and low pressure networks with pressure regulating stations and their related facilities.

(5) Customer metering units with safety equipments.
The construction cost estimates shall be detailed enough to show the quantities, unit cost and total cost of various works and supply items. In addition to the cost of actual construction items, the estimates should include such indirect cost as preparation of the final design, supervision of construction, protection and maintenance during the construction period, the cost of land and rights of way.

4-4 Economic Justification

The project cost shall include, but not limited to, the followings:

(1) Land acquisition and compensation

(2) Fuel gas production plant

(a) Civil works

(b) Plant equipments

(c) Storages

(3) Pipeline networks

(a) High pressure network

(b) Medium pressure network

(c) Low pressure network

(d) Interconnection units between the networks

(e) Pressure regulating stations

(4) Customer metering units with safety equipments

(5) Operation and maintenance cost for

   (a) Fuel gas production plant

   (b) Compressor stations

   (c) Pipeline

   (d) Customer metering units

(6) Miscellaneous expenses

   (a) Engineering fee

   (b) Supervision of construction

   (c) Interest during construction

   (d) Contingency

(7) Project benefits

(8) Economic analysis which includes:-

   (a) Internal rate of return

   (b) Benefit cost ratio analysis at various rates

4-5 Financial Studies

The mission of experts shall make the financial studies of the project as the followings:-

(1) Finance of funds

   (a) Source of funds

   (b) Requirement on foreign and domestic currencies

(2) Repayment principles

(3) Revenues

(4) Cash flow schedule of the system for a period of 20 years.

4-6 Operation Studies

The mission of experts shall make a description and discussion on the operations and their related problems of all components of the fuel production plant and the fuel gas distribution system.

4-7 Report

The mission of experts shall perform the work as herein described and submit to the NEA the complete report in fifty (50) copies with their original reproducible.
This report should be prepared using the information supplied by NEA as well as the information from the mission of experts finding and researches.

5 Study Group Members

The members of the Bangkok Town Gas Project Feasibility Study Team, organized by the Japan Consulting Institute, were as follows:

Project Manager
Tsuneji Tanabe (Tokyo Gas Engineering Co., Ltd.)

Managing Director
Tadao Mera (Nippon Kokan Kabushiki Kaisha)

Pipeline Engineer (A)
Kiyokazu Kanase (Nippon Kokan Kabushiki Kaisha)

Pipeline Engineer (B)
Sadakazu Kojo (Nippon Kokan Kabushiki Kaisha)

Distribution Engineer
Yuichi Sugiyama (Tokyo Gas Engineering Co., Ltd.)

Civil Engineer
Kazuo Okamoto (Nippon Kokan Kabushiki Kaisha)

Plant Engineer
Kozo Sakurai (Tokyo Gas Engineering Co., Ltd.)

Plant Engineer
Yasuhiko Maki (Tokyo Gas Engineering Co., Ltd.)

Appliance Engineer
Shohei Ogo (Tokyo Gas Engineering Co., Ltd.)

Market Survey Specialist
Hirokuni Koshiba (Tokyo Gas Engineering Co., Ltd.)

Law, Finance, Labor Specialist
Takeo Otsuka (Nippon Kokan Kabushiki Kaisha)

Co-ordinator
Kiyoshi Yamaguchi (Japan Consulting Institute)

Planning & Public Relations Man
Kazuo Iwasaki (Ministry of International Trade and Industry)

6. Period of Survey

The period of the survey was as given in Table 0-6-1.

Table 0-6-1 Period of Survey

	September 1974	October	November	December	
Project Manager	20 —	—	—	— 20	91 days
Managing Director	20 —	— 4			14 days
Pipeline Engineer (A)	27 —	—	—	30	64 days
Pipeline Engineer (B)		15 —	—	— 13	59 days
Distribution Engineer		15 —	—	— 13	59 days
Civil Engineer	27 —	—	—	— 18	82 days
Plant Engineer (A)	27 —	—	—	30	64 days
Plant Engineer (B)	20 —	— 10			21 days
Appliance Engineer	27 —	—	—	30	64 days
Market Survey Specialist	27 —	—	—	30	64 days
Law, Finance, Labor Specialist	20 —	—	—	— 23	94 days
Co-ordinator	20 —	— 4		7 — 24	31 days
Planning & Public Relations man				7 — 24	17 days

7 Acknowledgements to Thai Government Agencies, and Public Corporations for their Cooperation with the Study

Throughout this survey, the study group enjoyed very warm assistance, advices, opinions and facilities extended by the below-listed government agencies and public corporations in Thailand, to whom the group is most thankful. Without these cooperations, the smooth and successful completion of the study would have been inconceivable.

Office of Under-Secretary of the Prime Minister
National Statistical Office
National Energy Administration
Dept. of Technical and Economic Co-operation
Office of the National Economic and Social Development Board
Royal Irrigation Department
Dept. of Business Economics
Department of Town and Country Planning
Police Department
Harbour Department
The Highway Department
Dept. of Mineral Resources
Office of Metropolitan Traffic Planning
Oil Fuel Organization
Port Authority of Thailand
Telephone Organization of Thailand
Metropolitan Water Works Authority
State Railway of Thailand
Metropolitan Electricity Authority
Electricity Generating Authority of Thailand
National Housing Authority
Bangkok Metropolis Administration
Asia Institute of Technology

CHAPTER I.

CONCLUSIONS

CHAPTER I CONCLUSION

I-1 Outline of Plan

I-1-1 Commencement of Town Gas Service

Town gas distribution should be started from 1979.

(1) In 1975, decisions should be made as to implementation of the project.

(2) In 1976, construction designs should be started in detal.

(3) In 1977 and 1978, detail preparations should be made for the startup of service.

I-1-2 Relevant Parameters Planned

By the end of the 12-year period, from the startup of service, the gas of approximately 187×10^6 m^3 per year should be distributed to approximately 200,000 houses residing in a 110 km^2 area of the central region of the Bangkok Metropolitan Area.
Details are as given in Table 1-1-1.

I-1-3 Diffusion Rate of Town Gas

Diffusion rate of town gas to the domestic consumers will be approximately 70 per cent.

I-1-4 Main Raw Materials for the Gas

Naphtha and refinery-off gas, both to be procured from the Bangchak Oil Refinery of Summit Industrial Corporation should be used as main raw materials for the town gas.

I-1-5 Calorific Value of the Gas Distributed

Distributed gas should have a calorific value of 5,000 $kcal/Nm^3$.

I-1-6 Amount of Investment

Approximately 2,000 million bahts (at the 1974 prices) should be invested during the ten-year period.

I-1-7 Balance of Payment

Assuming that the investment by the Thai Government is 330 million bahts (at the 1974

Table 1-1-1 Table of Relevant Parameters Planned

Item			Unit	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Demand	Number of consumers		10^3	5.6	9.1	17.7	32.6	54.7	79.5	104.2	127.8	149.5	171.4	187.3	194.5	197.5
	Net annual increment in the number of consumers		10^3	5.6	3.5	8.6	14.9	22.1	24.8	24.7	23.6	21.7	21.9	15.9	7.2	3.0
	Gas sales		$10^6 m^3$	1.0	6.8	13.7	25.6	44.6	67.1	90.6	113.6	137.9	162.9	177.7	184.3	187.0
	Gas sales in a peak day		$10^3 m^3$	13.1	30.5	57.5	107.8	178.0	252.1	328.7	401.8	479.0	565.6	590.8	607.8	607.8
Production	Amount of raw materials	Refinery-off gas (1)	$10^3 m^3$		53	108	200	350	445	445	445	445	840	1,981	2,486	2,674
		Refinery-off gas (2)	$10^3 m^3$	152	931	1,880	3,516	6,128	9,251	12,482	15,653	19,009	21,747	21,747	21,747	21,747
		Naphtha	kℓ	516	3,491	7,048	13,182	22,990	34,627	46,754	58,656	71,257	84,340	92,516	96,134	97,648
		LPG	ton						92	312	527	762	1,042	1,323	1,445	1,527
	Electric power consumption		10^3kwh	164	1,061	2,137	3,992	6,959	10,469	14,131	19,220	21,515	25,230	27,741	28,789	29,217
	Water consumption		10^3t	35	43	56	75	119	150	195	238	274	319	341	350	355
	Plant / Plant capacity	Gas production plant	$10^3 m^3$/d x each	50x2		100x1	100x1	100x1		100x1	100x1	100x1	100x1			
		Compressor	$10^3 m^3$/d x each	60x2		120x1	120x1	120x1		120x1	120x1	120x1	120x1			
		Gas cooling plant	$10^3 m^3$/d x each	120x1	200x1		200x1			200x1	200x1					
		Cooling tower	t/dxeach	5,000x2	5,000x1		5,000x1			5,000x1		5,000x1				
		Deep well	t/dxeach	200x1		400x1				400x1		400x1				
Distribution	High and medium pressure pipelines		10^3m	12.3	5.2	7.7	11.2	18.6	11.3	10.5	13.7	14.1	4.5			
	Low pressure pipelines		10^3m	67.1	102.5	98.5	87.7	149.2	127.5	91.8	163.9	198.1	102.2			
	Service pipelines and interior piping		10^3m	189.4	257.7	235.0	318.5	605.6	403.9	482.7	520.3	369.4	402.9	191.7	136.9	
	Governor		Unit	10	6	10	14	14	9	9	8	12	6			
	Gas holder		$10^3 m^3$ x each	60x1				60x1		60x1		60x1				
Number of gas burner sets readjusted			10^3	7.4	9.4	15.2	27.6	36.7	37.7	37.6	36.3	33.7	39.8	14.3	10.5	
Service personnel			Person	232	240	280	301	390	455	532	606	677	758	747	751	737
Investment (at the 1974 prices)			10^6 bahts	255.7	112.6	191.3	184.1	278.3	198.7	228.1	223.2	239.5	133.5	19.5	15.2	5.1

prices) and gas charge is 3.53 bahts/m^3 (at the 1979 prices), the profit/sales ratio for the ten-year period will be 4 per cent.

I-1-8 Form of Enterprise

A new enterprise should be organized in the form of 'authority'.

I-2 Conclusion

With conviction, we draw from the results of both pre-feasibility and feasibility studies a conclusion that the town gas service in the Bangkok Metropolitan Area is feasible, and that it can become a very effective utility service for the enhancement of the Thai people's living standard by ensuring the stable distribution of town gas as the best energy for household use in Thailand. As one of the typical facility-based industries, the town gas service requires a considerable amount of investment in its initial stage. However, such investment will constitute semi-permanent assets of the community. In the long run, it will grow doubtlessly to an ideal energy-supplying service capable of distributing a stable energy source at a low price.

The following requirements are mandatory for the promotion of this Project:

(1) To maintain and protect the service system as part of the national projects from the viewpoint of national interest.

(2) To establish a national consensus to support the Thai efforts for optimal utilization of their own energy, as realized by this Project.

(3) To establish a setup in preparation for the promotion of this Project for gas service business in Thailand.

(4) To provide government financial aid for raising necessary funds at the lowest possible interest.

(5) To give a priority to use of local materials and technology available in Thailand for implementing this Project.

(6) To enact a Gas Act, in order to protect the interest of gas consumers, and promote stable growth of the town gas service to enhance public welfare.

(7) To effect coexistence of both the town gas service body and the LPG retailers through promotion of their mutual cooperation in the field of consumer servicing activities involved in the town gas service.

CHAPTER II.

OUTLINE OF THAILAND AND BANGKOK METROPOLITAN AREA

CHAPTER II OUTLINE OF THAILAND AND BANGKOK METROPOLITAN AREA

II-1 Nature and Geography

II-1-1 Location

Thailand is situated in latitude 5° to 21°N. and longitude 97° to 106°E. at the center of the Indochina Peninsula, having her boundaries at northwest to west with Burma, at south with Malaysia, at northeast to east with Laos, and at southeast with Cambodia. Her coastlines comprise a distance of about 1,875 km which runs along the Gulf of Thailand, and the rest, about 740 km long adjoining the Indian Ocean.

Bangkok, her Capital, is located in latitude 13.7°N. or around, approximately at the center of the State, is near the mouth of the Chao Phraya River on an extensive alluvial plane formed by this river. The topography of this city area is perfectly flat.

II-1-2 Area (in square kilometer)

The area of Thailand measures approximately 514,000 km², or approximately 1.4 times the whole area of Japan. Her arable land occupies approximately 120,000 km² or 25 per cent of the whole national land, and includes rice zones of 70,000 km² or 59 per cent of the total arable land.

Bangkok City, together with the environs of Thonburi City situated on the other side of the Chao Phraya River, is forming the Bangkok Metropolitan Area or the Greater Bangkok of approximately 1,549 km².

II-1-3 Population

Thailand has a population of 38,359,008 in 1972, of which 19,316,933 are male and 19,042,075 are female. Annual rate of population increase is approximately 3.2 per cent. The population is distributed as follows: Middle Region 38%, Northeast Region 34%, North Region 15% and South Region: 13%, and if broken down by age groups, it accounts for 14 or less: 42%, 15 - 59: 53%, more than 59: 4%.

Population of the Bangkok Metropolitan Area is 3,793,763 (in 1972), or about 10 per cent of the national population is observed in this area. Annual rate of population increase in the area stands for approximately 5 per cent, resulting from inflow of rural population, which is posing an affliction on Thailand.

II-1-4 Climate

Seasonal variations in temperature are not large, and climate is subtropical throughout the year. There are rainy and dry seasons: generally speaking, the former falls in May to

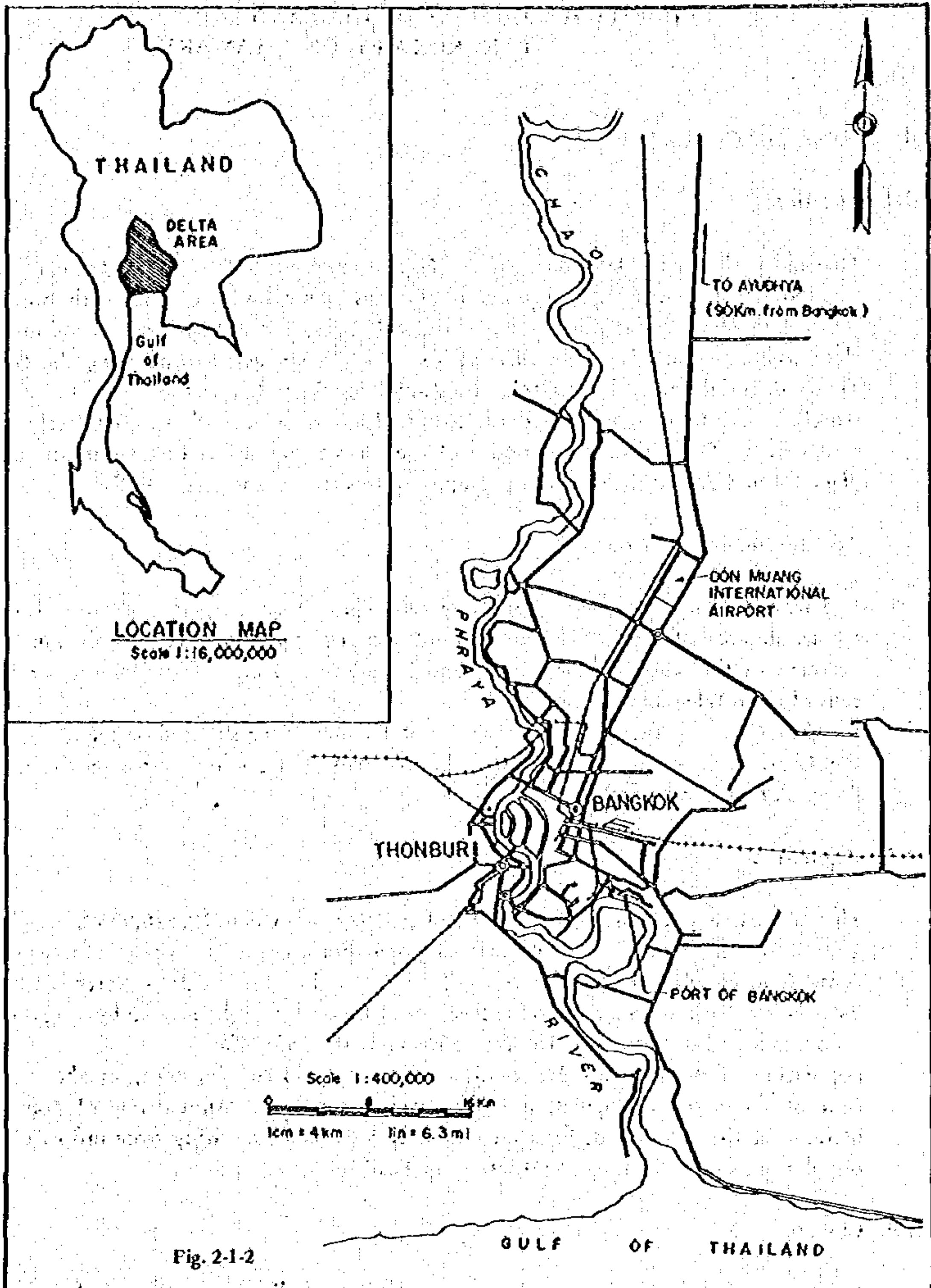


Fig. 2-1-2

GENERAL LOCATION PLAN

October, and the latter in November to April. In the rainy season, however, it rains but not all day long, and vehment squall for one or two hours with a rainfall of 100mm per hour at most.

The natural conditions of Bangkok feature rare occurrence of earthquakes and no strong wind. The maximum wind velocity ever recorded is approximately 18 m/sec. In the rainy season, lightning strikes very often.

The monthly mean maximum temperature, the monthly mean minimum temperature, the monthly mean temperature, the monthly mean relative humidity, and the monthly rainfall by region are as shown in Tables 2-1-1, 2-1-2, 2-1-3, 2-1-4 and 2-1-5 below, respectively.

Table 2-1-1 Monthly Mean Maximum Temperature in °C (1963)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Chiang Mai	29.1	33.1	34.0	36.9	33.0	32.6	31.6	30.4	30.4	31.4	28.5	27.3	31.5
Nakhon Ratchasima	32.0	35.8	36.6	37.7	36.0	35.3	33.8	33.6	33.0	30.4	28.9	28.1	33.4
Nakhon Sawan	33.0	36.4	36.6	39.6	35.9	34.7	34.4	32.9	32.2	31.9	30.5	30.0	33.9
Bangkok	32.5	33.8	33.4	35.2	34.3	33.4	33.2	32.8	32.1	32.4	30.7	30.2	32.8
Phuket	32.3	33.6	33.6	33.5	32.0	31.0	31.1	31.2	30.5	31.1	30.1	29.5	31.6
Songkhla	31.1	32.0	32.5	33.8	33.4	33.7	33.0	32.9	32.8	30.9	29.4	27.8	31.9

Table 2-1-2 Monthly Mean Minimum Temperature in °C (1973)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Chiang Mai	12.0	14.7	17.8	20.8	23.2	23.9	23.5	23.1	22.9	21.7	18.2	12.4	19.5
Nakhon Ratchasima	17.0	20.1	23.9	24.6	24.3	24.6	23.9	23.6	23.4	22.1	19.1	15.3	21.8
Nakhon Sawan	16.3	21.6	24.8	26.9	25.4	25.6	25.0	24.4	24.3	23.3	20.4	15.9	22.8
Bangkok	21.3	24.3	25.4	27.2	25.4	25.5	25.6	25.2	24.6	23.9	21.7	18.1	24.0
Phuket	23.9	24.3	24.6	25.1	24.6	24.6	24.2	24.7	23.7	24.1	23.8	23.4	24.2
Songkhla	24.1	24.4	23.6	24.3	24.1	24.4	24.0	23.9	23.6	23.8	24.1	22.9	23.9

Table 2-1-3 Monthly Mean Maximum Temperature in °C (1973)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Chiang Mai	19.6	22.7	25.1	28.7	27.3	27.4	26.7	25.9	25.9	25.9	22.6	19.0	24.7
Nakhon Ratchasima	23.9	27.2	29.4	30.3	28.7	29.0	28.0	27.8	27.1	25.8	23.7	21.3	26.8
Nakhon Sawan	25.8	29.8	30.8	33.6	30.5	30.1	29.7	28.5	28.0	28.0	25.9	23.7	28.7
Bangkok	26.2	28.4	28.8	30.5	29.2	29.0	28.6	28.3	27.6	27.5	25.6	23.6	27.8
Phuket	28.2	29.1	29.2	29.5	28.3	27.8	27.4	28.1	27.0	27.2	26.7	26.2	27.9
Songkhla	28.3	29.0	29.2	30.2	29.6	29.6	28.8	28.9	28.4	27.3	26.8	25.4	18.4

Table 2-1-4 Monthly Mean Relative Humidity in % (1973)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Chiang Mai	75	66	67	58	77	80	83	85	85	79	78	74	75
Nakhon Ratchasima	67	61	62	65	74	73	77	76	82	80	71	62	71
Nakhon Sawan	59	58	65	56	70	73	72	78	82	77	69	59	68
Bangkok	74	75	79	76	80	79	77	79	84	81	76	70	77
Phuket	69	66	69	74	80	81	83	78	83	81	81	76	77
Songkhla	74	71	72	73	75	71	74	73	75	83	84	85	76

Table 2-1-5 Monthly Rainfall in mm (1973)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Chiang Mai			86.5	4.4	163.0	128.7	233.5	330.1	295.4	30.2	25.0		1,296.8
			5days	2days	22days	17days	23days	27days	21days	11days	4days		4days
Nakhon Ratchasima		1.8	32.2	128.4	80.0	162.4	146.2	47.0	269.6	77.9	15.4		960.3
		1	5	7	18	12	18	13	21	12	7		114
Nakhon Sawan			108.6	27.4	148.3	131.2	188.6	219.2	193.2	60.1	9.3		1,085.9
			7	2	13	13	13	19	18	10	2		97
Bangkok			102.6	5.6	157.5	132.1	68.5	97.3	364.7	113.8	36.8	11.2	1,090.0
			9	2	18	16	14	20	25	15	5	1	125
Phuket	3.2	21.2	73.0	106.7	307.0	371.4	453.7	293.0	482.0	203.7	233.3	80.7	2,628.9
	2	2	7	10	21	24	21	18	25	23	23	11	187
Songkla	58.5		107.3	114.6	130.6	42.2	135.6	132.3	79.0	461.8	514.7	792.2	2,568.8
	9		9	6	16	9	14	13	9	25	28	27	165

II-1-5 Soil Conditions

Bangkok which is on an extensive alluvial plane formed by the Chao Phaya River has virtually uniform subsurface conditions. This area is covered with soft Bangkok clay of 12 - 16 m in thickness, the top several meters of which consist generally of weathered crust, slightly harder than the other part.

A layer of the stiff to hard clay, several meters thick, lies underneath the Bangkok clay layer. A highly dense gravel layer lies at a depth of 21 - 25 m. The ground water level stands generally close to the ground surface. The soft clay, therefore, containsexcessive moisture, with shearing force being markedly low. This means that the soil can be well consolidated.

The results of soil test show that the soil has a pH value of 6.5 - 8.5 and in neutral or weak alkaline base with a specific resistance of approximately 1,000 Ω-cm, indicating that the soil will be easy to become corroded. Earth temperature is virtually constant throughout the year, or 25 - 28°C at a depth of 1.5 m from the ground surface.

II-2 Outline of Economy

II-2-1 Gross Domestic Product

The gross domestic product of Thailand, when categorized by industry, accounts for agriculture with a share of approximately 1/3 which is followed by industries and commerce. The trend of shares in individual sectors in the last five years shows that the share of agriculture descreased year by year while that of industries increased, indicating a steady progress of industrialization in Thailand. The growth rates over the last five years are: electricity and water supply topped at 20.2%, followed by banking, insurance and real estate which stood at 15.1%, and manufacture at 10.5%.

Throughout the 1960's, the gross domestic product steadily increased due to a sharp rise in special procurement by the U.S. Forces and inflow of foreign capital investment. The record-high real growth of 8.5 per cent in 1968 was a turning point from which the growth rate began to slacken because of reduction in the special procurement by the U.S. Forces and deterioration of the environment for exporting primary products. In 1972, the first year of the Third Five-Year Plan registered only a 3.9% growth, far behind the target of 7 per cent, because of low agricultural production. Fortunately, the year 1973 enjoyed nice weather sufficient to expect agricultural production beyond the average year level. This certainly expresses that Thailand has recovered the growth rate. Trend of the gross domestic product is as shown in Table 2-2-1.

Trend of the gross domestic product per capita, which nearly doubled in ten years till 1972 when the value was approximately 4,000 bahts, is as shown in Table 2-2-2 and Fig. 2-2-1.

In the previous economic development policy, the elimination of in regional expenditure differentials has been aimed as one of the projected targets. However, it is likely that the differentials have still remained unchanged.

The region with the lowest expenditure level is the Northeast Region, whose level stalls at only 24 per cent of that in the Central Region including Bangkok. The South Region, a major rubber and tin producing area with a relatively high level of income, marks an expenditure of 54 per cent of that in the Central Region. Table 2-2-3 shows the expenditure levels by region.

Table 2-2-1 Gross Domestic Product by Industrial Origin and Its Growth Rates at 1962 Prices

(Million Baht)

	1968		1969		1970		1971		1972	
	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%
Agriculture	32,799	31.5	35,161	31.3	36,158	30.2	38,136	30.0	36,229	27.4
Mining and quarryment	1,733	1.7	1,810	1.6	1,848	1.6	1,935	1.5	1,850	1.4
Manufacturing	16,594	15.9	18,609	16.6	20,622	17.2	22,621	17.8	25,109	19.0
Construction	6,944	6.6	7,045	6.3	7,076	5.9	6,927	5.4	7,204	5.4
Electricity and water supply	1,441	1.4	1,562	1.4	1,861	1.6	2,248	1.8	2,685	2.0
Transportation and communication	6,818	6.5	7,289	6.5	7,843	6.6	8,305	6.5	8,704	6.5
Wholesale and retail trade	17,722	17.0	18,754	16.7	19,981	16.7	21,082	16.6	22,396	16.9
Banking, Insurance and real estate	3,507	3.4	4,056	3.6	4,781	4.0	5,264	4.1	5,768	4.4
Ownership of dwelling	2,092	2.0	2,202	2.0	2,294	1.9	2,393	1.9	2,500	1.9
Public administration and defense	4,409	4.2	4,725	4.2	5,915	4.3	5,559	4.4	6,059	4.6
Services	10,227	9.8	10,941	9.8	11,945	10.0	12,780	10.0	13,794	10.4
Total	104,286	100.0	112,155	100.0	119,604	100.0	127,250	100.0	132,299	100.0
Index	100		108		115		122		127	

Source: Bank of Thailand Monthly Bulletin

Table 2-2-2 Per Capita G.D.P. at Current Prices

(Million Baht)

Year	Amount	Year	Amount
1964	2,411	1969	3,520
1965	2,633	1970	3,603
1966	3,064	1971	3,737
1967	3,166	1972	3,994
1968	3,303	1973 (Estimated)	4,539

Source: Bank of Thailand Monthly Bulletin

Fig. 2-2-1 Per Capita G.D.P. of Asian Nations (in U.S. Dollars) 1971

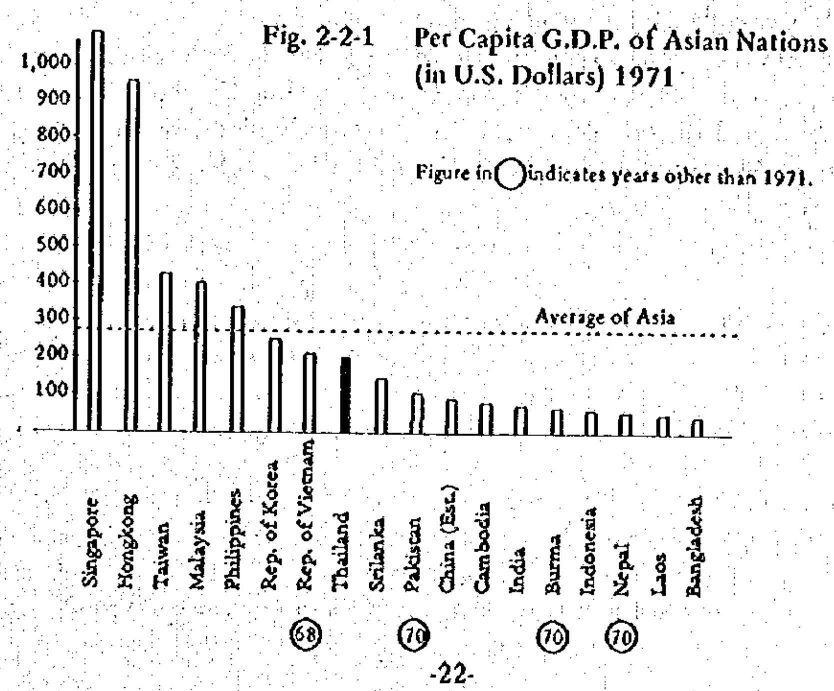


Table 2-2-3 Expenditure per Capita (Nominal) by Region, 1971

	Gross domestic product (10^9 bahts)	Expenditure per capita (dollars)	Ratio (%)
North Region	21.2	129	37
Northeast Region	21.4	84	24
Central Region	84.8	346	100
South Region	17.2	187	54

II-2-2 International Balance of Payments

The characteristics of Thai international balance of payments can be observed in the fact that Thailand has continued to register foreign trade deficits for the last several years and such deficits have been made up even by foreign private investments, credits, and earnings from the special procurement by the U.S. Forces and cash flow from tourists. Foreign currency reserve hit the bottom in 1970 when Thailand reserved only 767 million dollars, and since then was continuously increasing to 1.5 billion dollars in June, 1974. Such an increase in foreign currency reserve, despite of growing deficits in foreign trade, is due, not only to the policy to restrict imports by raising customs duties, and also to the recovering world market of agricultural products, but to the inflow of hot money for the most part.

Table 2-2-4 Transition of International Balance of Payments

(Million U.S. dollars)

	1968	1969	1970	1971	1972
Foreign trade balance	Δ 512	Δ 543	Δ 589	Δ 484	Δ 409
Invisible trade balance	298	281	291	260	324
Trasnferred balance	74	57	49	43	39
Capital income balance	116	125	101	83	186
Errors and omissions	46	36	21	81	51
Overall balance of payments	22	Δ 44	Δ 127	Δ 17	Δ 191

Table 2-2-5 Gold and Foreign Exchange Rserves

(Million U.S. dollars)

Period	Gold	Reserve Position in IMF	Foreign Exchange	Total	Period	Gold	Reserve Position in IMF	Foreign Exchange	Total
1965	96	19	590	705	1970	82	34	651	767
1966	92	24	748	864	1971	89	52	636	777
1967	92	24	800	916	1972	89	67	813	969
1968	92	24	822	938	1973	99	75	908	1,082
1969	92	24	778	894	1974(Jun.)	99	75	1,344	1,518

Source: Bangkok Bank Monthly Review

Table 2-2-6 Foreign Trade

Exports (F.O.B.) (Million Bahts)

	1969	1970	1971	1972	1973	%
Japan	3,192	3,770	4,277	4,660	8,410	26.1
United States	2,168	1,985	2,264	2,841	3,275	10.2
West Germany	510	533	640	556	770	2.4
United Kingdom	406	305	435	368	662	2.1
Hongkong	1,156	1,113	1,152	1,674	2,362	7.3
Malaysia	1,079	830	731	1,120	1,952	6.1
Singapore	1,154	1,018	1,225	1,955	2,661	8.3
Taiwan	635	720	498	830	1,308	4.1
Others	4,422	4,498	6,059	8,487	10,826	33.4
Total	14,722	14,722	17,281	22,491	32,226	100.0

Imports (C.I.F.) (Million Bahts)

	1969	1970	1971	1972	1973	%
Japan	9,515	10,107	10,093	11,401	15,078	35.7
United States	3,922	4,011	3,807	4,841	5,915	14.0
West Germany	2,354	2,288	2,075	2,279	3,211	7.6
United Kingdom	2,034	2,014	2,054	1,620	2,715	6.4
Hongkong	411	374	314	417	589	1.4
Malaysia	248	145	456	490	385	0.9
Singapore	294	263	215	435	598	1.4
Taiwan	617	603	747	1,058	1,383	3.3
Others	6,571	7,204	7,033	8,334	12,310	29.3
Total	25,966	27,009	26,794	30,875	42,184	100.0

Source: Bank of Thailand Monthly Bulletin

II-2-3 The Third Economic Development Plan

The Economic Development Plans of Thailand have been established and put into effect since 1961 when the First Plan started and this required six years. The Second Plan continued for five years from 1967. The Third Plan began in 1972 and are scheduled to be completed in 1976.

The First Economic Development Plan marked a high average annual economic growth rate of 8.1 per cent surpassing its original target of 6 per cent. With the population increase of 3.2 per cent taken into account, the increase of national income per capita recorded a 4.8 per cent increase.

The Second Plan, encouraged by the success of the First Plan, set an ambitious layout with the target of a 8.5 per cent growth per year, but actually its attainment was somewhat below 7.2 per cent.

The Third Plan now in progress was worked out to relieve stresses accumulated by the economic growth of the 1960's during which period the increased import of capital goods and raw materials had aggravated foreign trade balance; the agricultural sector still remained low in efficiency; and public investment was not sufficient. With a view to overcoming these problems, the Plan was established with emphasis on the promotion of export industries and the diversification of agriculture.

The principal points of the Third Economic Development Plan are:

(1) To make the economic structure adaptable to varying environmental conditions so as to increase production and income.

(2) To keep the economy stabilized.

(3) To accelerate the economic growth of local regions and reduce income differentials.

(4) To establish social equillibrium.

(5) To implement educational programs and to increase employment opportunities.

(6) To promote regional development by private enterprises.

Specific target values for the abovementioned principal points are as follows:

(1) Economic growth rate per year: 7%

(2) Increase rate of annual income per capita: 4.2%

(3) Increase rate of agricultural production per year: 5.1%

(4) An appropriate amount of foreign currency reserve

(5) Export growth rate: 7%

Import growth rate: 2.8%

In contract to the First and Second Plans which laid emphasis on economic growth and development of infrastructure, the Third Plan is construed that it place stress on the promotion of exports and the accumulation of appropriate level of foreign currency reserve so as to establish a stable economy with respect to a long-term aspect.

The records and targets of gross domestic product categorized by industry are as shown in Table 2-2-7.

Table 2-2-7 Gross Domestic Product (Based on 1962 Price)

(Billion Baht)

	1971 (Results)		1976 (Target)		Average Annual Growth Rate	
	Amount	%	Amount	%	1967-71	1972-76
Agriculture	38.1	29.9	47.8	26.8	4.1	5.1
Mining & quarryment	1.9	1.5	2.8	1.6	8.3	6.0
Manufacturing	22.6	17.8	31.4	17.6	9.2	8.0
Construction	6.9	5.4	11.7	6.6	8.4	6.5
Electricity & water supply	2.3	1.8	3.9	2.2	19.0	15.0
Transportation & communication	8.3	6.5	11.5	6.5	7.5	6.0
Wholesale & retail trade	21.1	16.6	29.3	16.4	7.7	7.0
Banking, Ins. & Real estate	5.3	4.2	11.0	6.2	14.4	15.0
Ownership of dwelling	2.4	1.9	2.7	1.5	4.1	2.5
Public administration & defense	5.6	4.4	7.6	4.3	10.0	6.0
Services	12.8	10.0	18.5	10.3	8.8	7.0
Total	127.3	100.0	178.2	100.0	7.2	7.0
Per Capita G.D.P. (Baht)	3,380		4,132		4.0	4.2

II-2-4 Commodity Prices

In the past, prices in Thailand showed a very stable trend in spite of the worldwide tendency in which prices have been continuously rising. However, in 1972, prices started spiralling and this trend gained momentum from 1973 to 1974. As for consumer's prices foodstuff prices and traffic charges are showing sharp increases whereas wholesale prices of foodstuff, construction materials and chemical products are also not exceptions. It is remarkable that the unusual rise of foodstuff prices which share 50% among the consumer's price index is pressing the living of the people.

Although these phenomena are partly due to price-rising manipulation at their distribution stages and the shortage of goods, it should be noted that they have emerged from the effects created multiplicatively by the inflationary trend of the world and the rising import prices due to international adjustment of currencies. This reflects the fact that the Thai national economy has been gradually joining the flow of the inernational economy.

The consumer's price index in Bangkok Metropolitan area and the wholesale price index in the State are shown in Tables 2-2-8 and 2-2-9, respectively.

Table 2-2-8 Consumer Price Index for Bangkok Metropolitan Area by Groups (Oct. 1964 – Sept. 1965 = 100)

Period / Weights	All items	Food	Clothing	Housing	Personal and Medical care	Transportation	Recreation reading and education	Tobacco and alcoholic beverages
Weights	100.0	49.0	9.4	17.8	7.2	6.1	5.6	4.9
1965	100.3	100.1	99.9	100.6	100.2	100.3	100.1	100.0
1966	104.1	106.6	100.4	102.2	104.0	99.0	101.5	99.9
1967	108.2	114.2	100.4	102.2	107.9	99.0	101.8	99.9
1968	110.5	118.1	100.7	103.0	107.9	102.8	101.9	99.9
1969	112.8	122.8	100.5	104.1	107.9	99.0	101.9	99.9
1970	113.7	123.1	102.4	106.7	108.1	100.1	101.7	100.4
1971	116.0	123.9	103.3	110.3	110.9	112.4	106.1	101.2
1972	120.6	131.8	104.3	111.5	113.9	113.2	107.4	101.2
1973	134.8	150.8	119.2	120.3	118.1	129.0	114.8	103.7
1973 Aug.	134.8	150.0	121.9	121.1	118.5	124.9	120.2	101.2
1974 Aug.	170.5	200.2	146.2	131.3	138.7	180.9	138.3	116.8

TABLE 2-2-9 Wholesale Price Index for Thailand by Groups

Period / Weights	All items	Agricultural Products	Food-stuffs	Textiles and Textile Products	Construction Materials	Chemicals and Chemical Products	Transportation Equipment	Machinery and Equipment
Weights	100.00	28.43	21.31	6.46	7.66	5.50	6.18	7.24
1968	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1969	103.3	104.5	98.9	104.6	103.2	108.8	100.3	100.4
1970	102.8	100.5	93.7	106.9	105.6	116.1	108.9	104.2
1971	103.1	98.4	95.1	107.6	102.6	120.0	120.0	106.8
1972	111.2	109.4	106.8	110.9	106.7	127.8	132.2	110.2
1973	136.6	134.6	134.4	129.3	143.3	158.0	155.9	129.9
1973 Aug.	139.9	139.1	131.7	130.2	145.5	155.6	158.9	136.3
1974 Aug.	181.5	177.1	191.0	159.0	198.3	220.5	200.1	159.5

Source: Bank of Thailand Monthly Bulletin

II-2-5 Future Development Plan of Bangkok Metropolitan Area

The latest development plan for the Bangkok Metropolitan Area is called the Greater Bangkok Plan, prepared by the Department of Town and Country Planning, Thai Government. The draft of the Plan has not yet been formally sanctioned, but has been promoted in live with the spirit thereof.
The draft is summarized as follows:

II-2-5-1 Project

The project area covers the land of approximately 732 km^2 centered on Bangkok City which is located in the Bangkok Metropolitan Area of 1,550 km^2.

II-2-5-2 Population

Population of the Project Area in 1990 is presumed to reach 6,500,000. This seems to be a much conservative figure when compared with the approximate 10 million persons as estimated on the basis of the current rate of 5.1% annual population increase. In order to achieve the target population, the following counter-steps are established.

(1) To encourage outflow of population by promoting the economic development in urban areas outside the Bangkok Metropolitan Area.

(2) To facilitate transfer of population by developing and improving traffic facilities

(3) To plan regional development as part of the national policies.

(4) To promote household planning.

II-2-5-3 Land Utilization Plan

The land utilization plan is classified as follows:

(1) Housing zone

For the housing zone, the area of 416 km^2 or approximately 57 per cent of the total Project Area is required. The estimated population of the housing zone will be 5,810,000 or 89 per cent of the total population of the Project Area. The housing zone is subdivided into high, medium and low density zones, area of which is 32 km^2, 224 km^2 and 160 km^2, respectively, with each population density levels standing at 32,500 persons/km^2, 16,700 persons/km^2 and 7,500 persons/km^2.

(2) Commercial zone

The commercial zone requires the area of 44.3 km^2, 32 km^2 of which is planned to be the commercial complex to concentrate commercial activities.

(3) Industrial zone

The area of 84.3 km^2 is allocated as the industrial zone. The industries which may pollute their environs are to be disposed isolating from the housing zone, while those of non-pollution character are to be located where expedient for production and transportation.

(4) Government-office zone

The government-office zone requires the area of 63.1 km^2.

(5) Parks and green zones

The parks and green zones require the area of 62.4 km^2.

In Fig. 2-2-2, the land utilization plan is mapped out.

II-3 Utilities in the Bangkok Metropolitan Area

At present, no town gas is distributed in the Bangkok Metropolitan Area. Fuels used by

households in general are LPG in cylindrical containers, charcoal, etc. Utilities in this area consist of roads, electricity, telephone, water supply, and sewerage. These facilities are widespread to a considerable extent.
They are as outlined in the following subparagraphs.

II-3-1 Roads

Most roads are constructed by reclaiming former waterways called 'Khlons'. They are wide with surfaces well paved. However, the khlons still existing constitute big obstacles to road construction work. The ratio of the existing roads in the area is 10 per cent, only less than half the ratio of the roads in large cities in the world. Improvement and construction of new roads can hardly come up with the rapid increase of population. Because these roads are the only media for traffic and transport in the city, they are highly conjested.
Development of business towns and housing zones is made along highways planely. This means that traffic conditions will become worse year by year. The presently proposed construction works include three circular roads and each one bridge in Bangkok and Thonburi. A new comprehensive traffic survey has been under way since 1970 with the aid of West Germany, for which good result will be expected.
The number of registered motor cars in Bangkok and Thonburi Metropolitan Cities, as officially announced by the Traffic Improvement Committee stood at 303,748 in 1970, and since then has been increasing by more than 20,000 cars annually. Breakdown of the registered motor cars is as follows:

Bus	4,194
Truck	40,749
Passenger car	203,488
Motor cycle	55,317
Total	303,748

II-3-2 Electricity

Today, the electric power administration of Thailand is in the hand of the National Energy Administration (NEA) a division of the Office of Undersecretary of the Prime Minister. NEA is an agency engaged in planning and coordination of the national comprehensive development projects. The electric enterprises are engaged in by the Electricity Generating Authority of Thailand (EGAT) in the sector of power generation and transmission and the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA) in the sector of power distribution.

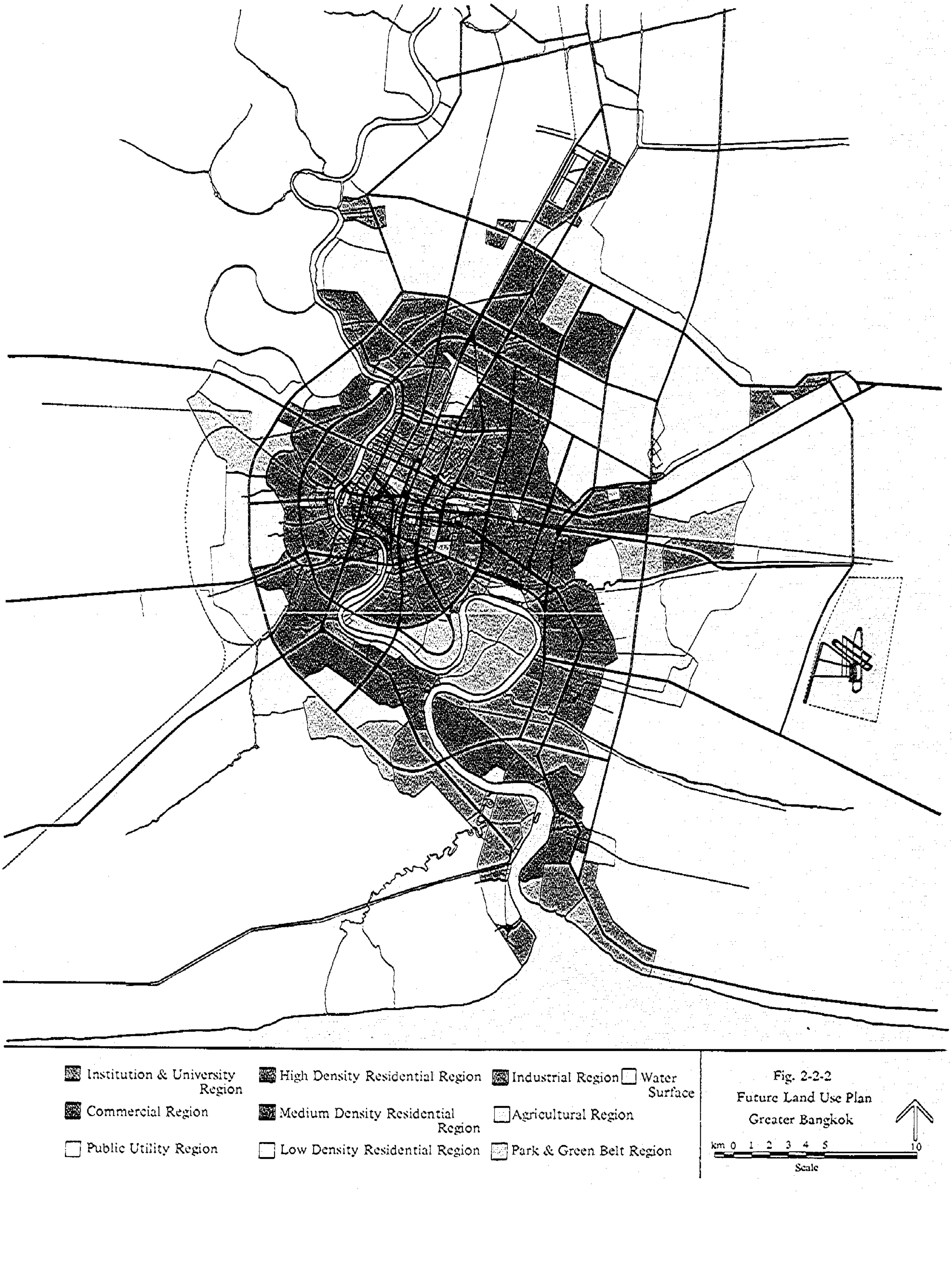


Fig. 2-2-2
Future Land Use Plan
Greater Bangkok

II-3-2-1 Power Generating Capacity

Capacity of the existing electric power generating plants as of 1973 is classified by the type of generation as below.

Hydro electric	15 plants	515,300 kw	(35.56%)
Thermal	12 plants	740,000 kw	(51.07%)
Gas turbin	11 plants	165,000 kw	(11.39%)
Diesel	34 plants	28,600 kw	(1.95%)
Total	72 plants	1,448,900 kw	

Major power generating plants in these plant groups are North Bangkok Thermal Plant (237.5 MW), South Bangkok Thermal Plant (400 MW) in Bangkok and Bunibol Hydro Power Plant (420 MW) in North Thailand. The combined total capacity of these three largest plants shares approximately 73 per cent of all Thai power plant capacity.

The gross generation of all Thai power plants is $6,872.84 \times 10^6$ kWH, of which thermal generation share 71.5 per cent and for recent several years this figure has been increasing every year by approximately 20 per cent.

II-3-2-2 Power Consumption in Bangkok Metropolitan Area

MEA is undertaking power distribution for the Greater Bangkok Area (population: 4,740,000 in 1972), the outline of which, as of 1972, is as follows:

The number of consumers stand at 418,377 of approximate 63 per cent of the total consumers in the Greater Bangkok, which is equivalent to 38.5 per cent of those in all Thailand. Power sales accounts for $3,675 \times 10^6$ kWH, representing 70 per cent of all Thailand power sales, and is increasing at a rate of 18 per cent per annum.

Present capacity of MEA's power distribution is 1,000 MW, which is sufficient to meet demand with a considerable margin.

What is to be noted here is that, during 1959 through 1966, the standard high and low distribution voltages were changed to higher levels. It is said that, by this voltage change, the loss in distribution lines was reduced to only 7 per cent from the previous 20 per cent.

The existing high voltage power transmission consists of 69 kV, 24 kV and 12 kV while the power distributed to domestic consumers is at 220 V, 50 Hz.

Electric charges are subject to the approval of the Government. They have been revised to lower levels every or every other year up to 1972 when charges were raised because of the occurrence of oil crisis, and have continued unchanged up to the present.

The transition of electric charges for domestic use is given in Table 2-3-1.

Table 2-3-1 Transition of Electricity Rates for Domestic Use

	1966	1968	1970	1972	1974
First 5 kWH	5.00	5.00	5.00	5.00	5.00
Next 45 kWH	0.75/kWH	0.73/kWH	0.72/kWH	0.70/kWH	0.70/kWH
Next 100 kWH	0.67/kWH	0.65/kWH	0.63/kWH	0.62/kWH	0.72/kWH
Next 350 kWH	0.55/kWH	0.54/kWH	0.53/kWH	0.52/kWH	0.74/kWH
Balance	0.45/kWH	0.44/kWH	0.42/kWH	0.41/kWH	0.78/kWH
Minimum charge	5.00	5.00	5.00	5.00	5.00

As can be seen from the above transition, the diminishing system for the charges classified by consuming volume had been adopted until 1972 and after the oil crisis it was changed to gradual increase system. Another remarkable feature is that the electric charges in the area outside the Greater Bangkok are higher than those in the Greater Bangkok by approximately 50 per cent.

II-3-3 Telephone

Telephone service is operated by the Telephone Organization of Thailand (TOT), a state enterprise. During the past ten years, the number of subscribers have been increased by more than four-fold. TOT introduced the microwave communication system into the trunk toll line circuits, and the crossbar automatic exchange system into the exchangers, both in a full scale, as part of TOT's efforts to improve telephone service.

Presently, the additions and improvement of telephone facilities are under way in a steady pace under the Third Infrastructure Development Five-year Plan.

The development of telephone facilities in the Bangkok Metropolitan Area is shown in Table 2-3-2.

The total number of telephone sets provided in Thailand in 1973 stands at 254,896, approximately 80 per cent of which are gathered in Bangkok.

Table 2-3-2 Growth in the Past 5 Years

	1969	1970	1971	1972	1973
Telephone Exchanges	13	14	21	23	23
Capacity	74,340	84,285	156,944	162,700	162,700
Line Assigned	56,395	66,384	105,550	127,291	133,440
Telephone Instruments	103,988	118,809	161,192	190,136	201,731

The total number of telephone sets provided in Thailand in 1973 stands at 254,896, approximately 80 per cent of which are gathered in Bangkok.

II-3-4 Water Supply

Water supply to the Bangkok Metropolitan Area is managed by the Metropolitan Water Works Authority (MWWA), a State enterprise. The annual water consumption in 1973 recorded 440 x $10^6 m^3$, 70 per cent of which was fed from treatment plants, and 30 per cent from deep wells. The service water is not suitable for drinking due to the lack of perfect water treatment plants.

The consumers amount to approximately 280,000. Water consumption and the number of consumers during the last five years are shown in Tables 2-3-3 and 2-3-4.

Table 2-3-3 Surface and Ground Water Supply Rates in $10^3 m^3/D$

	1969	1970	1971	1972	1973
Surface Water	585.8	609.9	625.4	742.5	844.1
Ground Water	309.8	307.6	333.7	363.5	368.7
Total	895.6	917.5	959.1	1,106.0	1,212.8

Table 2-3-4 Number of Consumers Based on the Number of Meter Connections

	1969	1970	1971	1972	1973
Bangkok	159,761	169,093	175,838	181,690	185,947
Thonburi	80,181	80,701	84,055	89,063	86,133
Nonthaburi		3,314	3,946	4,482	5,070
Samut Prakan		2,940	3,104	3,254	3,337
	239,942	256,048	266,943	278,489	280,487

It is likely that considerable regions are insufficiently supplied with service water. This trend seems to grow stronger in the future as population increases and industrialization progresses. In order to overcome this problem, a considerably large-scale plan has been worked out to set the target water consumption of 5,500,000 tons per day in the last year of the plan in 2,000, at which time about 8,400,000 people will be provided with the water supply. This plan was projected by Camp Dresser & MacKee, a US consulting engineer, and the first stage construction work is now going on.

The total number of employees of MWWA counts 5,500. Present water charges are as shown in Table 2-3-5, and it is noteworthy that no raise in the water charges was made in the last several years. The gradually diminishing rates system has been in practice.

Table 2-3-5 Water Charges

0 - 6 m^3	Free of charge
6 - 12 m^3	0.5 bahts/m^3
12 - 25 m^3	1.0 bahts/m^3
25 - 50 m^3	1.5 bahts/m^3
50 - 200 m^3	2.0 bahts/m^3
More than 200 m^3	2.5 bahts/m^3

II-3-5 Sewerage

Sewerage is under the control of the Bangkok Municipal Office. Although sewerage is provided in all trunk roads, sewage is directly discharged into khlons because of no final treatment plant, and this has been spoiling the khlons to a great extent.

Since the ground level of Bangkok is nearly zero meter above the sea level, water drainage depends largely upon pumping. The present shortage in the pumping capacity causes most roads to be flooded particularly in the rainy season and the traffics to be congested.

To solve this problem, the Thai Government has contracted with Camp Dresser and McKee for the carrying out a study to establish a practical plan, incluidng designs. The project includes the construction of a separate sewer system in both Bangkok and Thomburi Cities totaling 400 km^2, as well as the flood prevention work in the down-stream of the Chao Phraya River and the building of sewage water treatment plants. Some of them are now under construction.

II-4 Energy Situation in Thailand

II-4-1 Transition in Energy Sources

As of 1973, energy sources in Thailand consist of crude oil, coal, hydraulic power, charcoal, firewood, paddy husk, bagasse, etc. Crude oil shares 87 per cent of the whole energy sources, playing the most important role.

Other potential energy sources include oil shale and uranium, but are far from practical use.

A total oil shale deposit of 480 x 10^6 barrels (in terms of crude oil) has been confirmed at Amphur Mae Sod in Tak Province and Amphur Lee in Lampoon Province, but not yet industrialized because of its refining cost.

Uranium content of 5.74 – 15.25 per cent has been confirmed in the water of Phuket Songlka tin mine. Nuclear power plant is being planned by using this uranium.

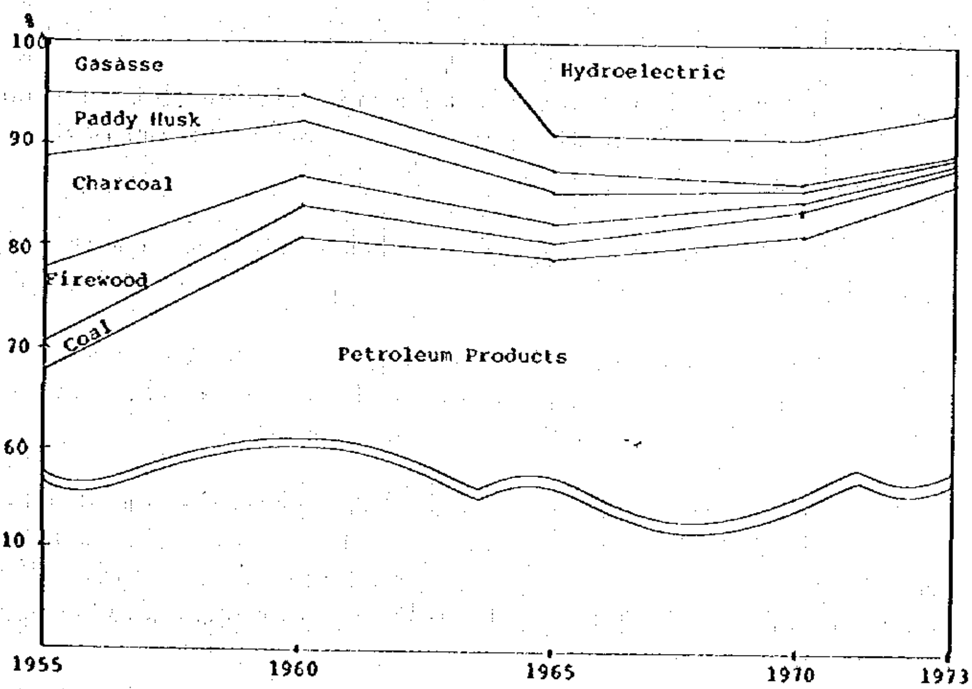
Historically, coal, firewood, paddy husk, and bagasse used to be the main energy sources until 1954.

For this year, however, the world-wide ocnversion of energy sources from solid fuels to liquid ones, which is called the energy revolution, as well as the reduced, forest area due to the development of industry and the increase of population (increase in housing area), has caused the petroleum series fuels to have the leading part of it in this country.

Thailand, however, is not rich in underground resources. Despite the Thai Government's devoted efforts, domestic petroleum production has stalled at 1,000 barrels per day, or only 0.7 per cent of the whole demand for oil.

Thailand produces all coal at home. Coal is originated from Mae Moh lignite mine, Krabi lignite mine, and Lee coal mine, totaling 1,000 to 2,000 tons per day. Lignite is used mainly in thermal power plants and coal mainly in tobacco plants, etc.

Fig. 2-4-1 Ratios of Energy Sources Distributed in Thailand in Percentage



Hydraulic power is used principally for generating in hydroelectric power plants, taking advantage of much rainfall.

The transition of energy resources composition in Thailand is shown in Figure 2-4-1.

II-4-2 History of Energy Consumption

Energy consumption in Thailand is rapidly increasing. Through the past 10 years until 1973, the total energy consumption has increased approximately by 4.5 times, and a per capita energy consumption increased approximately by 3.2 times, (refer to Fig. 2-4-2).

The rate of increase in energy consumption surpasses considerably those of GNP at 3.87 per cent and population increase at 3.5 per cent per year, as shown in the table 2-4-1, and also the average of world consumption.

In the absolute values, however, the levels of Thailand are far below the world average. (Refer to Fig. 2-4-3.)

In the Bangkok Metropolitan Area which accounts for only 12 per cent population of the whole country, it consumed 63.7 per cent or more than half of the national energy consumption in 1969. (Refer to 2-3-4.) A per capita energy consumption in the Bangkok Metropolitan Area stands at 1.1 tons in coal equivalent.

Figure 2-4-5 shows the national energy consumption by region.

II-4-3 Energy Balance

As mentioned above, Thailand depends on the imported energy, because it produces very limited crude oil at home althougoh the energy revolution has shifted the main energy from solid to liquid fuels.

The demand for energy is very high in the Bangkok Metropolitan Area, and 92 per cent of it is met by petroleum energy in 1969.

Dependence upon imported energy sources is growing as the energy consumption of all kinds increases. The rate of dependency was 40 per cent in 1954 and 86 per cent in 1973. The relationship between them is shown in Fig. 2-4-6.

Of all domestically produced energies, hydroelectric power shares most at 44.9 per cent, which is followed by bagasse at 33.4 per cent and coal at 10.1 per cent. Development of hydraulic power generation has been vigorously continued. Potentially, hydraulic power exploitable will presumably be 3,182 x 10^{10} Kcal, or equivalent to 2.5 times the total produced energy in this country.

Fig. 2-4-2 Energy Consumption

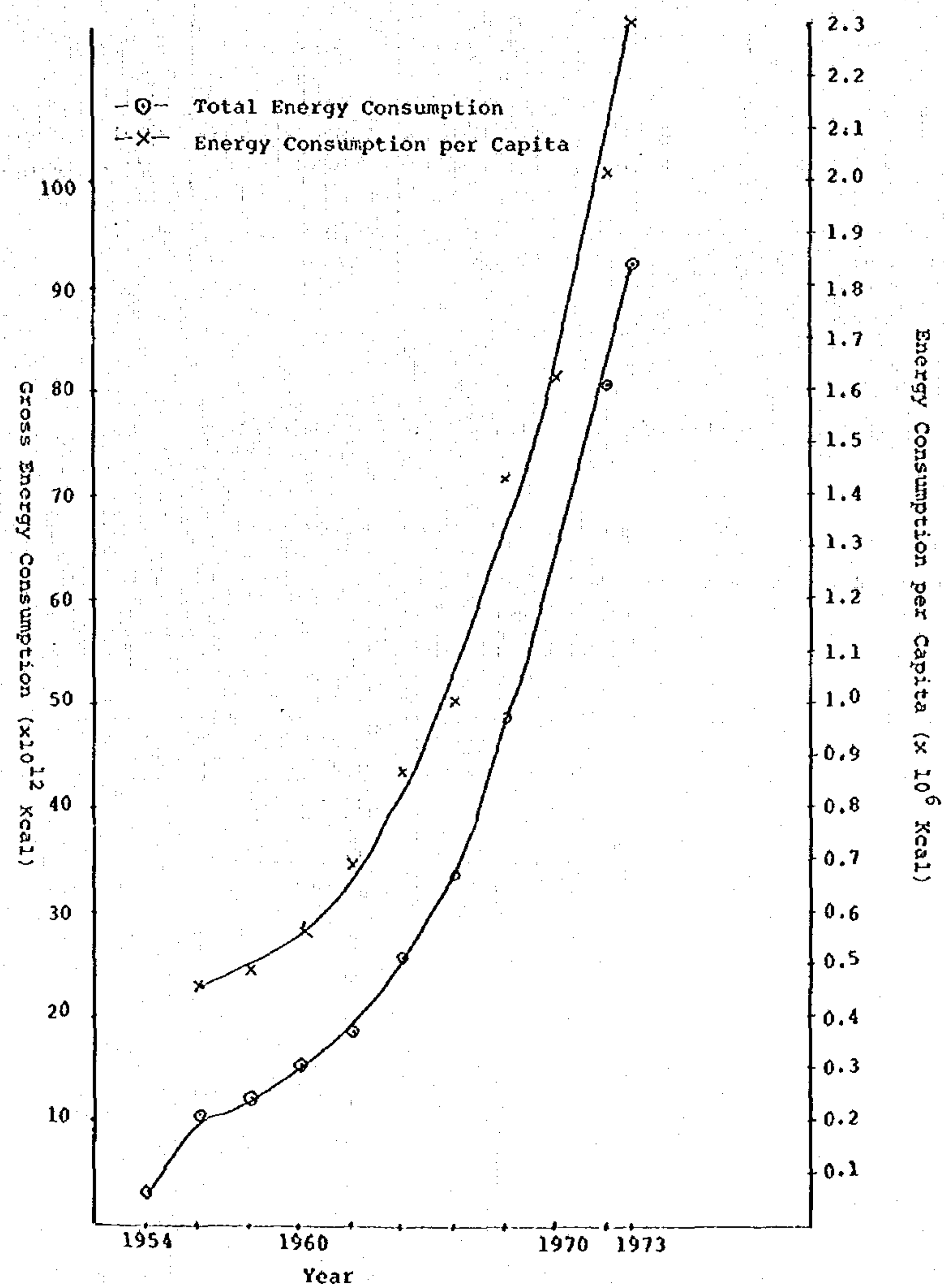


Table 2-4-1 Rates of Increase in Energy Consumption, Population, and Gross National Product

	Total energy consumption	Energy consumption per capita	Population	GNP
1963	20.6×10^{12} kcal	0.73×10^{6} kcal	$28{,}312 \times 10^{3}$ persons	2,440 bahts per capita
1973	92.0×10^{12} kcal	2.30×10^{6} kcal	$29{,}946 \times 10^{3}$ persons	3,568 bahts per capita
1973/1963	4.47	3.15	1.41	1.46
Average rate of increase	16.1%/year	12.2%/year	3.5%/year	3.87%/year
World average rate of increase	5.1%/year	3.1%/year	2%/year	

Fig. 2-4-3 Energy Consumption and Gross Domestic Product of World Countries

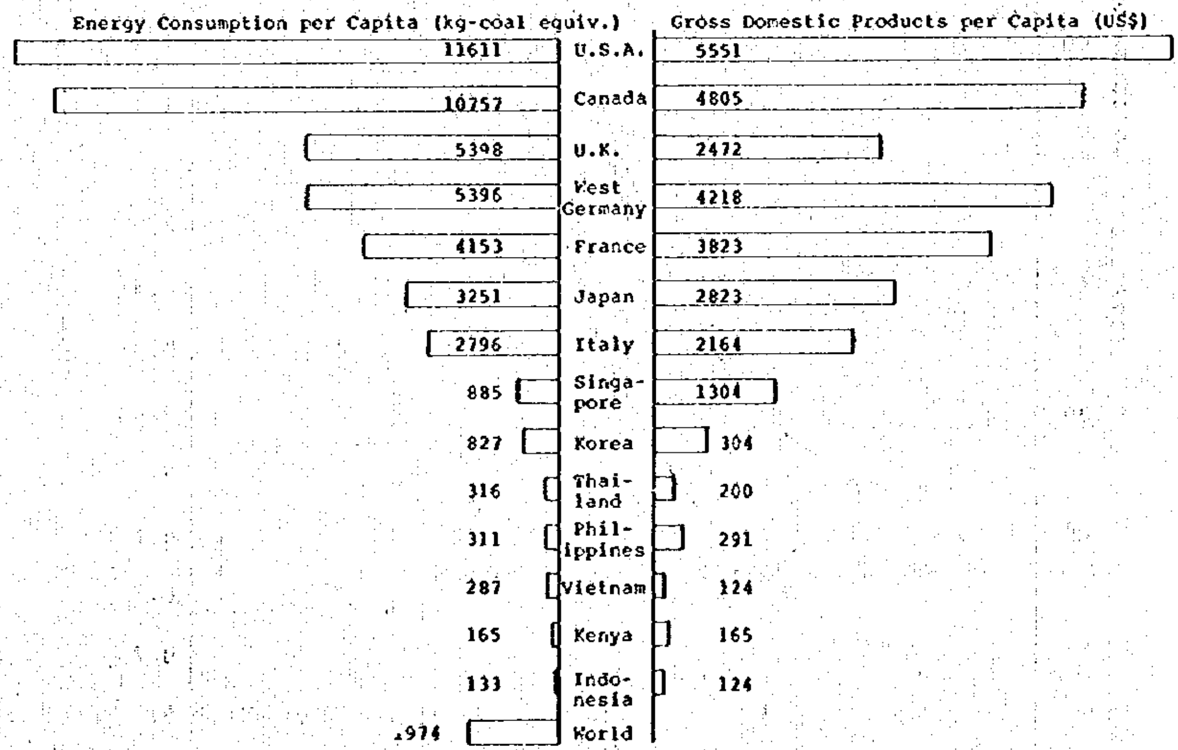


Fig. 2-4-4 Energy Consumption per Capita kg-coal equivalent (Year 1969)

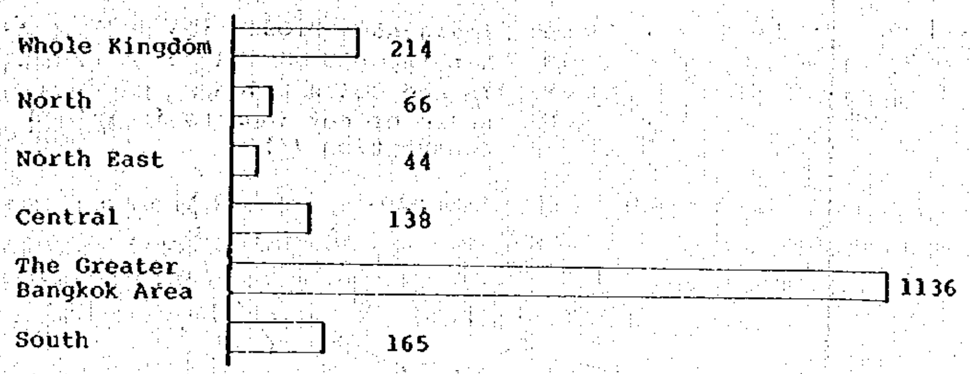


Fig. 2-4-5 Energy Consumption by Region (1969)

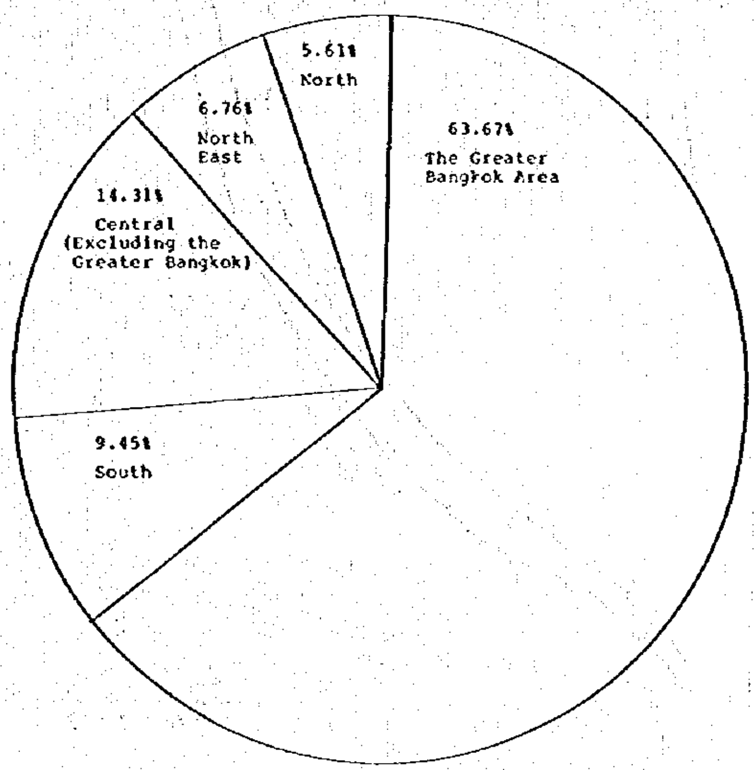
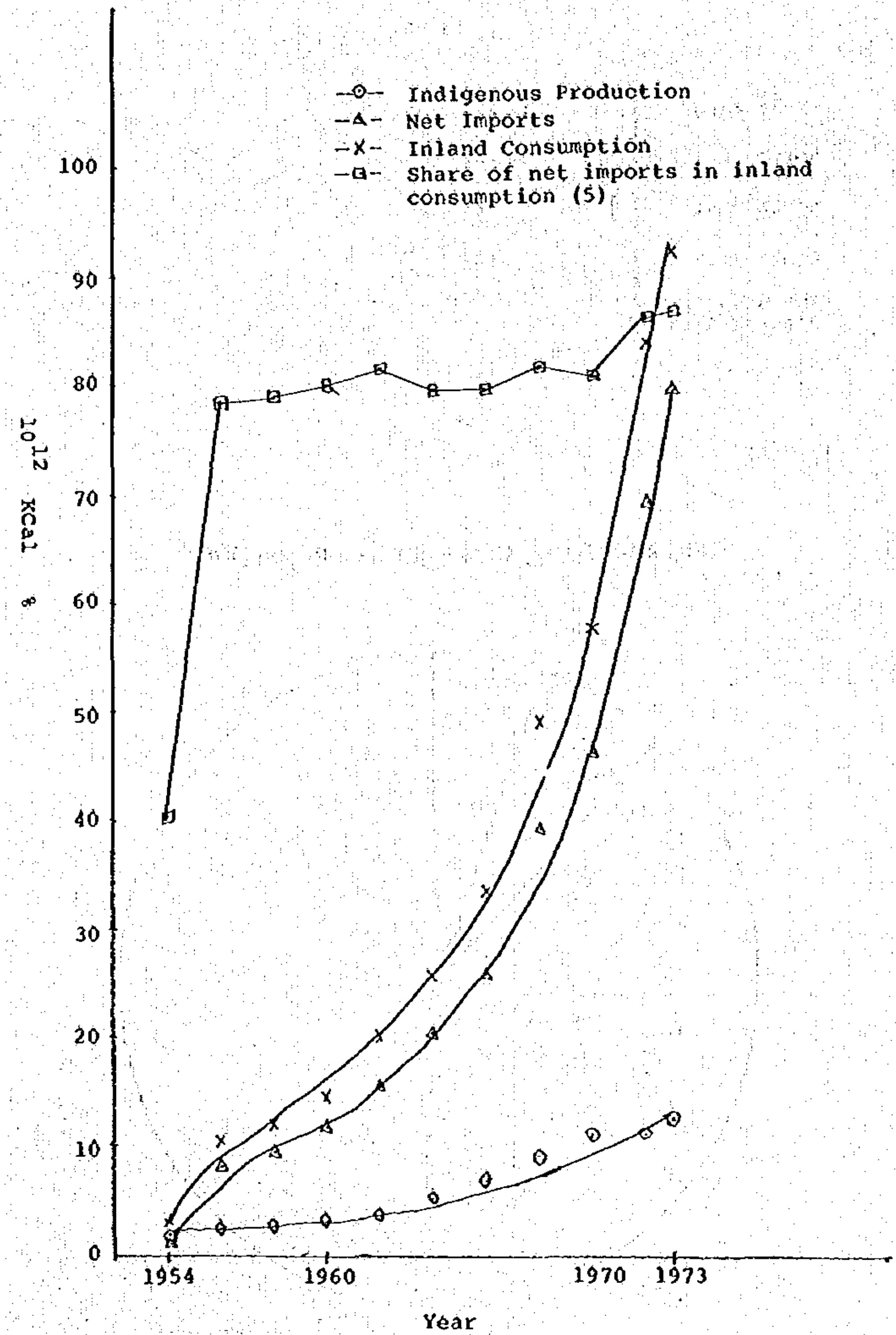


Fig. 2-4-6 Gross Energy Balance



II-4-4 LPG (Liquefied Petroleum Gas)

In 1973, the consumption of LPG stood at 2,116 x 10^9 Kcal (approximately 180,000 tons) sharing only 2.7 per cent of petroleum products and 2.3 per cent of the total energy consumption of Thailand according to the 'Energy Situation of Thailand' compiled by NEA. But the ratio of increase during the past ten years (1963 - 1973) amounts to 300 times, which figure is the largest value recorded in all kinds of energy consumption.

The consumption of LPG before 1960 used to be less than 100 tons per annum, entirely depending on imports. Oil refineries were built in Thailand during 1964 through 1969 and this reflected on the rapid increase of LPG yearly consumption starting from 1964. Today, LPG is recognized as the main fuel for domestic use.

Particularly in the Bangkok and Thonburi areas, approximately 80 per cent of all the national LPG consumption is consumed (as of 1969), showing that households have been shifting from charcoal, fuel wood and kerosene to LPG in parallel with enhancement of their standards of living.

Metropolitan Areas will grow, and this trend will continue.

Figure 2-4-7 shows the consumption of LPG by region and Fig. 2-4-8 indicates the trend of LPG consumption.

Fig. 2-4-7 LPG Consumption by Region (1969)

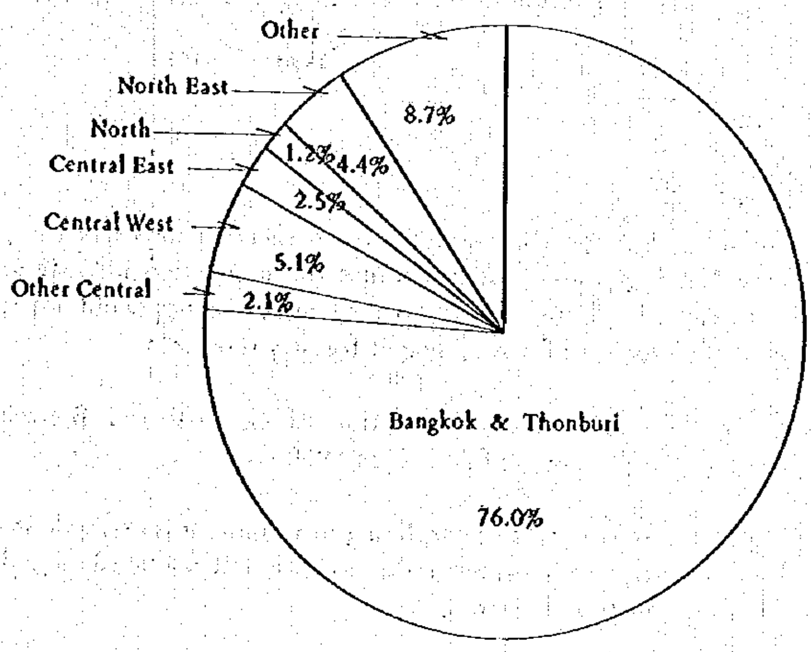
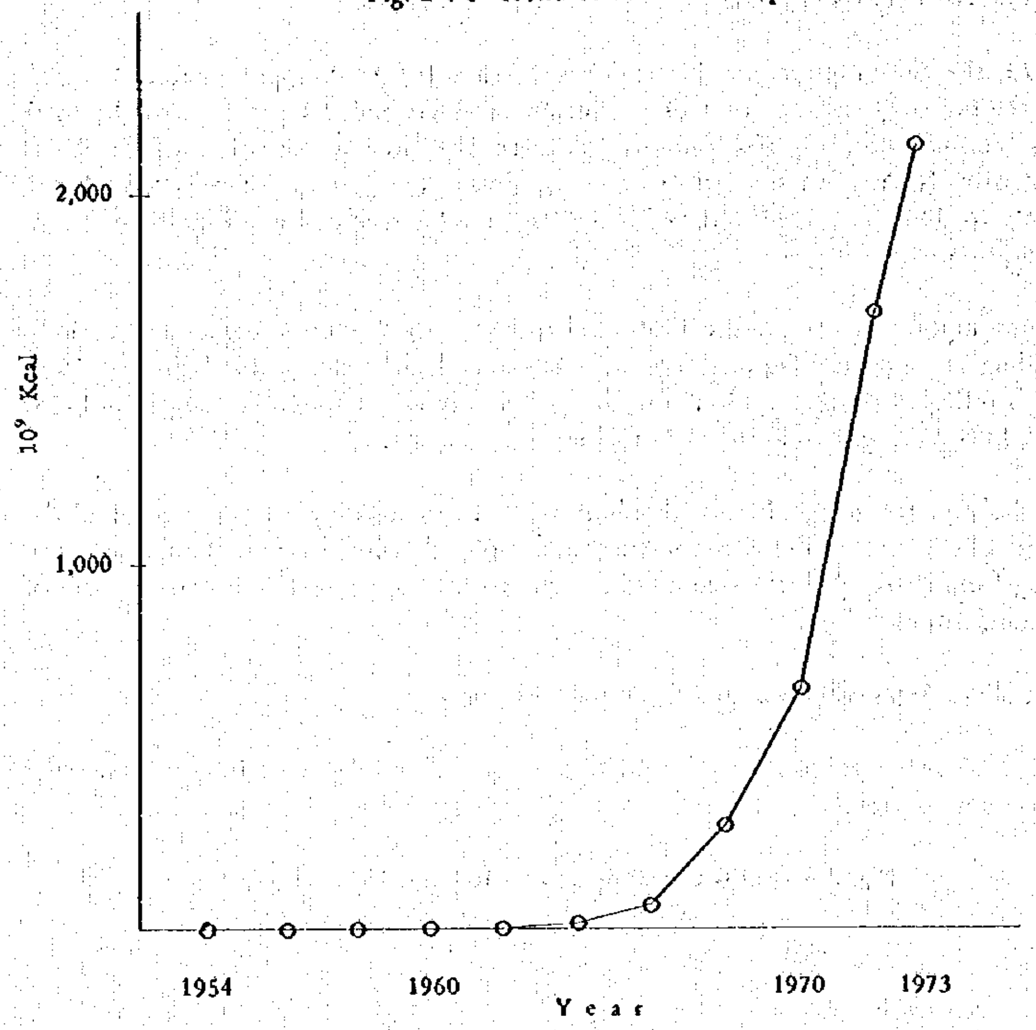


Fig. 2-4-8 Trend of LPG Consumption



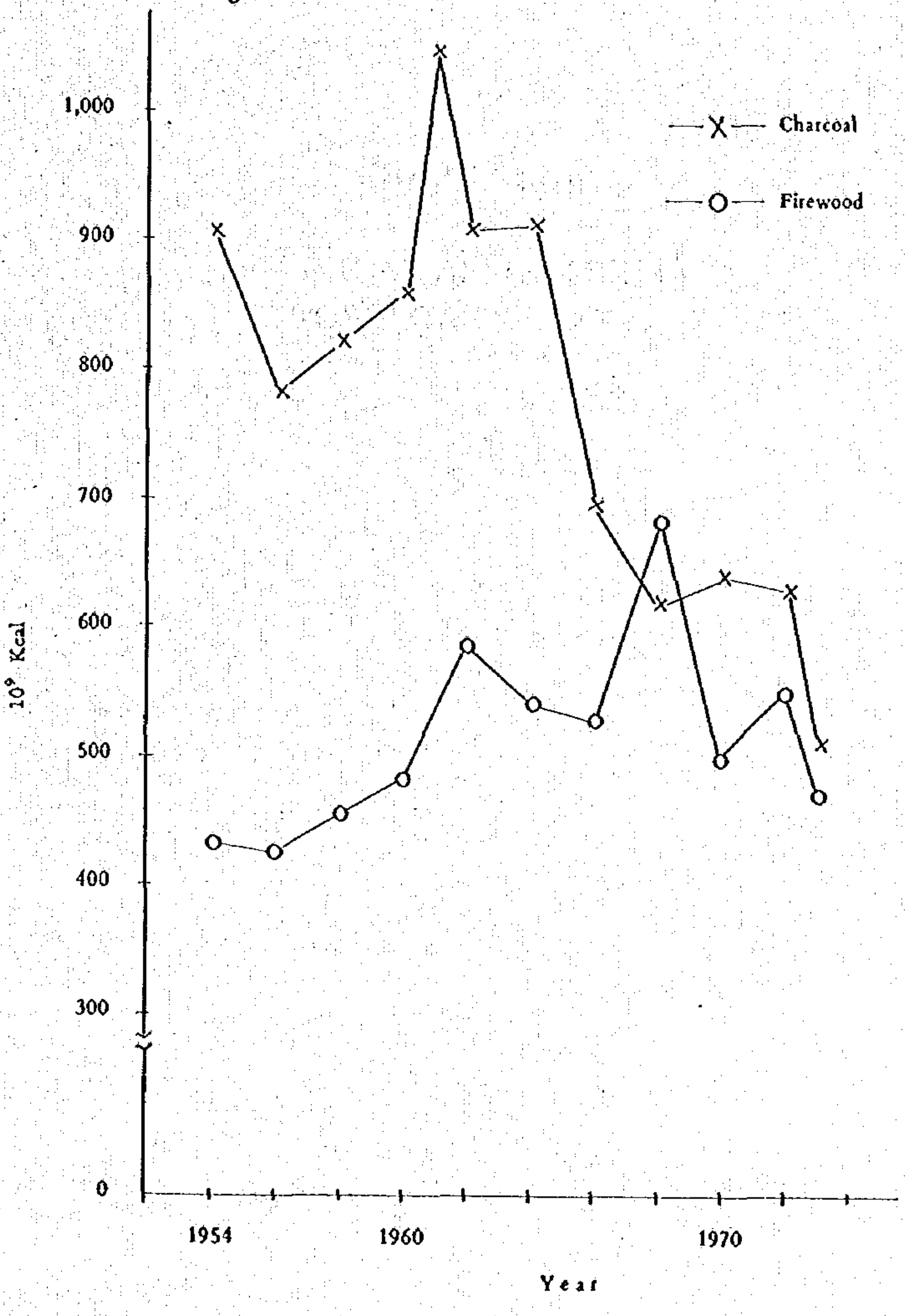
II-4-5 Charcoal and Firewood

Charcoal and firewood used to be the two important energy sources in the past in Thailand. They have lost importance partly because the population increase and the industrial development caused a decrease in forest area, but their supply did not increase due to a long period of time required for recycling of forestry resources.

Figure 2-4-9 expressly shows that the consumption of charcoal and firewood has gradually decreased after their peak in the first half of 1960.

Since the today's world forest resources are declining in volume, it is desirable that they should be utilized not as energy sources, but rather as materials for housings and furnitures so as to make best use of their characteristics.

Fig. 2-4-9 Firewood and Charcoal Production



CHAPTER III.

TECHNICAL ASSESSMENT OF TOWN GAS SERVICE

CHAPTER III TECHINICAL ASSESSMENT OF TOWN GAS SERVICE

III-1 Forecast of Demand for Town Gas

The greatest factor to determine the scale of a town gas service is the group of users to whom the service is to be rendered. The magnitude of service can hardly be determined without precisely comprehending who should be the object of the service, and how much town gas should be supplied to them. In this study, therefore, emphasis is placed on measuring the future demand for town gas.

The method employed in this study for determination of demand is to survey the fuel-using status of people in Bangkok, to collect data from the government offices and private firms concerning the fuel-using status in Bangkok City and Thailand, and on various factors which are influencing fuel utilization, then to estimate the magnitude of present and future gas consumption.

For estimating the amount of future demand, a block diagram shown in Fig. 3-1-1 was prepared, on the basis of which various surveys were carried out. The block diagram was made for the purpose of searching the methods for survey in Thailand, and some of it were later found not available during our survey in Thailand.

III-1-1 Decision of Service Area

In this study, the main part of the project gas service area includes the districts with densely crowded houses among other parts of the Greater Bangkok, and most of the town gas users here are expected to be household users for domestic purposes. The scope of this gas service area was found almost identical to the one obtained by the Prefeasibility Study. Priority is given to those districts where houses are already crowded, then to their outskirt areas where street plans have been carried out and a high tempo of future development is foreseen.

III-1-1-1 Estimating the Number of Households

The transition of the population and the number of households in the ten amphoes, i.e. administrative wards, including the area, where we planned to distribute the town gas, are shown for the period of 1965 through 1973 in Table 3-1-1 and Fig. 3-1-2.

These amphoes cover those districts which are almost saturated with houses and streets through developments of the districts which our presumptive plan is to include. However, these amphoes are more or less varied in the degree of the crowdness. Population over the last nine years in the three of these amphoes in the central part of Bangkok City (Phranakorn, Bangrak and Sampantawong) has been either declining or has remained unchanged; while in the other two amphoes in the semi-central part (Pomprap and Patumwan) it has been slightly increasing; and in the five other outer amphoes (Dusit, Bang Khean, Phaya Thai, Phrakanon and Yanawa) increasing at a higher rate. As for the increasing trend of population in the outer five amphoes, although not clarified yet which part of the wards is most obviously increasing, the increased population could be naturally spread from the part closest to the city center toward outer areas according to the typical rule of urban development.

In this planning, gas distribution over all of these large wards is not advantageous to accomplish a highly efficient investment in pipelines, and this required estimating of future population by smaller blocks in the individual amphoes.

Moreover, in the proposed plant area some question is posed of whether past trend can be relied upon as a basis for estimating the future demand, because this is the area for which Bangkok Municipality is taking measures for its overpopulation, according to its city plan. In spite of this, in the city plan no specific population targets for the project town gas supply area were clarified, but only an overall regional plan with a target population of 6,500,000 for the Greater Bangkok. Therefore, the trend of the past record was forced to be used as a basis for forecasting the future demand.

We have chosen to employ the expressions of trend based on the primary regression, under a supposition that the population and the number of households will not fluctuate sharply because the gas plan area is an already developed urban area.

The results are as shown in Table 3-1-1, Figs. 3-1-2 and 3-1-3.

Fig. 3-1-1 Block Diagram of Demand Forecast

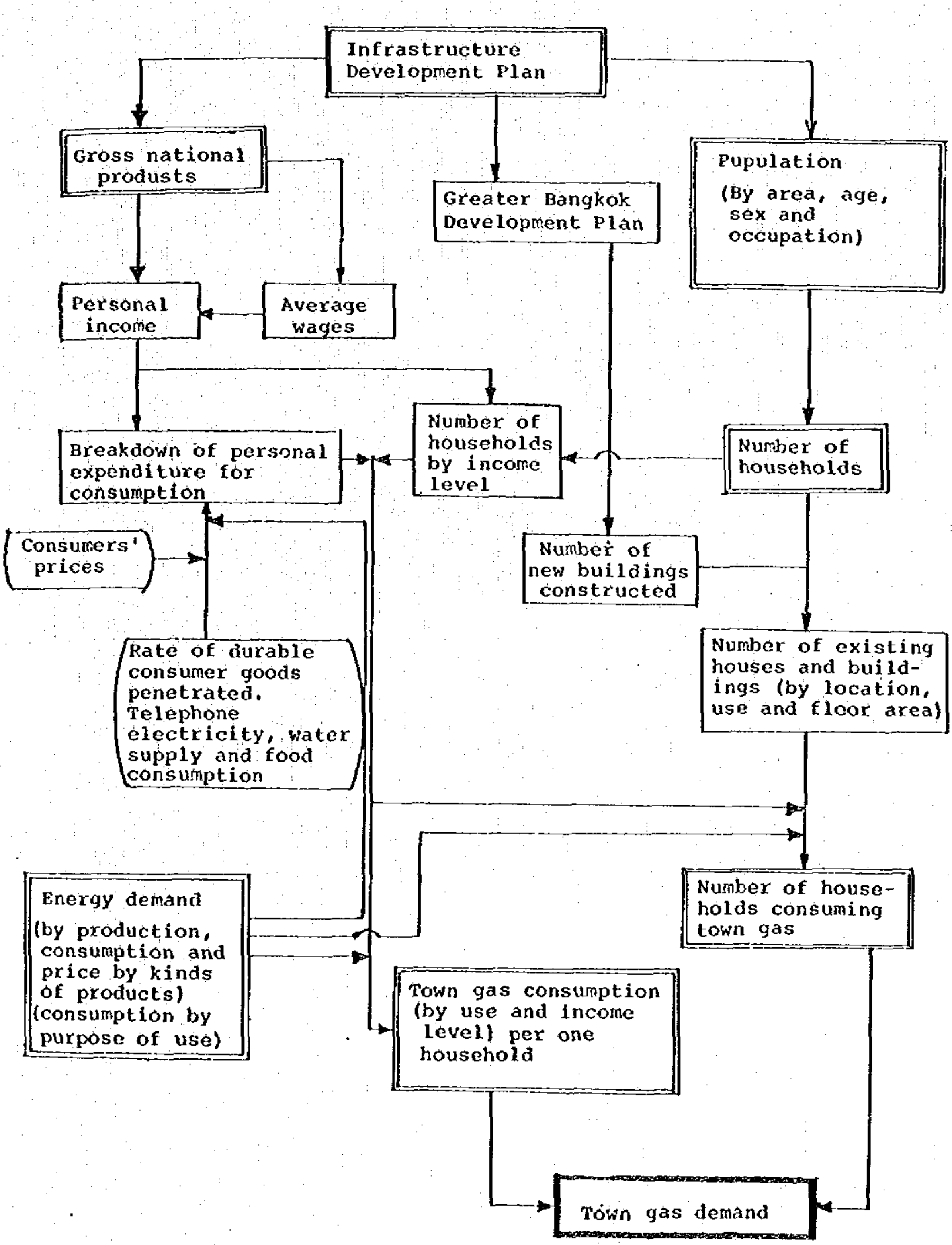


Fig. 3-1-2 Population

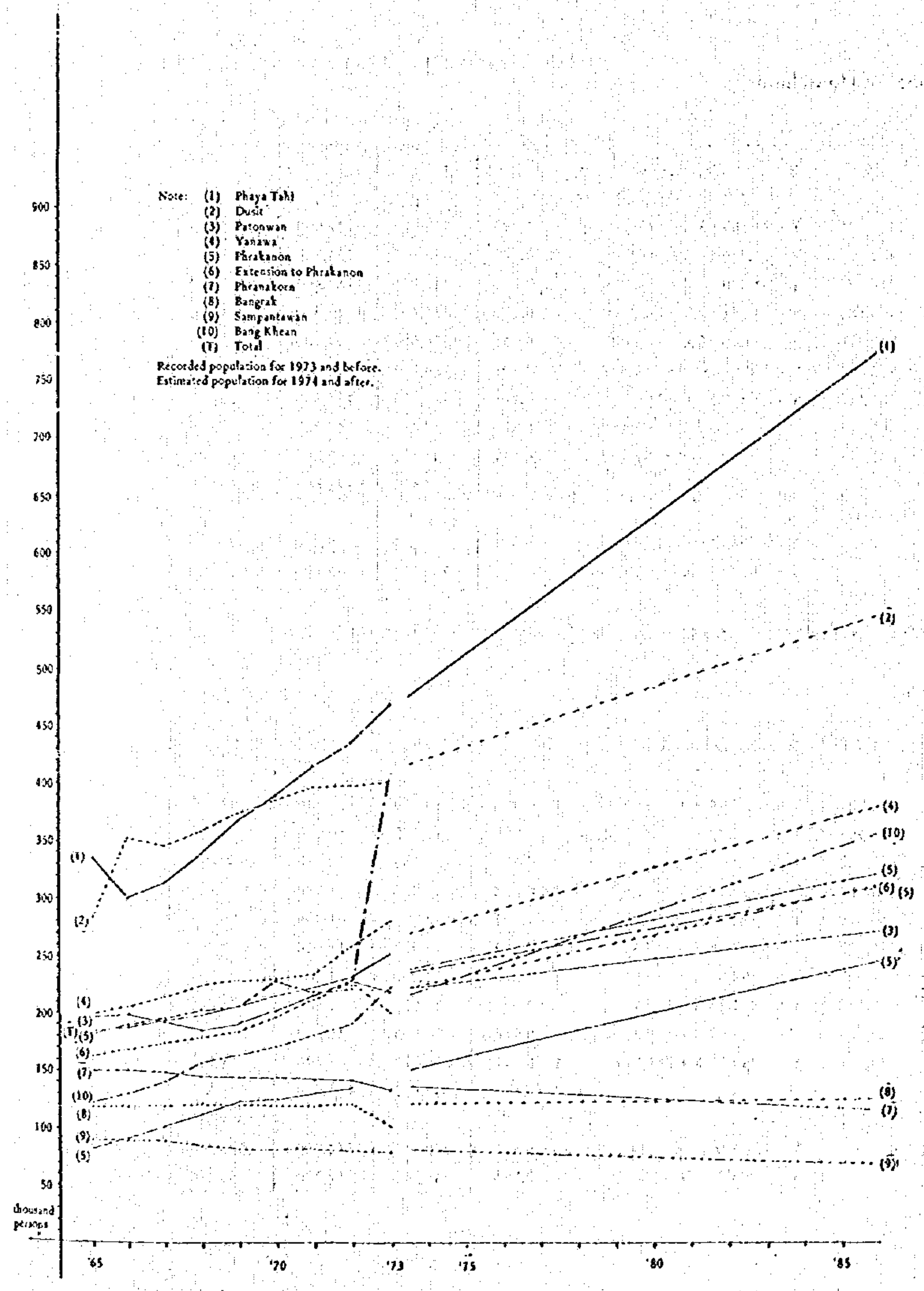


Fig. 3-1-3 Number of Households

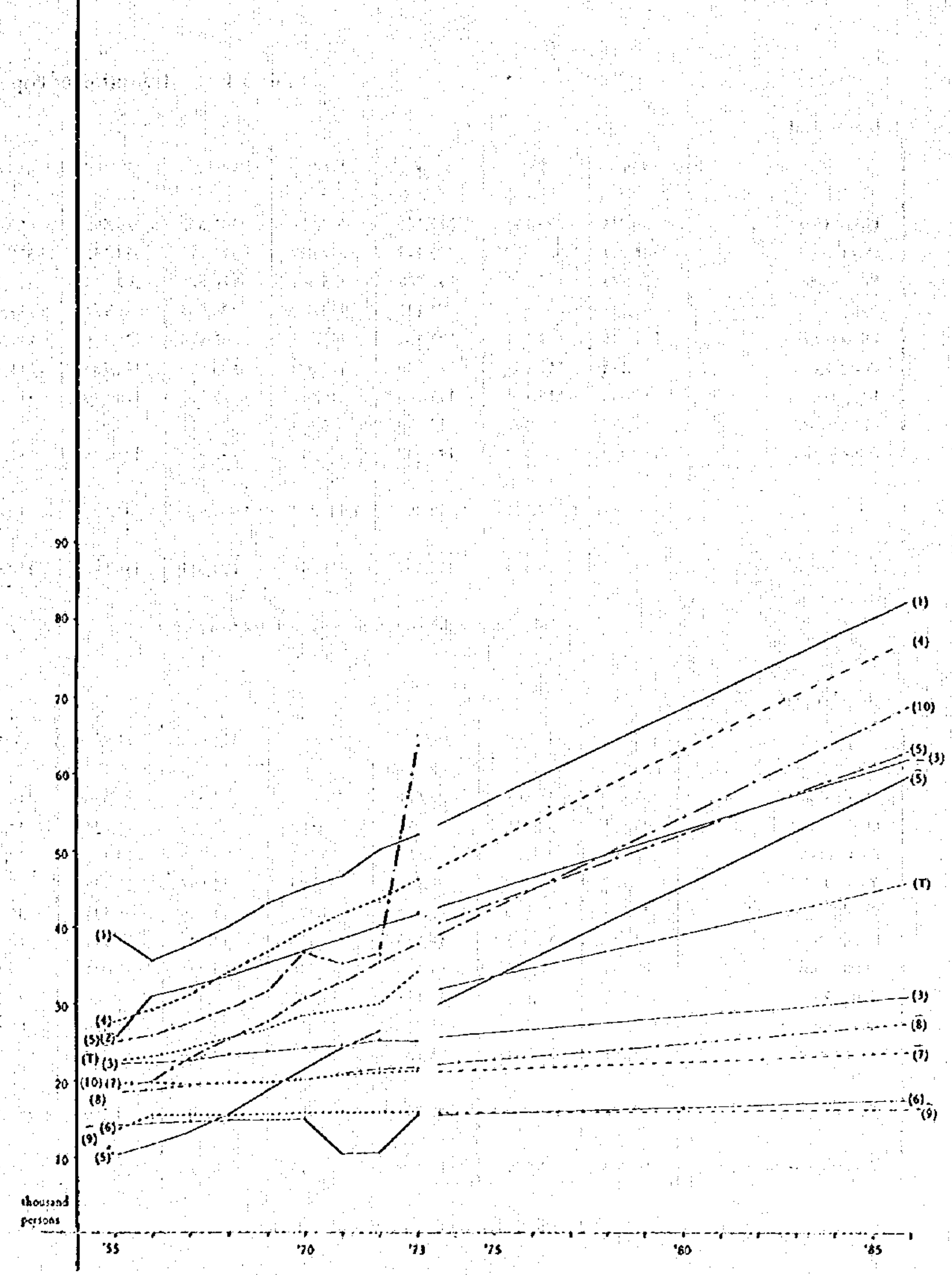


Table 3-1-1 . Transition of Population and Number of Households

[Population]

	1965	1966	1967	1968	1969	1970	1971	1972	1973	Retrogressive line & coefficient correlation		1980	1985	1990
Phaya Thai	*334,746	299,742	317,123	338,114	366,349	388,690	413,025	433,775	466,846	Y = 23,809.43 X + 247,005	R: 0.998	628,000	747,000	866,100
Dusit	*281,247	331,337	345,119	357,487	372,813	384,162	395,826	397,496	400,506	Y = 10,386.12 X + 315,970	R: 0.976	482,100	534,100	586,000
Pantonwan	196,749	196,839	191,688	185,809	190,271	202,314	215,269	228,151	217,891	Y = 4,036.18 X + 182,595	R: 0.766	247,200	267,400	287,500
Yanawa	198,098	205,528	213,115	223,333	228,034	229,924	233,506	257,060	*404,688	Y = 8,781.88 X + 185,861	R: 0.950	326,400	370,300	414,200
Phrakanon	181,248	189,171	195,531	202,957	205,594	227,378	217,111	220,033	200,996	Y = 6,063.96 X + 177,590	R: 0.931	274,600	304,900	335,300
Pomprap	162,611	168,648	173,249	172,321	183,564	196,736	211,817	227,254	132,866	Y = △ 1,745.32 X + 152,819	R: 0.921	124,900	116,200	107,400
Bangrak	118,452	118,126	119,305	120,076	119,859	118,996	119,683	121,338	*101,610	Y = 319.56 X + 118,041	R: 0.775	123,200	124,800	126,400
Sampantawan	89,897	89,404	88,879	86,194	85,221	84,921	84,497	83,287	81,298	Y = △ 1,046.40 X + 91,187	R: 0.979	74,400	69,200	64,000
Bang Khean	122,363	130,618	141,547	156,210	163,458	171,396	181,406	191,858	81,298	Y = △ 1,046.40 X + 91,187	R: 0.979	74,400	69,200	64,000
Total	1,835,214	1,879,201	1,933,207	1,987,441	2,059,960	2,147,704	2,214,094	2,302,099	*2,507,377		Total	2,836,500	3,181,800	3,526,900
										Y = 67,365.11 X + 1,741,722	R: 0.994	2,819,600	3,156,400	3,493,200
Extension to Phrakanon	82,664	,9,834	100,651	111,575	120,011	124,572	130,675	134,844		Y = 7,674.57 X + 77,433	R: 0.989	200,200	238,600	277,000

* Excluded because this is an anomalous value due to a change in amphoe border. Population for Bangrak, including the 1973 value, can be obtained by a formula: Y = △ 967.60 X + 122,322 R:

[Number of Households]

	1965	1966	1967	1968	1969	1970	1971	1972	1973	Retrogressive line & coefficient correlation		1980	1985	1990
Phaya Thai	*38,860	35,569	37,601	40,066	43,063	44,950	46,565	50,164	51,909	Y = 2,364.04 X + 30,734	R: 0.998	68,560	80,380	92,200
Dusit	*25,424	30,918	32,016	33,607	35,100	36,836	38,239	49,146	41,667	Y = 1,565.77 X + 27,454	R: 0.999	52,510	60,340	68,160
Pantonwan	22,181	22,359	22,523	23,486	23,816	24,255	24,488	25,013	25,048	Y = 407.15 X + 21,639	R: 0.983	28,150	30,190	32,220
Yanawa	27,734	29,202	31,110	34,093	36,697	39,439	41,633	43,707	46,164	Y = 2,393.78 X + 24,573	R: 0.998	62,970	74,940	86,910
Phrakanon	24,999	25,896	27,414	29,371	31,466	36,625	35,003	36,298	63,598	Y = 1,837.57 X + 22,615	R: 0.961	52,020	61,200	70,390
Pomprap	14,258	14,417	14,530	14,745	14,741	14,971	*10,221	*10,531	15,372	Y = 137.35 X + 14,130	R: 0.994	16,330	17,010	17,700
Phranakarn	19,773	19,758	19,338	19,546	19,821	20,041	20,627	20,929	21,037	Y = 194.03 X + 19,127	R: 0.863	22,230	23,200	24,170
Bangrak	18,332	18,700	19,187	19,647	19,976	20,420	20,989	21,334	21,430	Y = 411.18 X + 17,946	R: 0.994	24,520	26,580	28,640
Sampantawan	*13,496	15,304	15,432	15,417	15,493	15,579	15,688	15,731	15,705	Y = 61.92 X + 15,203	R: 0.968	16,190	16,500	16,810
Bang Khean	19,091	19,707	22,933	25,212	27,510	3,0644	32,579	35,260	37,181	Y = 2,399.05 X + 211,179	R: 0.997	54,190	66,190	78,180
Total	224,148	231,730	242,084	255,190	267,683	283,760	286,132	299,113	*339,111		Total	397,670	456,530	515,380 *339,111
										Y = 111,122.45 X + 211,179	R: 0.995	389,140	444,750	500,360
Extension to Phrakanon	10,403	11,579	13,285	16,599	18,714	21,429	21,682	26,304		Y = 2,398.32 X + 6,868	R: 0.994	45,240	67,230	69,220

* Excluded because this is an anomalous vlaue.

III-1-1-2 Establishment of Gas Distribution Area

The only available information giving the number of households in tle subdivisions of the individual areas was those used by the City Traffic Planning Board of the Ministry of Interior for Road Planning. In this information the ten amphoes are subdivided into a total of 116 blocks for each of which, the population, population density, magnitude of building construction, motor car ownership, etc. in the year 1972 are shown.

The data served for judging to which blocks the population increase formula can be applied. Then, the number of households in 1990 in the 116 blocks is estimated by the aid of the formula. Those blocks which are forecast to become saturated with households (i.e. the blocks where the ratio of open space is zero) are selected as the presumed town gas distribution area, with top priority. In the outer parts of the city, those saturated areas, which are not directly neighboring the inner circle amphoes, are excluded; while some other unsaturated areas located around factories were included in the gas service area in order to effectively utilize the gas distributing facilities.

III-1-1-3 Setting Individual Gas Service Areas by Year

The pace at which town gas distribution is started for the individual areas selected by the gas distribution plan is determined by the ability of local contractors for constructing gas distribution facilities. In this report, the quantity of work was estimated on the basis of the number of households in the subdivided blocks, and the target set was that gas distribution service should be started by the end of the Plan Period (1979 through 1990) for the whole Gas Plan Area. Then the Area was divided so that both the number of households and the quantity of work for each year would be approximately equal. To be concrete, the Plan aimed at 30,000 households and 160,000 km of the pipeline to be laid. Distribution was to be extended gradually, starting at those areas close to gas making plant and those densely populated. For the first three years, work was planned to be performed in annual increment, because work performance depends upon the number of workers and their skill. The plan areas by year are as shown in Fig. 3-1-4.

III-1-2 Household Consumption Prospect

The uses of fuels in Bangkok City are largely classified as follows:

Household use	Cooking	Hot water	
Commercial use			
Restaurant	Cooking		
Hotel	Cooking	Hot water	
Barber and beauty saloon		Hot water	
Public bath		Hot water	
Office			
Department store			
Laundry shop		Hot water	Drying
Government offices and school		Hot water	Laboratory
Hospital and practitioner		Hot water	
Industry	Heating, processing, melting and drying		

Gas consumption data for Bangkok City and particularly in the project gas supply area were not available, but some structural difference between Japan and Europe and America was observed; in Bangkok, quantities of fuels used for household use dominated these for industrial use. Of the fuels for households use, the consumption of those for hot water making stood at a low rate, but that for air conditioning weighed extremely high due to the location of Bangkok City in the semi-tropical zone.

Primarily, this study should have been directed forward comprehending the demand for town gas in all sectors and the possibility of transferring into town gas from other fuels, but, for practical purpose, it chose only hotels, restaurants, etc. from among housoehold and commercial uses predicted high with respect to investment efficiency.

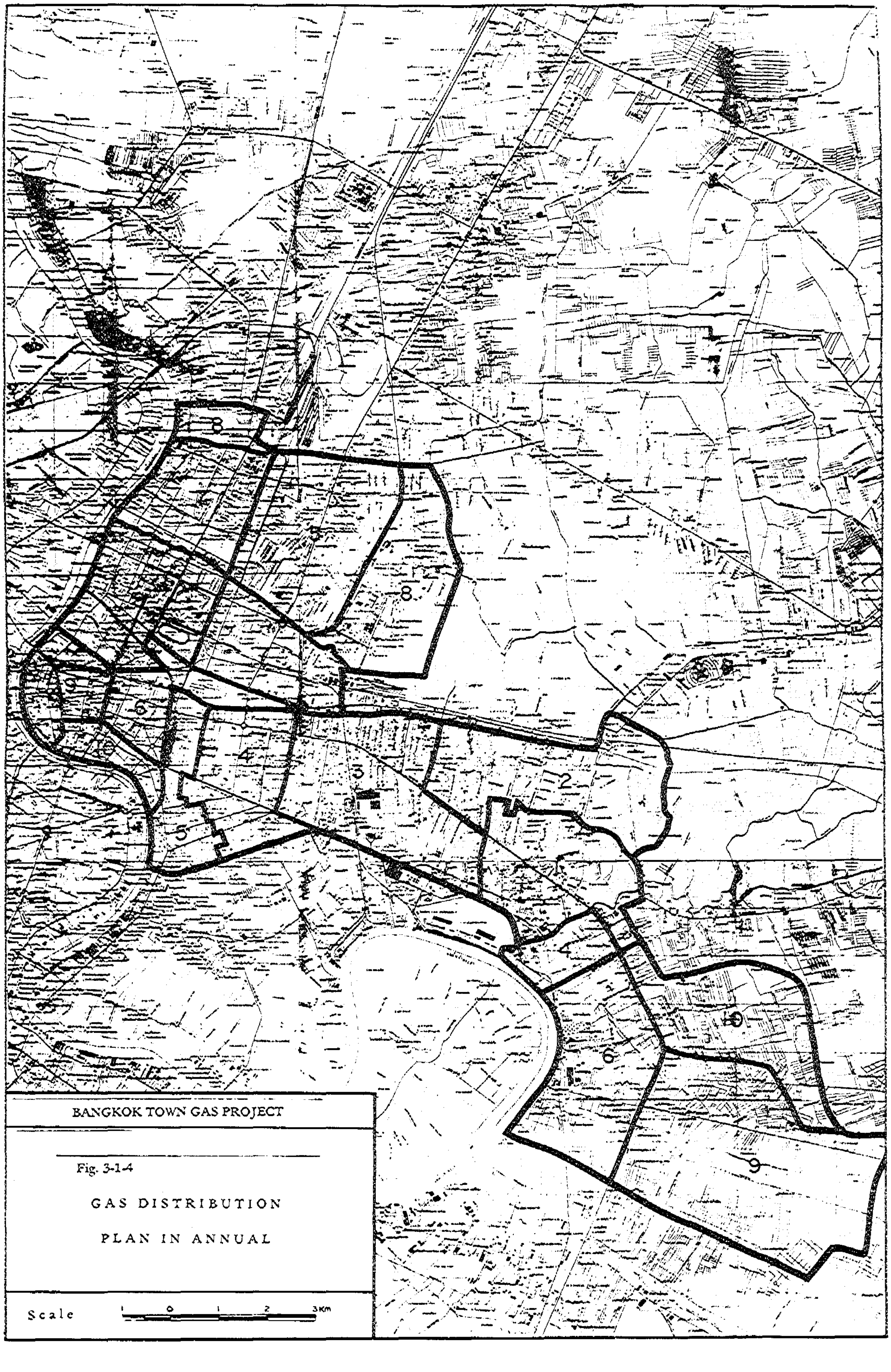
III-1-2-1 Number of town gas household consumers

Fuels now used by household consumers are LPG, charcoal, kerosene and electricity.

The only data obtained by the Study Team on the using practice of the individual types of fuels were those offered by NEA which conducted two fuel researches in the past. Therefore, the Study Team made a new research through personal interviews with users to learn current fuel consuming status.

(1) Interviews with consumers

The Study Team classified by income and fuel consumption rate all the 13,437 samples obtained during the fuel research of NEA in March, 1974, and selected 700 samples, with whom interviews were made on nine items including types and quantities of fuels, living expenses, family members, and fuel consciousness. As a result, 556 answers were obtained. (Refer to Table 3-1-2.)



BANGKOK TOWN GAS PROJECT

Fig. 3-1-4

GAS DISTRIBUTION

PLAN IN ANNUAL

Scale 1 0 1 2 3Km

Table 3-1-2 Main Items of Interview Research

Ward (Amphoe) \ Item	Number of answers	Number of family members	Fuel diffusion rate classified by living expenses (Bahts/month) (Upper column: charcoal) (Lower column: LPG): 500 or less	1,000 or less	1,500 or less	2,000 or less	3,000 or less	5,000 or less	5,001 or more	Average	Household consumption (Upper column: cost paid) (Lower column: m³/month): LPG	Charcoal	Average	Commercial consumption: LPG	Charcoal	Average	Potential user of town gas: LPG user: Yes	No	Charcoal user: Yes	No
Phaya Tai	83	5.8		100.0	66.7	91.7	56.3	64.3	70.0	67.5	70.4	61.9	76.1	215.0	60.3	255.2	41	1	8	1
				0.0	33.3	33.3	59.4	64.3	80.0	54.5	37.8	63.3	60.5	133.3	53.2	168.8				
Dusit	74	7.2		0.0	33.3	80.0	65.2	46.4	52.9	54.8	87.0	97.1	111.2	283.3	99.5	241.2	44	2	15	8
				100.0	100.0	50.0	52.2	64.3	85.7	63.0	50.5	76.9	75.6	189.9	101.8	196.8				
Patumwan	61	6.7			100.0	75.0	47.8	58.3	50.0	60.7	110.6	53.7	80.2	360.0	210.0	260.0	17	4	14	24
						16.7	47.8	41.7	37.5	34.4	66.1	45.0	56.8	356.1	232.9	274.0				
Yanawa	61	9.1			87.5	93.3	88.9	81.3	66.7	85.7	76.1	49.0	68.1	173.0	205.9	256.6	21	1	27	12
					25.0	40.0	22.2	50.0	83.3	39.7	43.7	40.5	49.5	106.4	124.8	156.1				
Phrakanong	111	7.4	100.0	100.0	88.9	60.0	80.6	70.8	90.9	77.0	87.8	77.2	93.0	526.4	320.9	722.5	51	3	16	10
					33.3	55.0	35.5	91.7	81.8	56.0	51.1	72.6	73.1	342.4	264.2	520.3				
Pomprap	20	7.7			0.0	100.0	40.0	57.1	50.0	45.5	118.0	60.3	103.9	360.0		360.0	14	0	1	6
					100.0	0.0	60.0	71.4	100.0	68.2	68.1	43.0	63.6	237.4		237.4				
Phranakorn	29	7.2		100.0	100.0	57.1	62.5	67.1	100.0	67.9	81.5	52.6	79.4				13	2	3	5
				0.0	33.3	42.9	62.5	85.7	0.0	53.6	45.7	48.4	57.4							
Bangrak	32	6.9		100.0	75.0	33.3	82.4	100.0	0.0	65.6	77.0	67.5	75.8		70.0	70.0	12	1	10	11
				0.0	25.0	66.7	29.4	0.0	100.0	40.6	44.4	58.3	56.2		53.2	53.2				
Sampantawong	26	8.5				100.0	75.0	40.0	35.7	48.0	96.8	97.1	116.3	130.0	60.0	190.0	16	3	4	3
						0.0	75.0	80.0	75.7	59.4	54.4	79.4	77.3	71.2	53.2	124.5				
Bang Khean	59	7.1			71.4	45.5	63.2	57.1	20.0	55.3	75.4	46.5	78.6	176.7	315.0	290.0	36	4	5	11
					57.1	54.5	89.5	64.3	100.0	73.2	41.9	39.5	50.9	126.6	186.3	188.1				
Total	556	7.3	100.0	81.8	80.0	70.1	64.9	55.2	51.7	63.6	85.5	66.3	87.4	314.6	202.6	365.7	265	21	103	91
			0.0	18.2	37.5	42.5	49.4	65.5	70.7	52.8	48.8	58.7	63.1	207.8	155.5	259.5				

Table 3-1-3 Number of Household Town Gas Users (At each year end)

Rating	Item \ Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1st	Total number of households	11,192	11,292	11,392	11,493	11,592	11,693	11,793	11,893	11,993	12,093	12,194	12,295
	Town gas diffusion rate	50	60	70	70	70	70	70	70	70	70	70	70
	Number of household town gas users	5,596	6,775	7,974	8,045	8,114	8,185	8,255	8,325	8,395	8,465	8,536	8,607
2nd	Total number of households		11,591	11,839	11,963	11,963	12,087	12,211	12,335	12,459	12,584	12,708	12,831
	Town gas diffusion rate		50	60	70		70	70	70	70	70	70	70
	Number of household town gas users		5,796	7,029	8,287	8,374	8,461	8,548	8,635	8,721	8,809	8,896	8,982
3rd	Total number of households			15,703	15,839	15,974	16,110	16,248	16,383	16,518	16,654	16,790	16,933
	Town gas diffusion rate			50	60	70	70	70	70	70	70	70	70
	Number of household town gas users			7,852	9,503	11,182	11,277	11,374	11,468	11,563	11,658	11,753	11,853
4th	Total number of households				32,708	33,434	34,163	34,887	35,616	36,341	37,068	37,796	38,523
	Town gas diffusion rate				50	60	70	70	70	70	70	70	70
	Number of household town gas users				16,354	20,060	23,914	24,421	24,931	25,439	25,948	26,457	26,966
5th	Total number of households					38,732	39,267	39,801	40,337	40,871	41,407	41,943	42,479
	Town gas diffusion rate					50	60	70	70	70	70	70	70
	Number of household town gas users					19,366	23,560	27,861	28,236	28,610	28,985	29,360	29,735
6th	Total number of households						32,566	33,010	33,454	33,897	34,339	34,784	35,228
	Town gas diffusion rate						50	60	70	70	70	70	70
	Number of household town gas users						16,283	19,806	23,418	23,728	24,037	24,349	24,660
7th	Total number of households							31,931	32,433	32,935	33,438	33,941	34,442
	Town gas diffusion rate							50	60	70	70	70	70
	Number of household town gas users							15,966	19,460	23,055	23,407	23,759	24,109
8th	Total number of households								29,092	29,455	29,817	30,181	30,542
	Town gas diffusion rate								50	60	70	70	70
	Number of household town gas users								14,546	17,673	20,871	21,127	21,379
9th	Total number of households									24,621	25,308	25,992	26,679
	Town gas diffusion rate									50	60	70	70
	Number of household town gas users									12,311	15,185	18,194	18,675
10th	Total number of households										31,092	31,513	31,934
	Town gas diffusion rate										50	60	70
	Number of household town gas users										15,546	18,908	22,354
Total	Total number of households	11,192	22,883	38,810	71,879	111,695	145,886	179,881	211,542	239,090	273,800	277,842	281,886
	Town gas diffusion rate	50.0	54.9	58.9	5 58.7	60.1	62.8	64.6	65.7	66.7	6 66.8	68.9	70.0
	Number of household town gas users	5,596	12,571	22,855	42,189	67,096	91,680	116,231	139,019	159,495	182,911	191,339	197,320
	Number of new town gas users per annum	5,596	6,975	10,284	19,334	24,907	24,584	24,551	22,788	20,476	23,416	8,428	5,981

The diffusion rate of LPG was found 52.8 per cent, and that of charcoal 63.6 per cent. While 30 per cent of the charcoal users wished a shift to LPG. The consumption rate of LPG classified by living expenses is as shown in the following table, suggesting that a decline in charcoal consumption and transfer to LPG are proceeding in parallel with improving standards of living.

Living expenses	500 or less	1,000 or less	1,500 or less	2,000 or less	3,000 or less	5,000 or less	More than 5,000	Average
LPG diffusion rate (%)	0.0	18.2	37.5	42.5	49.4	65.5	70.7	52.8
Charcoal diffusion rate (%)	100.0	81.8	80.0	70.1	64.9	55.2	51.7	63.6

Note: Living expenses by bahts per month

Consciousness of those using charcoal only overwhelmingly thought that LPG was dangerous and costly. On the contrary, those using LPG only answered that they use LPG for its cleanliness and simple handling.

As for the use of town gas, they answered that, although they had no knowledge of it, they would use it if town gas has the same properties as those of LPG and is more convenient, because, like electricity and water supply, town gas needs no delivery labor. Under the condition that town gas charge is almost the same as that of LPG, 93 per cent of the LPG users and 53 per cent of the charcoal users preferred use of town gas. It is notable that a majority of those who were interviewed answered that they would use town gas only after ascertaining the experience of town gas users around them. This indicates that in the initially year the rate of transfer to town gas will be low, but it can be boomed depending on successful fostering of opinion leaders.

In this plan which aims at supply of town gas for the living of urban people, the first priority is given to cooking and hot water uses. It is reasonable to preclude the air conditioning use because electric conditioning is dominant, and besides, gas conditioning apparatus could hardly be used widely due to local climatic conditions. Therefore, the demands for LPG and charcoal can be estimated to be transferred into that of town gas. Since town gas resembles LPG in properties and apparatus, it is likely that the demand for town gas will come mostly from that for LPG.

(2) LPG in the Bangkok Metropolitan Area

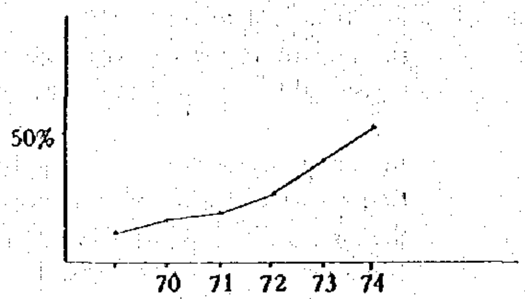
LPG consumption is as described in Paragraph 4, Chapter 2 above. The 1969 LPG consumption in Bangkok Metropolitan Area shared 76 per cent in the whole Thailand. In the NEA report, it also referred to the effect that LPG consumption was rapidly increasing in parallel with the rising standards of living in the Metropolitan Area, due to transfer from charcoal and firewood. The increasing rate of all energy consumption per capita largely exceeds that of the population. This is possibly due to the improved living standards of people, resulting from the growth in commerce and industry. Further transfer to LPG is, therefore, expected in the future.

(3) Town Gas Diffusion Rate

From the result of this study and the trend of LPG consumption, the Study Team estimated that town gas can be penetrated by 70 per cent into the total number of households.

LPG consumption rate today is said to be 52.8 per cent, largely deviating from the 43.2 per cent obtained by the NEA research of March 1974. This difference can be interpreted as caused by an increase during the half year since March of the same year. The following table shows the years when use of LPG began. As much as 13 per cent of the above 52.8 per cent LPG users began using LPG within last one year. If this trend is supposed to continue, LPG consumption rate will reach 100 per cent by 1980.

1974	52.8%
1973	39.9%
1972	27.5%
1971	18.9%
1970	15.6%
Before 1970	11.5%



However, any goods sharply changing in grouth degree does not rarely follow its past value for a long period of time, and any kind of goods can hardly accomplish a 100 per cent saturation in its diffusion rate. Forecasting the LPG consumption rate in the first year of this Gas Distribution Project is difficult, and hence the future town gas diffusion rate was forecast using the current LPG diffusion rate and the rate of desire for transferring from charcoal to LPG.

The Study Team assumed 50 per cent for the first year town gas diffusion rate, or 93 per cent of the current LPG consumption rate 52.8 per cent, and 70 per cent of the saturated town gas consumption within the project period, the percentage being obtained by adding 66 per cent (or 93 per cent of the estimated LPG diffusion rate 68.4 per cent, which includes those desirous of transferring from charcoal to LPG) and another 4 per cent conceivable of transferring directly from charcoal to town gas.

The period during which town gas consumption grows from 50 per cent to 70 per cent in the individual project blocks requires three years, because of the reasons that LPG diffusion rate during the project period will be considerably high, and knowledge on town gas will be ample, with the exception of the problem of price involved when transferring to town gas, and hence town gas will penetrate at a fast speed.

The presumed number of town gas users for household use is as broken down in Table 3-1-3.

III-1-2-2 Consumption per Household

(1) The interviews under this study have shown that LPG consumption per month, in town gas equivalent (5,000 Kcal/m^3), is 48.8 m^3 per domestic user. Taking into consideration that LPG is mostly used for cooking at present, the above consumption seems excessively large when compared with the Tokyo Gas Company's value, but this is conceivable because of a large difference in the number of family mem-members per household, as shown in the table below.

Year	Number of family members per household		Cooking gas consumption per domestic user under Tokyo Gas Co. (m^3/household)
	Bangkok (person)	Tokyo 23 wards (person)	
1965	8.18	3.04	22.1
1966	8.10	3.00	20.6
1967	7.96	2.87	23.2
1968	7.75	2.85	22.3
1969	7.61	2.80	20.6
1970	7.45	2.77	18.0
1971	7.56	2.73	
1972	7.49	2.72	
1973	7.39	2.70	
Increasing rate	△ 1.26 %	△ 1.47 %	

From this table, the gas consumption for cooking per person of user under Tokyo Gas is 7.32 m^3 on average, and that of Bangkok, as calculated from above, is approximately 6.7 m^3, almost equal per person.

The number of family members per household in this town Gas Plan Area tends to decline, and amount of LPG sold per household user is predicted also declining. If this household member declining trend alone is taken into consideration, the amount of LPG sold is 1988 per household user will decrease from the present 48.8 m^3 to 39.3 m^3. Meanwhile, LPG consumption per household user, as classified by the living expenditure level, shows that the higher the living expenditure level is, the more the LPG consumption per family member is, suggesting an increase in the consumption due to the rising standards of living, as shown below.

Income level (bahts/month)	Family members (person)	LPG consumption per household (m^3/month)	LPG consumption per family member (m^3/person)	Ratio in terms of number of households (%)
- 500	3.00	0	0	0.2
501 - 1,000	7.45	32	4.30	2.3
1,001 - 1,500	6.15	34	5.53	8.2
1,501 - 2,000	6.32	37	5.85	17.9
2,001 - 3,000	6.86	45	6.56	35.7
3,001 - 5,000	7.78	55	7.07	23.8
5,001 -	9.43	63	6.68	11.9

Therefore, assumption was made that 50 per cent of a GNP increase (estimated to be 6 per cent per annum) would contribute an increase in town gas consumption, and this was allowed for addition to an annual decrease in population; 52.6 m^3 for 1979 and 60.1 m^3 for 1988.

Assuming that the ratio of housing cost to be present living expense per household and the ratio of LPG expense to the housing cost remain unchanged in the future, and that LPG price moves in parallel with a rise in consumer prices, then, LPG consumption per household user will reach 54.7 m^3 in 1979 and 62.8 m^3 in 1988. Refer to the table below.

	1962	1968	1971
Average living expense per month (baht)	1,438.15	2,357.17	2,870.63
Average housing cost per month (baht)	233.43	311.43	466.97
Ratio of housing cost (%)	16.23	13.21	16.27
Consumer price index	100.0	114.4	120.1

From those figures, the basic town gas consumption was estimated to be 50 m^3 in 1979 and 60 m^3 in 1988.

(2) Trend of the overall energy volume per household including charcoal was taken into account. The declining trend of charcoal consumption, as mentioned in Paragraph 5, Chapter 2 above, can be taken as representing a potential demand for other fuel substituents, and therefore we added it to the individual basic town gas consumption values.

This study found that the overall energy volume per household is 63.1 m^3 (in town gas equivalent of 5,000 Kcal) in which LPG is 25.8 m^3, and charcoal 37.3 m^3. However, in terms of thermal efficiency, of the overall volume, LPG shares 80 per cent and charcoal only 30 per cent, the net energy volume utilized from charcoal is estimated to be 14.0 m^3. The overall energy consumption per household is expected to increase as the standards of living rises. Therefore, if the current ratio between LPG and charcoal remains unchanged, charcoal consumption would be 24.2 m^3 in 1988. Whereas, as previously mentioned, charcoal consumption of the whole Thailand is estimated to come to nought, if its declining trend continues. The amount of charcoal as an increased energy volume will have to be replaced with other fuels, 50 per cent of the replacement was estimated transferring to LPG. In concrete, 4.3 m^3/household will be transferred to LPG in 1979 and 12.1 m^3/household in 1988.

(3) Current energies are rarely used for making hot water, also wiht a very low consumption rate in water heaters (3.5% by this Feasibility Study, and 0.7% according to the import and production statistics). Future change in the living patterns will be directed toward the use of bath and hot water. Today, ordinary households are practicing cold water bathing only, but houses who have experienced a life abroad are using hot water.

Since this project aims at the promotion of people's standards of living by town gas, the project should make it a policy to expand the demand for hot water. Therefore the following allowances are estimated:

Diffusion rate of water heating apparatus:

> 50% of the level of water heater using rate in the initial period (1955 through 1964) in the service area of Tokyo Gas Co..

Consumption per unit of water heater:

> 163 m^3/year, obtained by adjusting the gas consumption for water heating per gas consumer in the Tokyo Gas service area (313 m^3/year in 1970) by the average water temperature difference.

Consumption per gas user:

0.0 m³/month in 1979 and 1.4 m³ in 1988.

(4) Rice, the staple food of Thai, is in most cases boiled in a similar way as in Japan, besides steaming it. Many households are seen using electric rice cookers. Findings of this Feasibility Study indicate that the using rate of electric rice cookers stands at 42.2 per cent. In Tokyo Gas service area; the using rate of rice cookers in 1974 was 80.0 per cent, of which gas cookers share 43.3 per cent and electric cookers 36.7 per cent. Since Thai custom of rice meals will not rapidly change and use of automatic rice cookers will further increase, the Study Team have estimated the demand for gas from gas rice cookers.

The future diffusion rate of electric rice cookers was estimated first from the increasing rate of the G.N.P. over the past ten years as 42% in 1974, 52% in 1979 and 74% in 1988. With the target that transfer to town gas should be promoted through selling of rice cookers, the transfer rate of 50 per cent in the final year of this project was set.

For calculation, gas consumption per unit of cooker is set at 34.1 m³/year, a level of consumption per cooker now recorded in the Tokyo Gas service area, presuming that difference in water temperature does not influence the rice cooking.

The foregoing is as tabulated below.

(m³/household/month)

Year	Basic consumption	Transfer from charcoal	Water heater	Rice cooker	Total
1979	50.0	4.3	0.0	0.0	54.3
1980	51.0	5.2	0.2	0.1	56.5
1981	52.1	6.1	0.2	0.2	58.6
1982	53.1	6.9	0.3	0.2	60.5
1983	54.2	7.8	0.5	0.3	62.8
1984	55.3	8.7	0.6	0.4	65.0
1985	56.5	9.5	0.6	0.6	67.2
1986	57.6	10.4	0.6	0.7	69.3
1987	58.8	11.3	1.2	0.9	72.2
1988	60.0	12.1	1.4	1.1	74.6

III-1-3 Forecast of Demands for Other Uses

For these other than for household use, the Study Team selected the commercial use to estimate each demand by the categories of restaurants, coffee shops, and other places where food is served, and hotels or the like.

III-1-3-1 Restaurants, etc.

(1) Number

The 1970 edition of the Business Census reported that the total number of restaurants, coffee shops and other places where food is served in Phranakorn, Thomburi, Samut Phrakan, Non Thaburi, and Patun Thani Prefectures (Changwats) were 2,567, found through a commercial research. As for households, meals for breakfasts and dinners are often cooked at home, with the exception of lunches which are taken either at neighboring eating houses or made up with cooked by-foods. Such eating houses are therefore closely related to each community, and the number of these houses in the ten amphoes was estimated to be 1,390, as calculated by the ratio of population. Meanwhile, the 1970 edition of the Population and Housing Census gave the population research results of changwat Phranakorn by occupation. It says that the employees of restaurants and coffee shops totalled 10,469. The Study Team re-estimated the number of these shops in the ten Bangkok amphoes by use of the ratio of population to the number of employees per shop and obtained the figure amounting to 1,380 shops. Further, the number of the shops of this kind in the ten amphoes by use of the 1973 telephone directory classified by trades came to 1,381 shops, through the research of the Study Team.

From these values, the number of food-serving shops in 1974 was estimated to be 1,400, or 4 shops per 1,000 households.

(2) Diffusion Rate of Town Gas

According to the consumer research of this Feasibility Study, LPG diffusion rate stood at 63.0 per cent, and charcoal at 82.6 per cent. Whereas, the NEA's research reported that LPG stood at 61.0 per cent, while charcoal 81.0 per cent. The reason why LPG consumption rate was higher in the commercial users than in the household users is that commercial users prefer LPG for its easy delivery, cleanliness and simple handling. Charcoal commercial users desirous of using LPG were found accounting for 35 per cent, sharing more as compared with 30 per cent of household users.

If this demand is transferred to LPG, the estimated LPG diffusion rate will reach

76.1 per cent. In addition, the research made, similarly in the case of that for household use, on the possibility of transfer from LPG to town gas, clarified that 96 per cent answered that they would agree to transfer to town gas, although partially conditional.

From this, the Study Team estimated that the Diffusion rate of town gas in the commercial trades would be 60 per cent in the first year, 67 per cent in the second year, and 75 per cent in the third year and after under this project.

(3) Consumption Volume per Town Gas User

Research under this study shows that LPG consumption in restaurants is 207.8 m^3 per month. Meals taken at restaurants are usually influenced by the effect of the rise of income. Therefore, the Study Team presumed that 50 per cent of the rise of GNP (about 6% per year) would contribute to their LPG consumption; in concrete, 241 m^3 in 1979 and 314 m^3 in 1988. In addition, as is the case for household use LPG, consideration was given to the share 128 m^3 of charcoal in the total energy consumption per restaurant of 160 m^3, and its declining trend. Therefore, the Study Team assumed that, beside the above income effect, 50 per cent of the charcoal consumption decline (in all Thailand) would be replaced with the demand for LPG. The LPG consumption thus estimated would be 260 m^3 in 1979, and 360 m^3 in 1988.

III-1-3-2 Hotel

(1) Number

In the 1973 telephone directory, the total number of hotels in the ten Bangkok amphoes is 250. The 1970 eddition of the Business Census reported that the total number of hotels were 228, of which 149 were surveyed in the encuss. This report, as mentioned above, compiled the surveys over the five metropolitan changwants, but did not clarify the number in this project town gas area. However, hotels, by nature, are presumably gathered in the central part of the metropolis. Moreover, the latest road map showing the Metropolitan Area covers 26 member hotels of the Hotel Association and 234 non-hotel members, totalling 260 hotels.

From these figures, the Study Team assumed that the number of hotels in the project gas distributing area is 250. In view of the geographical conditions of Bangkok which would form part of the Asian resort areas, the number of hotels is expected to increase with increase of tourists in the future. However, in this study report there was no assumption made as to increase of hotels in number since the future possibility of acquiring land for hotel use and construction of high-rise hotel buildings could not be predicted.

However, since the total number of hotels mentioned above vary in scale ranging from those fully equipped to those not equipped with hot-water and air-conditioning systems, the Study Team estimated the number of hotels by scale as shown below, where the ratios of the individual class of hotels are shown in terms the number of employees and the amount of annual sales, according to the said Business Census.

Number of employees	Less than 5	5 - 9	10 - 19	20 - 49	50 - 99	100 and more
Ratio (%)	8.1	29.1	18.9	18.9	12.8	12.2
Sales (1,000 bahts per year)	Less than 5	50 - 99	100 - 499	500 - 999	1,000 - 4,999	5,000 and more
Ratio (%)	6.7	8.7	35.6	21.5	22.8	4.7

Furthermore, taking into consideration the fact that 26 hotels are members of the Hotel Association, large hotels fully equipped with hot-water, air-conditioning systems and dining halls were estimated to be 20 per cent, medium hotels with at least one dining hall 50 per cent, and other hotels 30 per cent.

(2) Town Gas Diffusion Rate

For the large hotels, large LPG storage must be provided and this is considered unfavorable with respect to safety and transport in urban area, the town gas diffusion rate was set at 100 per cent from an urban policy viewpoint. For the medium hotels, it was set at 75 per cent, the same level with restaurants generally and for smaller hotels, 70 per cent, the level equal to that of household consumption.

(3) Consumption Volume per User

In this Study, two hotels belonging to the category of large scale were surveyed, the results being as follows:

	Number of rooms	Number of dining halls	Number of LPG apparatus	LPG consumption	Others
A	213	4	77	10,446	Hot water by fuel oil and air-conditionning by electricity.
B	227	-	17	3,561	Ratio of LPG to electricity consumption is 2 : 8.

Note: The LPG consumption is in 5,000 Kcal/m^3 of town gas equivalent.

The town gas consumption of 19 hotels in the Tokyo Gas service area, each with approximately 200 rooms, is 13,300 m^3 per month. From these values the consumption per large scale hotel in Bangkok was estimated to be 10,000 m^3.

For the medium hotels, each was assumed having one dining hall, and consuming 360 m^3, the same level as that of the demand of town gas in restaurants, etc. in the final project year.

For smaller hotels, each was assumed not provided with dining hall but capable of serving meals to their own managers and employees, thus consuming 75 m^3, the same level as a household user.

III-1-3-3 Others

Gas demand in boilers of public bath, many of which are seen in Bangkok, was estimated as follows.

(1) Number of Users

The 1973 telephone directory carries in it 81 public baths in the ten amphoes, whereas the Business Census reported 71 public baths. The Study Team estimated them to be 80 in the project town gas plan area.

(2) Town Gas Diffusion Rate

This Study Team serveyed the demand in 11 public baths having 6 LPG boilers and 5 fuel oil boilers. From this, town gas consumption rate was estimated to be 55 per cent, with no increase or decrease.

(3) Consumption Volume Per User

From the average consumption of the 6 LPG consumers, the town gas consumption per public bath was estimated to be 2,000 m^3 per month, and further assuming that these buildings will not be added or modified, neither increase nor decrease was estimated.

On the basis of the number of users and the consumption volume per user in individual demand sectors, town gas consumption for the individual project years was estimated as categorized in Table 3-1-4.

Table 3-1-4 Amount of Town Gas Sold by Use

Use	Item \ Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Household	Number of users at year end	5,600	12,600	22,900	42,200	67,100	91,700	116,200	139,000	159,500	182,900	191,300	197,300	197,300
	Number of users at mid year	0	9,100	17,700	32,500	54,600	79,400	104,000	127,600	149,300	171,200	187,100	194,300	197,300
	Sales per user (m^3/month)	54.3	56.5	58.6	60.5	62.8	65.0	67.2	69.3	72.2	74.6	74.6	74.6	74.6
	Total sales (1,000 m^3/year)	912	6,170	12,447	23,595	41,147	61,932	83,866	106,112	129,354	153,258	167,492	173,937	176,623
Restaurant, etc.	Number of users at year end	25	58	104	191	320	405	510	609	694	795	823	848	848
	Number of users at mid year	0	42	81	98	247	354	458	560	652	745	809	836	848
	Sales per user (m^3/month)	260	270	279	290	300	312	232	335	347	360	360	360	360
	Total sales (1,000 m^3/year)	20	136	271	341	889	1,325	1,775	2,251	2,715	3,218	3,495	3,612	3,663
Hotel	Number of users at year end	6	13	32	51	78	114	129	147	162	182	182	182	182
	Number of users at mid year	0	10	23	42	65	96	122	138	155	172	182	182	182
	Sales per user (m^3/month)	3,525	3,260	3,000	2,745	2,759	2,874	2,899	2,645	2,666	2,668	2,668	2,668	2,668
	Total sales (1,000 m^3/year)	63	391	828	1,383	2,152	3,311	4,244	4,380	4,959	5,507	5,827	5,827	5,827
Others	Number of users at year end	2	3	7	12	20	25	31	36	37	37	37	37	37
	Number of users at mid year	0	3	5	10	16	23	28	34	37	37	37	37	37
	Sales per user (m^3/month)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
	Total sales (1,000 m^3/year)	12	72	120	240	384	552	672	816	888	888	888	888	888
Total	Number of users at year end	5,600	12,600	22,900	42,300	67,200	91,800	116,400	149,200	159,700	183,100	191,500	197,500	197,500
	Number of users at mid year	0	9,100	17,700	32,600	54,700	79,500	104,200	127,800	149,500	171,400	187,300	194,500	197,500
	Sales per user (m^3/month)	59.9	62.0	64.3	65.3	67.9	70.4	72.4	74.0	76.9	79.2	79.1	79.0	78.9
	Total sales (1,000 m^3/year)	1,007	6,769	13,666	25,559	44,572	67,120	90,557	113,559	137,916	162,871	177,702	184,264	187,002

III-1-4 Pattern of Gas Demand

Factor that determines the scale of production plants and distribution facilities is the amount of demand by day or hour. For determining the production capacity of gas making plants, the maximum gas demand per hour and when and how much demand generate by hour, must be clarified. For determining the supply pipe diameters, governers and the capacities of gas holders related to gas distribution facilities, the maximum gas demand per hour must be obtained.

In order to obtain these data, a load survey was conducted on LPG users.

III-1-4-1 Load Survey

From the users subjected to the abovementioned demand survey, 17 LPG household users categorized by income level were selected, in addition to two restaurants, one little eating place, and one barber shop, as commercial users.

A gas meter was installed at each of these users to measure its gas consumption. Also, a data recorder was installed to record the user's gas-using status on a magnetic cassette tape in terms of number of pulses. Thus, consumption was measured at 15-minute intervals for one week.

These household users ranged over four ranks in income level and 2 to 11 family members, in whom all typical social strata in Bangkok were included. The data thus obtained may be interpreted as almost representing the gas-consumption status of all users.

Effective data were obtained from 16 household users and 3 commercial users. The using patterns of the both kinds of users in weekdays and weekends and holidays are as shown in Fig. 3-1-7.

III-1-4-2 Patterns of Demand by Hour

The patterns in the preceding sub-paragraph relate to only the 16 and 3 users. The more the number of users increase, the less frequently the simultaneous use of gas by different users occur. Hence, patterns of smoother curves are expected in the final project year when approximately 200,000 users will have been served, namely the time by hour when the maximum demand level indicated in the Figure will share less, and coversely daytime and midnight will share more in the total consumption. More precise future patterns must be obtained by analysis, using greater volume of data taking into consideration the features of gas-consuming status broken down by consumption scale and region.

Entirely no data of these kinds were available for the project area. Gas consumption patterns in Jakarta, as referred to in Fig. 3-1-5, was found not useful because of difference a considerable in the manner of consumption.

As a result, in order to determine the scale and operation of a gas making plant, the Study Team selected a hourly pattern in which the result of the present load survey is averaged by weight of the amount of gas sold for household and commercial uses. Fig. 3-1-5 shows this pattern.

III-1-4-3 Peak Day Consumption

The load survey showed the town gas demand by day, suggesting that occurrence of peak days was more frequent on weekend than weekdays; and the ratio of the average consumption on weekdays to that on weekend days was 1:1.17.

The survey period ranged from October to November, including the rainy and dry seasons, with the nearly mean temperature of the year. Moreover, the annual average monthly temperature varied by a little over only 6.9°C. In addition, the demand subjected to the load survey consequently covered town gas for cooking use, which is deemed as not sensitive to temperature. On all these grounds, the above ratio was judged to be of invariable through the year.

III-1-4-4 Peak Hour Consumption

The result of the load survey shows, as given in the table below, that the maximum consumption per hour is recorded during the time from 17:30 to 18:30 p.m. for household use, and from 8:00 to 9:00 a.m. for commercial use.

	17:30 to 18:30		8:00 to 9:00	
	Household use	Commercial use	Household use	Commercial use
Average	0.1828	0.1778	0.0599	0.5075
Maximum	1.1902	0.7574	0.3246	1.0279
Minimum	0	0	0	0
Standard differential	0.2190	0.2483	0.0845	0.3899

The above data would be used to estimate peak hour consumption, but the following equation was used taking into consideration the rate of simultaneous use:

$$Y = \bar{x} + k \cdot \sigma \cdot \sqrt{\frac{1}{\eta} + \frac{1}{N}}$$

where
- Y: Peak hour consumption
- $\bar{x}$: Average value
- k: Reliability coefficient
- σ: Standard differential
- η: Number of data
- N: Number of users presumed

The result is shown in Fig. 3-1-6.

The monthly consumption of town gas by users subjected to the load survey stood at 41.2 m^3 for household use, and 135 m^3 for commercial use. For saying pipelines, because those of such diameters that can satisfy the gas consumption in the final project year must be designed, peak hour demand was estimated by the use of a value obtained through the said average value modified to that of the final year.

What is most important in determining pipe diameters is that sufficient amount of town gas must be assured at end users, i.e. feed of town gas through governers to the pipelines. In this project, each governor is to handle 3,000 users on the average, as referred to hereinafter. Hence, the peak consumption per user for 3,000 users are estimated as shown in the following table.

Use \ Time	17:30 to 18:30	8:00 to 9:00
For household use	0.3744	0.1252
For commercial use	0.5856	1.5284
Weighted average	0.3789	0.1541

Therefore, the peak hour will range from 17:30 to 18:30 with a flow rate of 0.3789 m^3/hour.

For reference, the sales per user (in 1988) during 18:00 to 19:00 on the weekend, as estimated from the said hourly consumption pattern of peak days, will be 0.3706 m^3/hour, almost coinciding with the above values.

Fig. 3-1-5 Hourly Consumption Pattern

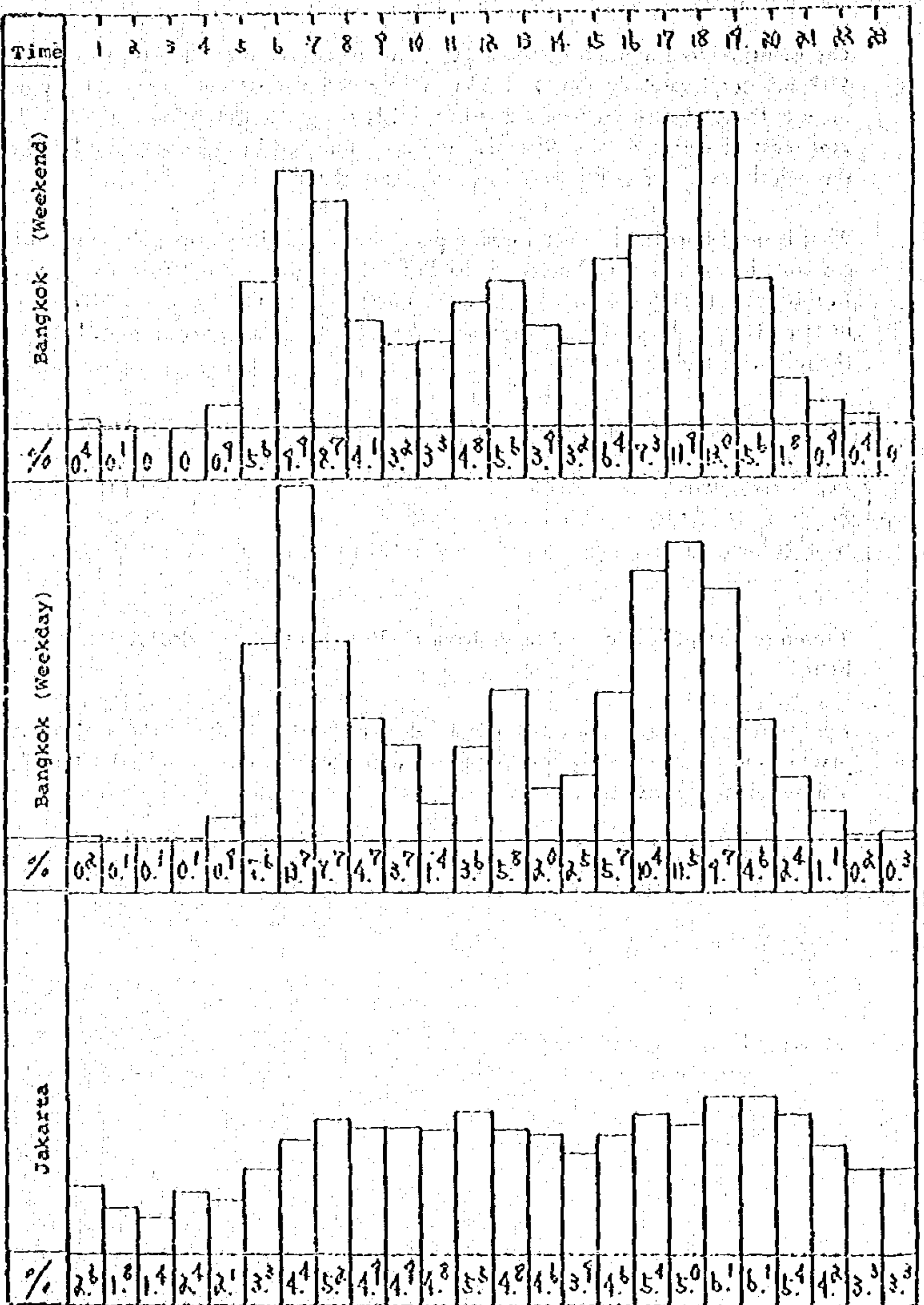


Fig. 3-1-6 Presumed Peak Hour Consumption

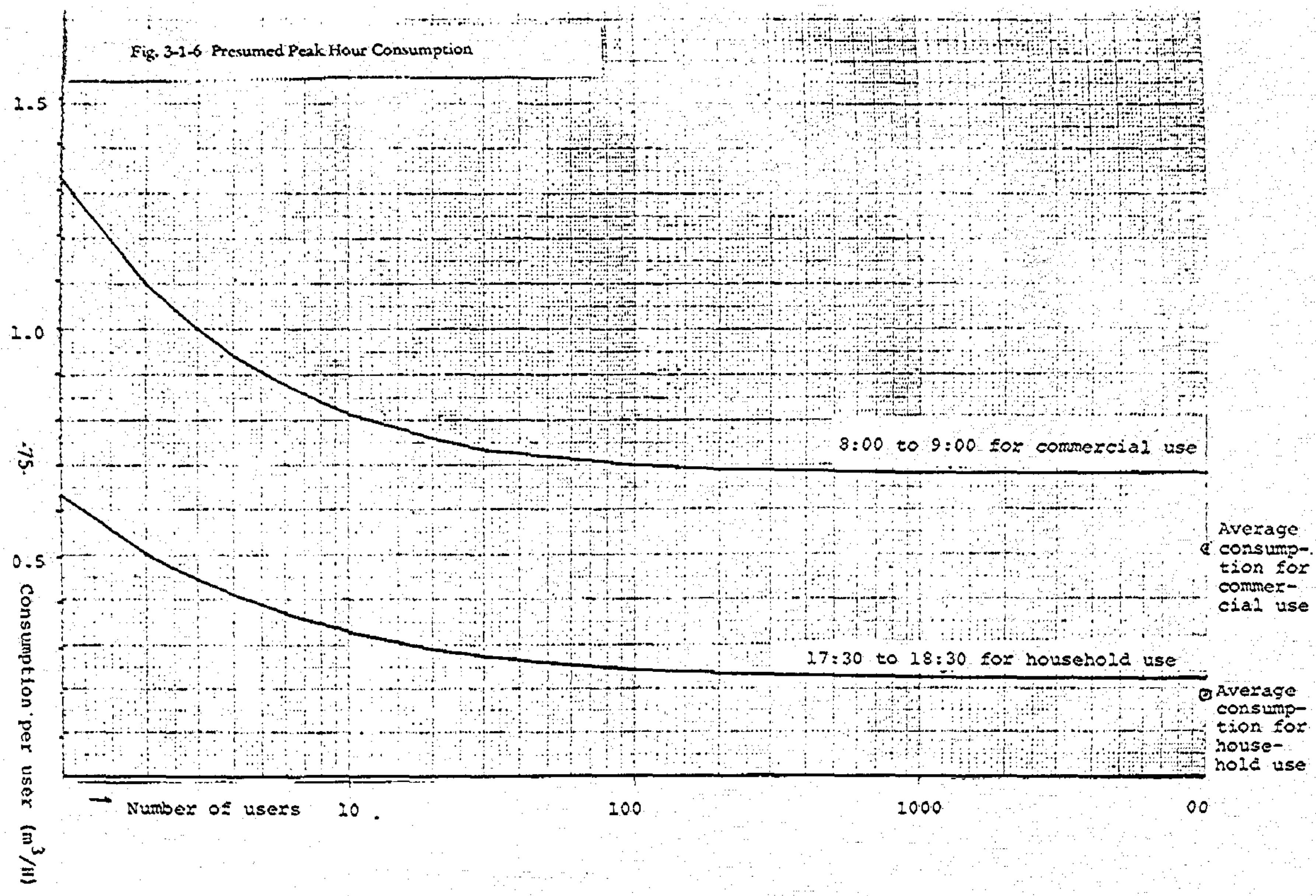


Fig. 3-1-7 Home Use Weekday

```
#######################
#     HOME    USE     #
#                     #
#     WEEKDAY         #
#######################

## A.M ##
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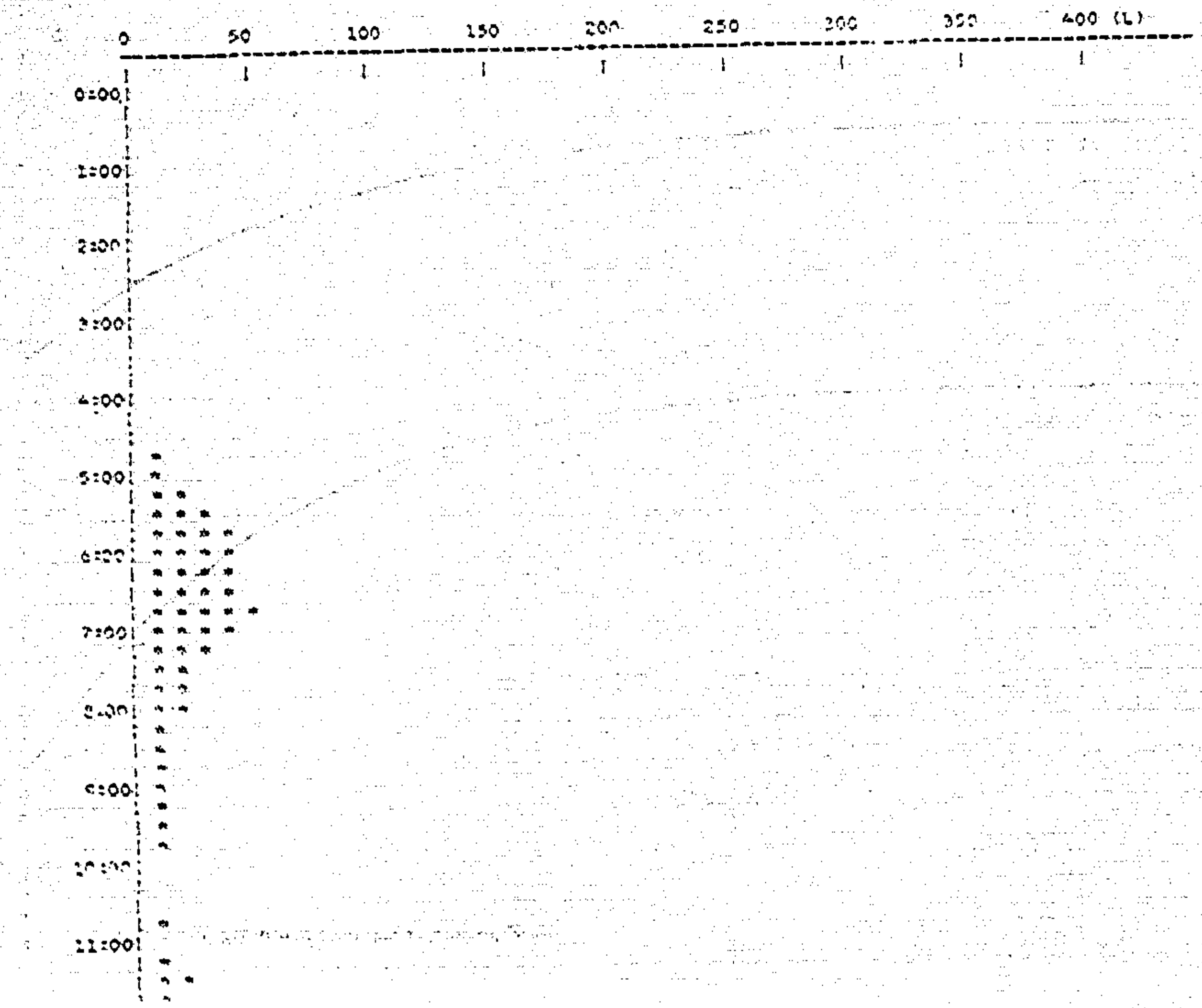
Note: * symbol represents 10 liters.

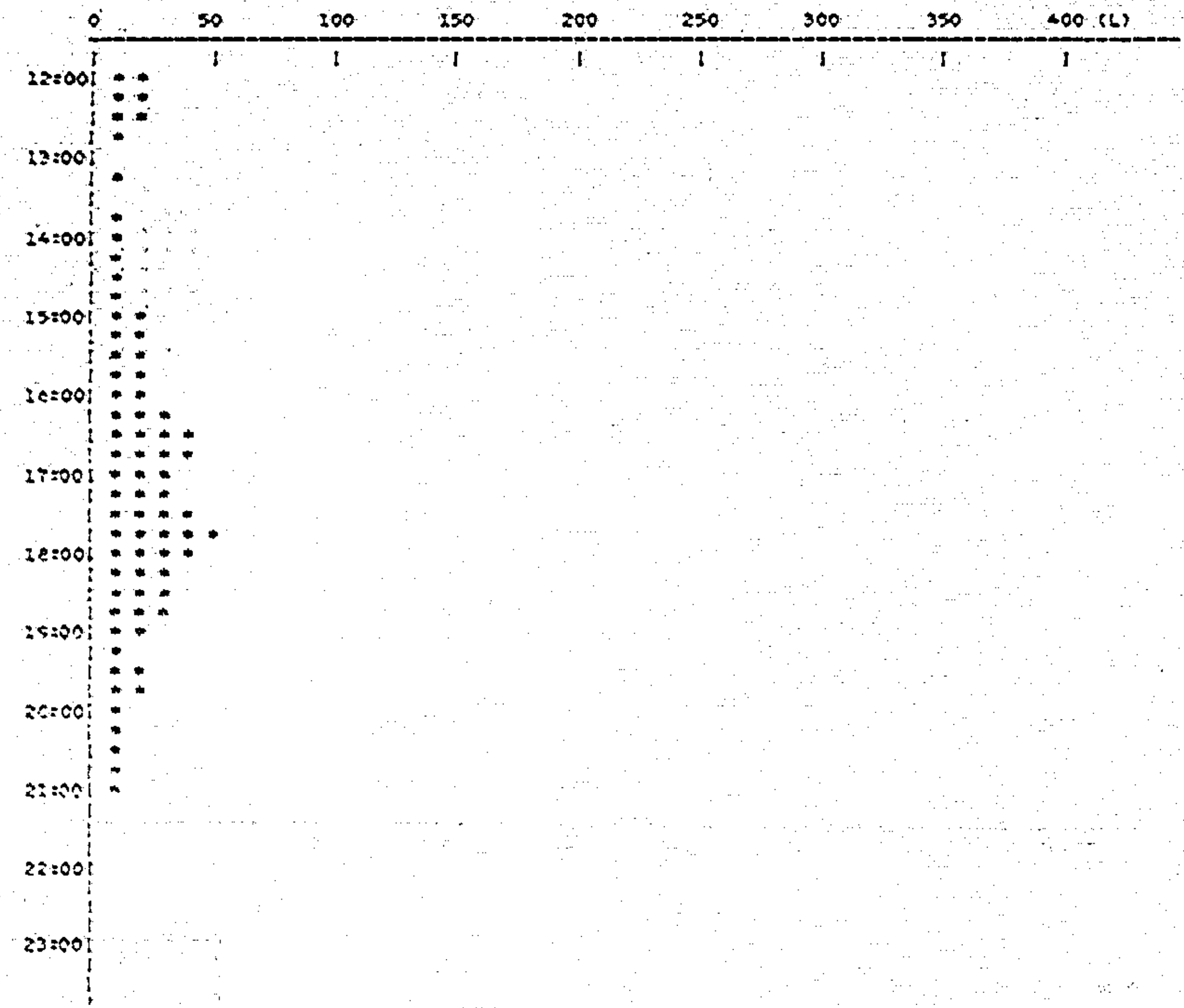


5000KCAL GAS (L)	PERCENT/DAY
0.00	0.00
0.00	0.00
2.10	0.16
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.70	0.05
0.70	0.05
0.00	0.00
0.00	0.00
0.00	0.00
0.00	[illegible]
0.00	0.00
0.70	0.05
0.00	0.00
0.70	0.05
2.81	0.21
3.51	0.27
5.62	0.43
9.13	0.71
21.07	1.64
27.40	2.13
41.45	3.23
44.26	3.44
42.15	3.25
43.56	3.39
47.77	3.72
36.53	2.84
25.29	1.97
20.37	1.59
21.96	1.71
21.07	1.64
11.94	0.93
14.05	1.09
11.94	0.93
12.64	0.98
10.53	0.82
14.04	1.16
7.94	0.61
4.70	0.36
4.63	0.36
1.45	0.12
5.72	0.44
4.84	0.37
7.48	0.75
16.35	1.27
[illegible]	[illegible]

HOME USE
WEEKDAY

P M

Note: * symbol represents 10 liters.



Time	5000KCAL GAS (L)	PERCENT/DAY
12:00	21.31	1.66
	19.67	1.53
	18.03	1.40
	13.93	1.08
13:00	4.05	0.31
	6.55	0.51
	4.91	0.38
	9.68	0.75
14:00	11.13	0.86
	5.56	0.43
	7.61	0.59
	6.76	0.52
15:00	18.78	1.46
	17.78	1.38
	18.02	1.40
	17.79	1.38
16:00	21.78	1.69
	33.72	2.62
	42.85	3.34
	35.83	2.79
17:00	30.21	2.35
	30.91	2.40
	41.45	3.23
	47.77	3.72
18:00	35.83	2.79
	34.42	2.68
	28.80	2.24
	27.40	2.13
19:00	15.45	1.20
	10.53	0.82
	18.26	1.42
	16.15	1.25
20:00	8.43	0.65
	9.83	0.76
	6.32	0.49
	5.62	0.43
21:00	7.72	0.60
	3.51	0.27
	0.70	0.05
	1.40	0.10
22:00	0.00	0.00
	0.70	0.05
	2.10	0.16
	0.00	0.00
23:00	2.10	0.16
	0.70	0.05
	0.00	0.00
	[illegible]	[illegible]

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*      HOME   USE      *
*                      *
*      WEEKEND         *
************************

** A * **
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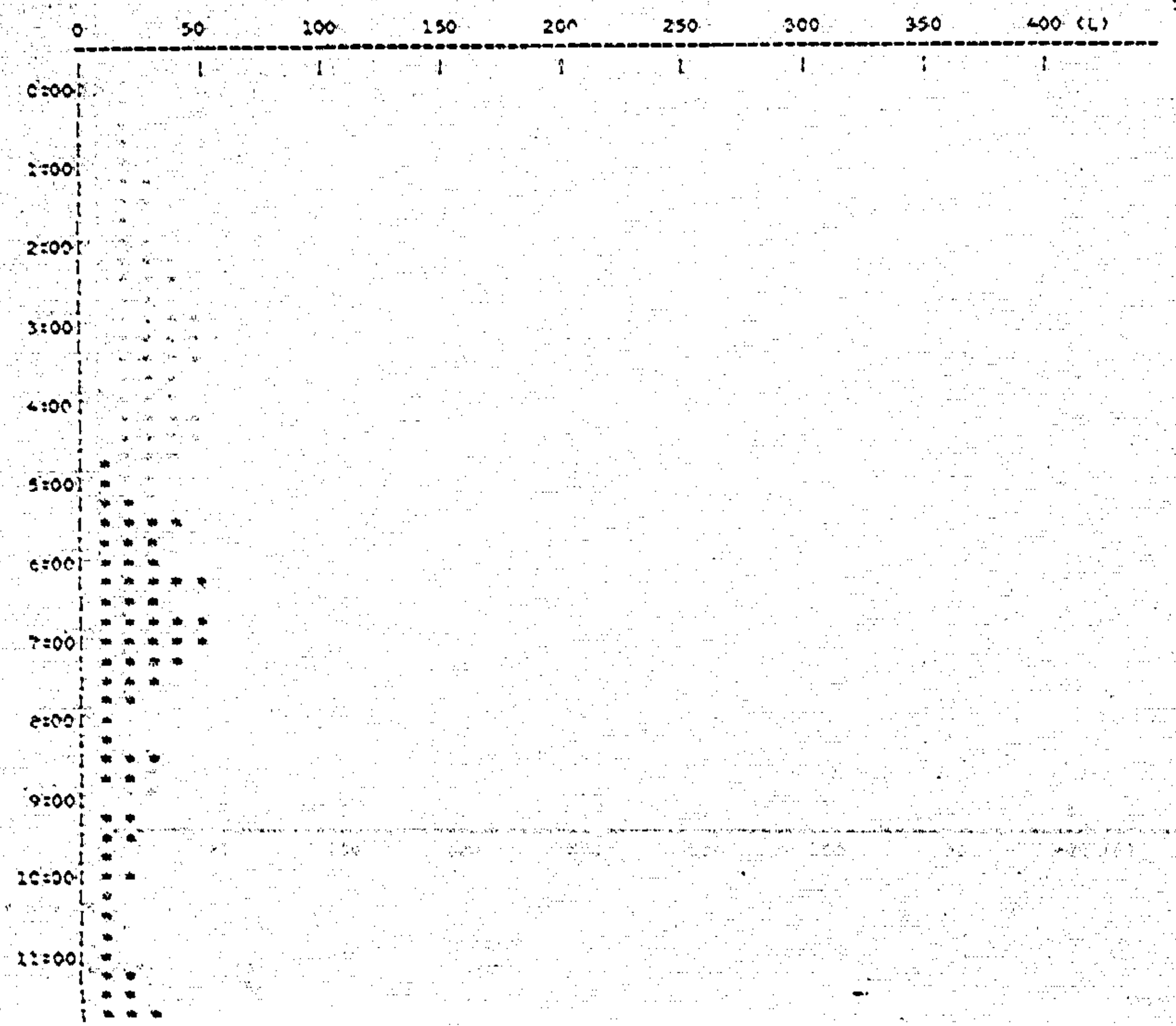
Note: * symbol represents 10 liters.



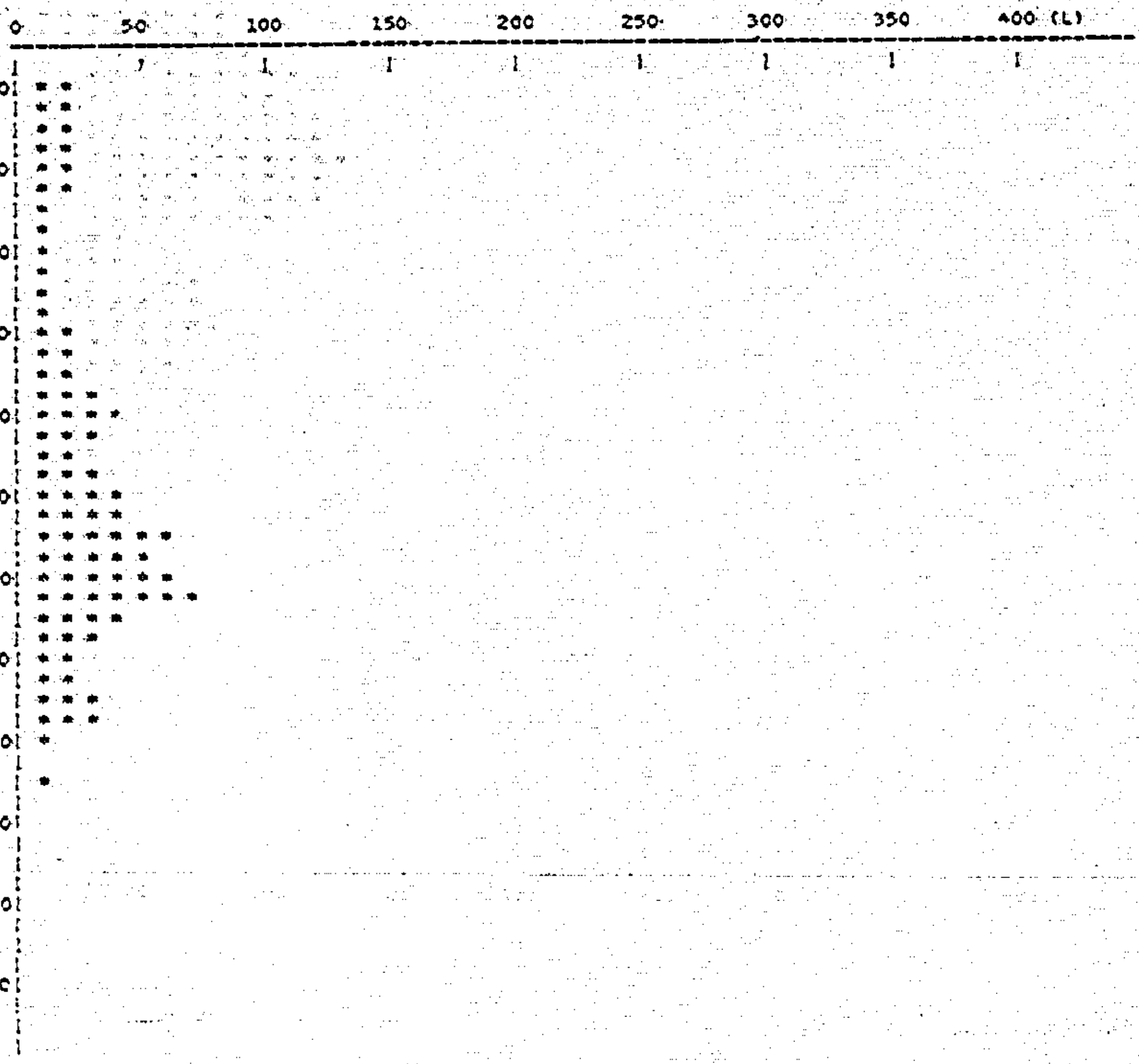
5000KCAL GAS (L)	PERCENT/DAY
1.59	0.10
1.59	0.10
3.18	0.20
0.00	0.00
0.00	0.00
0.00	0.00
1.59	0.10
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
3.18	0.20
1.59	0.10
7.95	0.50
6.36	0.40
17.50	1.10
35.00	2.21
31.82	2.00
25.45	1.60
47.73	3.01
31.82	2.00
54.10	3.41
52.50	3.31
44.55	2.81
25.45	1.60
17.50	1.10
6.36	0.40
12.72	0.80
27.05	1.70
15.91	1.00
4.77	0.30
15.91	1.00
15.91	1.00
12.36	0.78
15.45	0.97
12.36	0.78
12.36	0.78
10.82	0.68
7.72	0.48
17.00	1.07
23.18	1.46
27.82	1.75

HOME USE

WEEKEND

P M

Note: * symbol represents 10 liters.

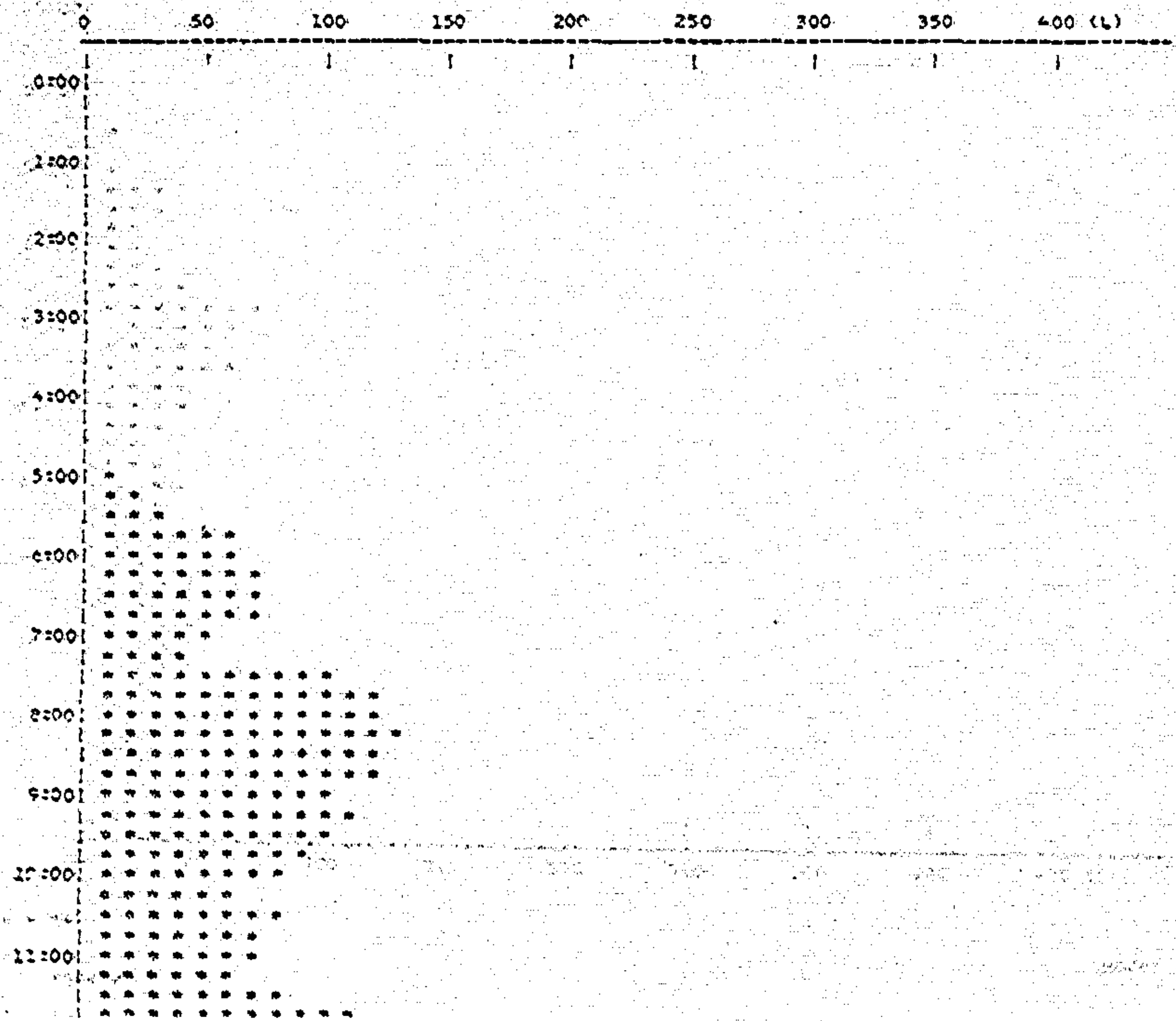


	5000KCAL GAS (L)	PERCENT/DAY
12:00	23.18	1.46
	24.73	1.56
	17.00	1.07
	23.18	1.46
13:00	24.73	1.56
	18.54	1.17
	9.27	0.58
	7.72	0.48
14:00	10.82	0.68
	12.36	0.78
	12.36	0.78
	13.91	0.87
15:00	23.18	1.46
	20.09	1.26
	24.73	1.56
	32.46	2.04
16:00	38.64	2.44
	30.91	1.95
	21.64	1.36
	25.45	1.60
17:00	36.59	2.31
	44.55	2.81
	63.64	4.01
	46.14	2.91
18:00	58.87	3.71
	66.82	4.22
	41.37	2.61
	25.45	1.60
19:00	20.68	1.30
	19.09	1.20
	25.45	1.60
	25.45	1.60
20:00	12.72	0.80
	4.77	0.30
	6.36	0.40
	3.18	0.20
21:00	3.18	0.20
	4.77	0.30
	3.18	0.20
	1.59	0.10
22:00	3.18	0.20
	3.18	0.20
	0.00	0.00
	0.00	0.00
23:00	0.00	0.00
	0.00	0.00
	0.00	0.00
	0.00	0.00

Note: * symbol represents 10 liters.

```
#  COMMERCIAL  USE  #
#                   #
#      WEEKDAY      #
#####################
```

A M



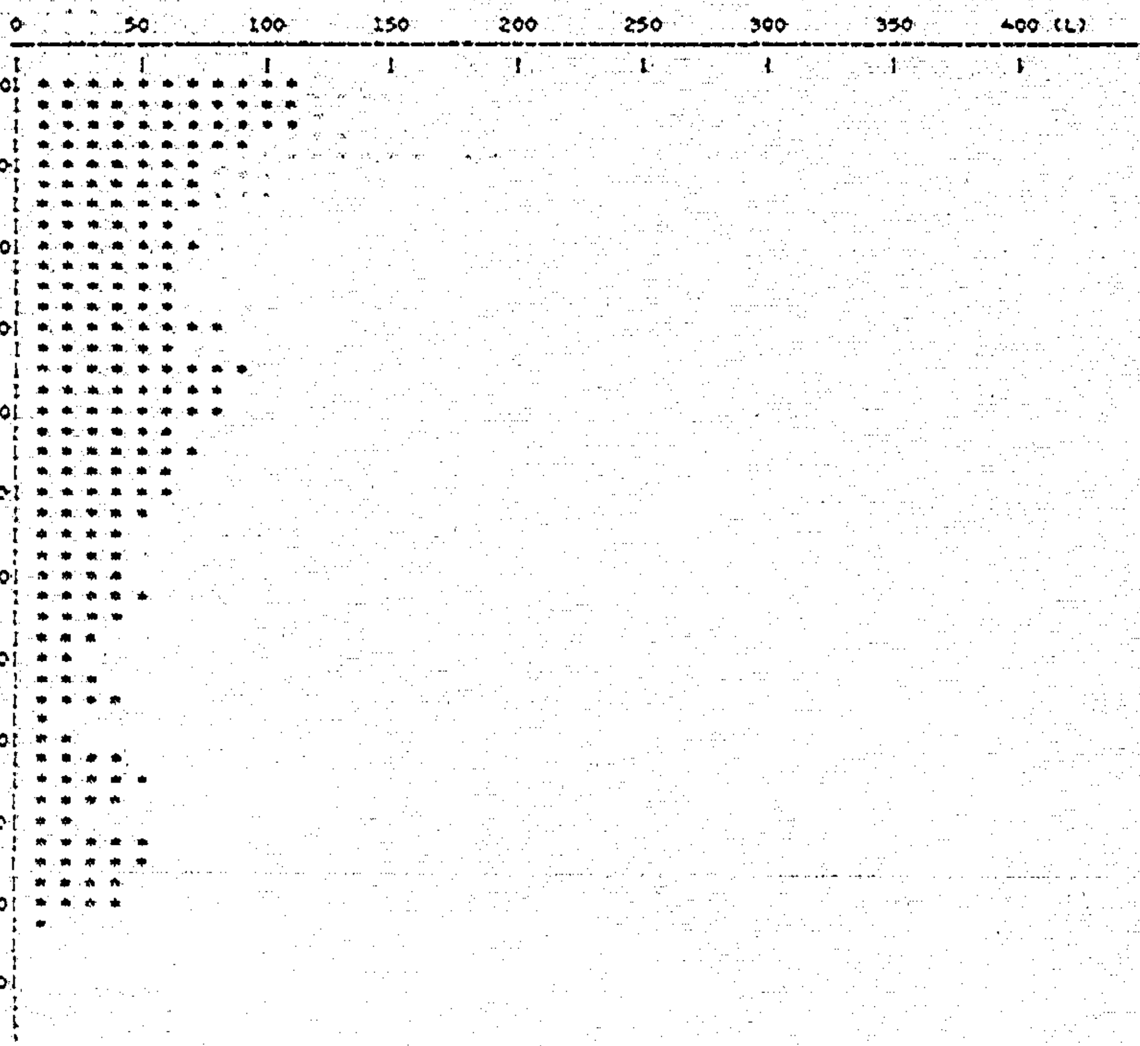
5000KCAL GAS (L)	PERCENT/DAY
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
3.40	0.07
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
10.82	0.23
18.03	0.39
32.46	0.70
61.31	1.33
57.70	1.25
68.52	1.49
72.13	1.56
72.13	1.56
50.49	1.09
43.28	0.94
104.59	2.27
115.41	2.51
122.62	2.66
133.44	2.90
119.02	2.59
122.62	2.66
104.59	2.27
111.80	2.43
100.47	2.18
88.87	1.93
83.23	1.81
63.11	1.37
81.15	1.75
67.62	1.47
72.13	1.56
59.60	1.27
81.15	1.75
112.70	2.45

COMMERCIAL USE
WEEKDAY

P. M

..384.PAGE

Note: "*" symbol represents 10 liters.

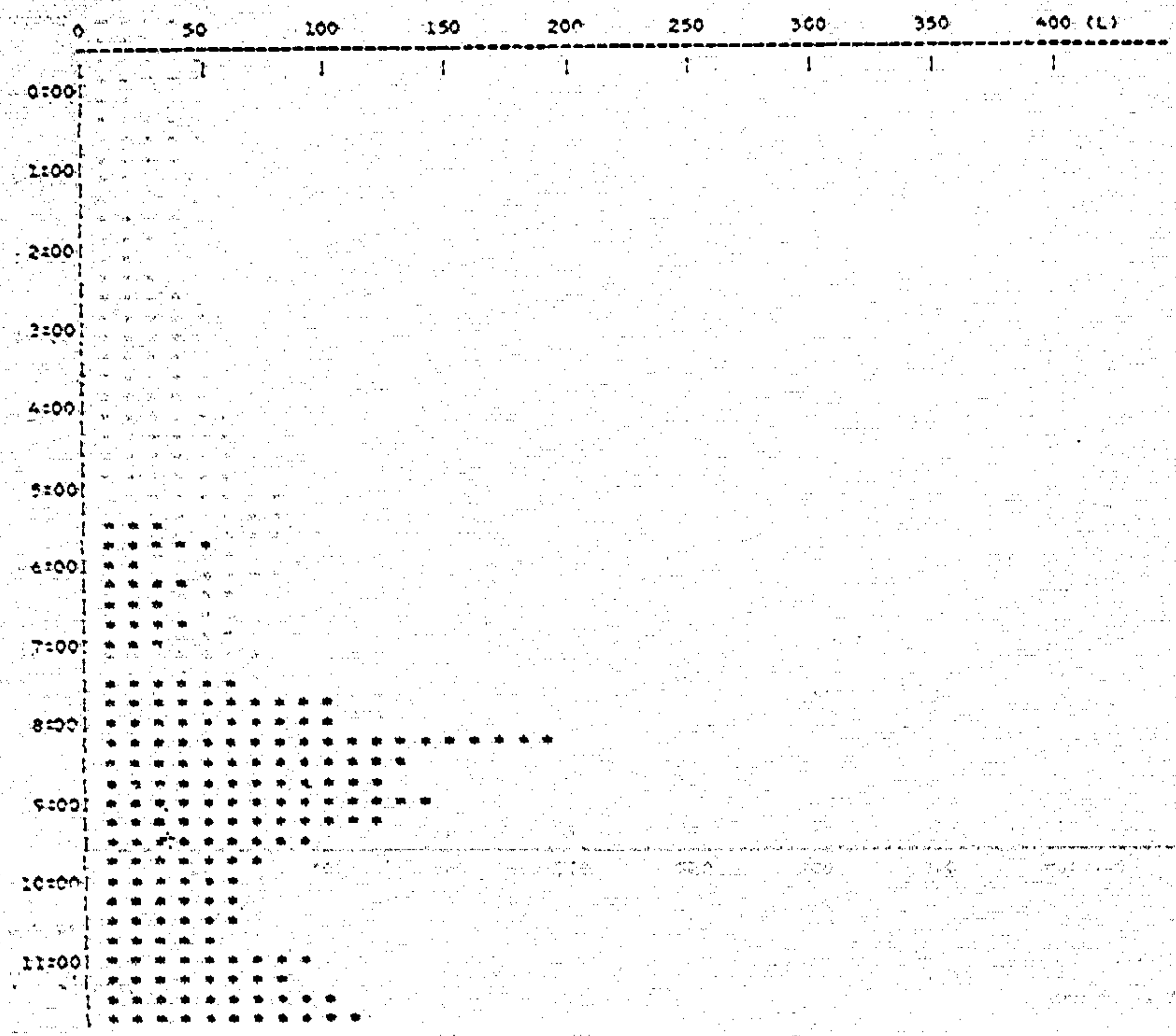


Time	5000KCAL GAS (L)	PERCENT/DAY
12:00	112.70	2.45
	112.70	2.45
	112.70	2.45
	94.67	2.06
13:00	72.13	1.56
	67.62	1.47
	67.62	1.47
	63.11	1.37
14:00	72.13	1.56
	58.26	1.26
	62.42	1.35
	58.26	1.26
15:00	79.34	1.72
	61.31	1.33
	86.56	1.88
	82.95	1.80
16:00	75.74	1.64
	64.92	1.41
	68.52	1.49
	61.31	1.33
17:00	64.92	1.41
	54.10	1.17
	36.06	0.78
	39.67	0.86
18:00	39.67	0.86
	50.49	1.09
	39.67	0.86
	32.46	0.70
19:00	21.64	0.47
	25.24	0.54
	36.06	0.78
	14.42	0.31
20:00	18.03	0.39
	43.28	0.94
	54.10	1.17
	39.67	0.86
21:00	21.64	0.47
	46.88	1.02
	46.88	1.02
	39.67	0.86
22:00	36.06	0.78
	14.42	0.31
	0.00	0.00
	3.60	0.07
22:00	3.60	0.07
	3.60	0.07
	0.00	0.00
	0.00	0.00

\# WEEKEND #

\## D A Y ##

Note: * symbol represents 10 liters.

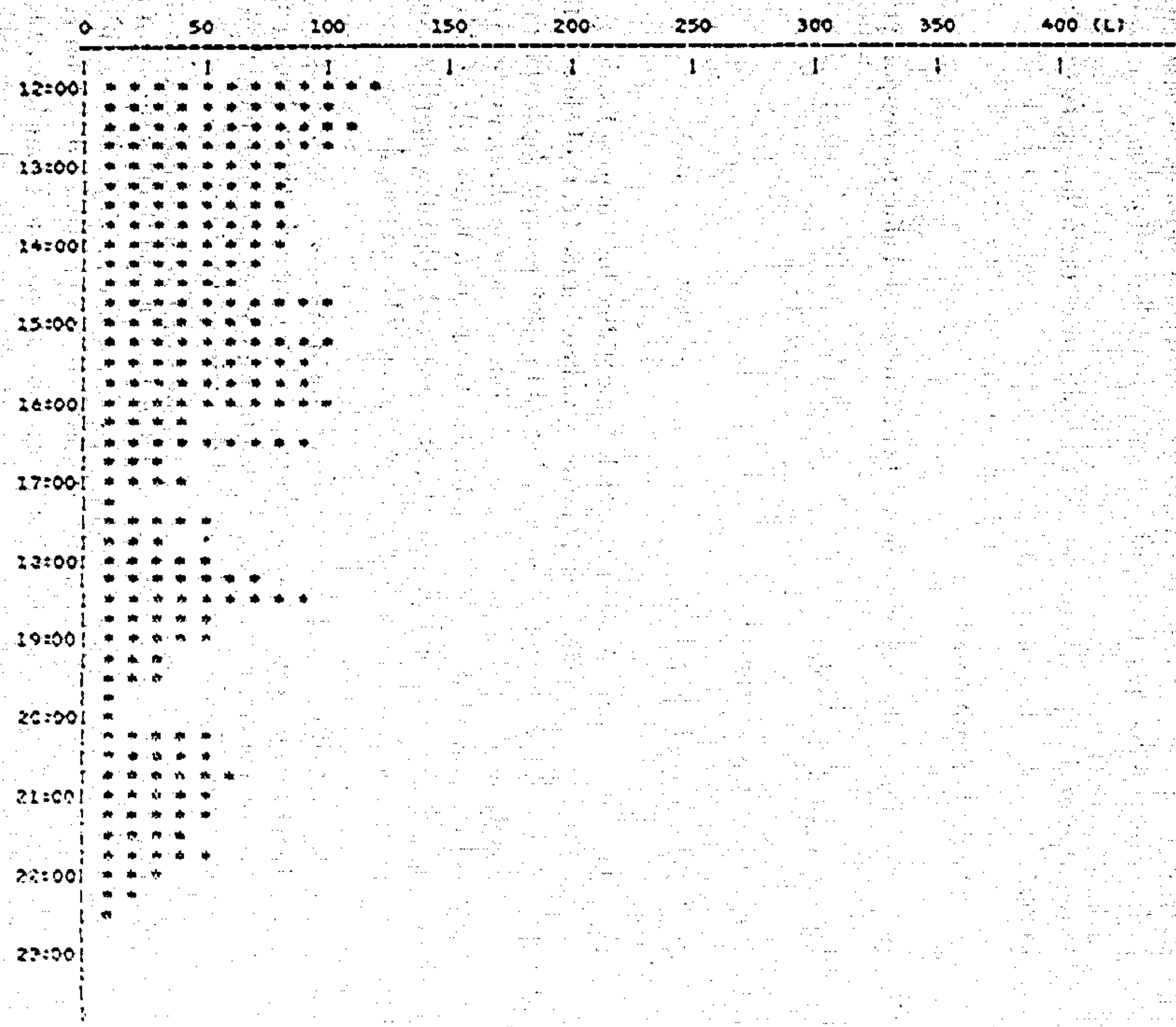


5000KCAL GAS (L)	PERCENT/DAY
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
27.05	0.59
45.08	0.99
18.03	0.39
36.06	0.79
27.05	0.59
36.06	0.79
27.05	0.59
0.00	0.00
63.11	1.39
99.18	2.19
99.18	2.19
189.35	4.19
126.23	2.79
117.21	2.59
135.25	2.99
117.21	2.59
90.16	1.99
72.13	1.59
63.11	1.39
63.11	1.39
63.11	1.39
54.10	1.19
90.16	1.99
81.15	1.79
99.18	2.19
108.20	2.39

COMMERCIAL USE
WEEKEND

P P

Note: * symbol represents 10 liters.



Time	5000KCAL GAS (L)	PERCENT/DAY
12:00	117.21	2.59
	99.18	2.19
	108.20	2.39
	99.18	2.19
13:00	81.15	1.79
	81.15	1.79
	81.15	1.79
	81.15	1.79
14:00	81.15	1.79
	72.13	1.59
	63.11	1.39
	99.18	2.19
15:00	72.13	1.59
	99.18	2.19
	90.16	1.99
	90.16	1.99
16:00	99.18	2.19
	36.06	0.79
	90.16	1.99
	27.05	0.59
17:00	36.06	0.79
	9.01	0.19
	54.10	1.19
	27.05	0.59
18:00	54.10	1.19
	72.13	1.59
	90.16	1.99
	45.08	0.99
19:00	45.08	0.99
	27.05	0.59
	27.05	0.59
	9.01	0.19
20:00	9.01	0.19
	54.10	1.19
	45.08	0.99
	63.11	1.39
21:00	54.10	1.19
	45.08	0.99
	36.06	0.79
	45.08	0.99
22:00	27.05	0.59
	18.03	0.39
	9.01	0.19
	0.00	0.00
23:00	0.00	0.00
	0.00	0.00
	0.00	0.00
	0.00	0.00

III-2 Gas Making System

III-2-1 Assessment of Town Gas Raw Materials

III-2-1-1 Selection of Raw Materials for Gasification

Natural solid and liquid fuels can be used as raw materials for gasification, each of which can be used as raw materials for gas-making, as well.

In Thailand, materials that may be used to make town gas are coal, lignite, crude oil, heavy fuel oil naphta, LPG and refinery-off gas (hereinafter called 'off-gas').

In selection of the optimal raw material for gasification, the following factors should be examined.

(a) Method of gasification

(b) Extent of availability of the optimal raw material, including its transport problem

(c) Cost of gas (variable)

(d) Amount of investment

(e) Processing of by-products

(1) Lignite is extracted at the Mae Moh Lignite Mine (in Lampang Province) and the Krabi Lignite Mine (in Krabi Province), and coal at the Lee Coal Mine (in Lanpoon Province). Both ores are produced at 500 to 700 tons per day, respectively, and mainly used for thermal power plant. Due to their qualities, gasification, particularly that of the lignite, is difficult. Gasification in the scale of this project would require a great amount of investment, and either the complete gasification process or the fluid dry distillation process should be employed.

Moreover, if these ores were used as raw materials for gas making, approximately 1,000 tons of coal per day would have to be consumed. This is almost impossible because the ores must be transported from these mines located more than 500 km away from Bangkok, and because of their mining capacities.

(2) Crude and heavy fuel oils can be taken from Bangchak Oil Refinery of Summit Industrial Corporation to the project service area, through pipeline. Gasification of crude oil is performed by the thermal cracking process or the steam reforming process using a catalyzer. Both processes will generate by-products, such as tar equivalent to 10 to 30 per cent of the raw material, and naphthalene.

Consumption of crude oil for this project service area would be approximately 300 kiloliters per day.

Tar in its original form cannot be a commodity. In Japan tar is distilled to obtain benzene, toluene, xylene, pitch, etc., which are sold as the secondary products. In Thailand, however, because the chemical industry is not very active, sale of these by-products would confront difficulties. They would be limited in quantity, as well.

Besides, equipments, if installed for processing of by-products, would require approximately the amount of investment twice as much as those required by the gasification of naphtha or off-gas than that of crude oil or fuel oil. Table 3-2-1 shows comparison of naphtha and off-gas with crude oil as raw materials for gasification.

Table 3-2-1 Comparison of Naphtha and Off-Gas with Crude Oil and Fuel Oil as Raw Materials for Gasification

Item / Raw material	Equipment investment	Variable expenses	Others
Naphtha and off-gas	330×10^6 bahts	0.2 bahts/1,000 kcal	No products are generated
Crude oil	600×10^6 bahts	0.21 - 0.22 bahts/1,000 kcal	Processing of by-products is difficult.

Note: Naphtha: 1,466.7 bahts/kℓ
Off-gas: 0.143 bahts/1,000 kcal
Crude oil: 1,333.3 bahts/kℓ
The variable expenses include only the cost of raw material or fuel.

Accordingly, naphtha and off-gas should be used as the principal raw materials for town gas.

LPG with respect to its chemical properties, may be used as a raw material for town gas, but it was decided that it would not be used as the main raw material because LPG is higher in cost than naphtha and off-gas and because, as previously mentioned in relation to the energy situation of Thailand, LPG may become short of its demand if the current increasing rate of the demand would continue, but it would be used as a substitute for off-gas in the event of the shutdown of refinery.

III-2-1-2 Procurement of Raw Materials

Approximate amount of raw materials required at the final stage of this project is:

Naphtha	260 kℓ/day
Off-gas	72,000 Nm^3/day

Off-gas, and naphtha also, can hardly be delivered by tanker truck. Conveyance by pipeline is therefore suitable. For this reason, the raw materials should be purchased from Bangchak Oil Refinery of Summit Industrial Corporation, the nearest refinery from the town gas service area.

III-2-1-3 Qualities and Quantities of Raw Materials

As for the quality of the raw materials, the values of naphtha and off-gas analyzed at Bangchak Oil Refinery are shown in Tables 3-2-2 and 3-2-3.

The quantities of the raw materials depend upon the capacity of the refinery, including their purposes. At present naphtha has no domestic demand in Thailand. Naphtha with a high octane value is processed to obtain gasoline, while that with a low octane value is exported in its original state.

The volume of naphtha available for this project from Summit Industrial Corporation is approximately 300 kℓ/day, sufficient to satisfy the project demand.

Off-gas, a kind of waste gas generated in the process of oil refining, mainly comprises hydrogen, methane, etc. with a calorific value of 10,000 $Kcal/Nm^3$. Off-gas, usually consumed by the refinery itself or burned off, has little commercial value.

Bangchak Oil Refinery uses only a part of its off-gas as a raw material for a hydrogen plant, while consumes the most part as fuel for its boilers.

Off-gas available for the project town gas is the part which has been consumed as fuel, having the following quantities:

Off-gas from No. 2 Plant:	14,370 Nm^3/day, 16,200 $Kcal/Nm^3$
Off-gas from No. 3 Plant:	65,120 Nm^3/day, 11,465 $Kcal/Nm^3$

This proves that off-gas supply will also be sufficient in quantity in view of the fact that the project gas making plant would require 72,000 Nm^3/day of off-gas.

The off-gas, however, is not generated during the regular maintenance service of the refinery. In this case, a substitute raw material will be required. Therefore, propane was selected as a substitute because, in order to reduce equipmental investment, the substitute must be allowed to use the same pipeline of off-gas, and also propane can use the pipeline safely but butane cannot, since the latter has a lower dew point and hence will be condensated inside the pipeline subjected to a pressure of approximately 4 kg/cm^2G.

Table 3-2-2 Chemical Naphtha Specifications (For Export)*

	Min.	Max.
Sp. gr. @ 60 °F	0.660	0.695
ASTM Distiliation		
IBP °F (°C)	86 (30)	-
10% vol.	113 (45)	149 (65)
90% vol.	185 (85)	239 (115)
FBP	-	265 (130)
PONA Analysis, vol. %		
Paraffin	75	-
Olefins	-	1.0
Naphthene	-	20.0
Aromatics	-	7.5
Sulfur content, wt %	-	0.05
Load content, (max.)		100 PPB
Color saybolt	+ 30	

* Stock available for export in April 1972.

Table 3-2-3 Refinery Off-Gas Base on Arabian Light Crude

Component	Plant No. 2	Plant No. 3
	Vol. %	Vol. %
H_2	24.96	60.87
C_1	12.15	7.02
C_2	39.08	8.60
C_3	5.92	5.17
iC_4	1.465	6.28
nC_4	7.12	5.68
iC_5	3.50	6.38
nC_5	5.84	-
	100.00%	100.00%

MW = 28.48 = 22.35 KSCFH = 59 MPH = 1,680 Lbs/Hr

MW = 18.7 = 4,994 Lbs/Hr

III-2-1-4 Prices of Raw Materials

The prices of raw materials should be decided mutually between the purchaser and supplier. In this study, the prices are determined on the basis of actual conditions, similar to those of Thailand prevailing in other crude oil importing countries. Table 3-2-4 shows the prices of various fuels in Japan, Thailand and Singapore.

Naphtha is priced at 1455.7 bahts/kℓ, taking into consideration its disadvantage that the quantity purchased by the town gas service concern is comparatively small, and the advantage that it can be delivered through pipeline, as well.

Off-gasis priced at a level 10 per cent higher in unit price per calorie than fuel oil, on the ground that the refinery converts it into fuel oil.

Off-gas from No. 2 Plant (abbreviated as 'OG 1'): 2.31 bahts/Nm^3
Off-gas from No. 3 Plant (abbreviated as 'OG 2'): 1.64 bahts/Nm^3

Although LPG price in Thailand has been stable without fluctuations even after the oil crisis, 3,000 bahts.

Table 3-2-4 Comparison of Prices between Naphtha, Butane and Fuel Oil

Nation / Material	Japan	Singapore	Thailand
Naphtha	1466.7 bahts/kℓ	1333.3 bahts/kℓ	
Propane	3333 bahts/ton		
Butane	2600 bahts/ton	2333 bahts/ton	2190 bahts/ton
Heavy fuel oil	1230 bahts/kℓ		1260 bahts/kℓ

Note: (1) Butane in Thailand (butane 80% and LPG 20%) is priced at its wholesale price minus tax.
(2) Heavy fuel oil in Thailand is priced at its selling price from refinery to EGAT minus tax.

Table 3-2-5 Prices of Various Raw Materials

Raw material	Price
Naphtha	1466.7 bahts/kℓ
OG 1	2.31 bahts/Nm^3
OG 2	1.64 bahts/Nm^3
Propane	3000 bahts/ton

III-2-2 Selection of Plant Site

A land required for the site of the project town gas making plant should be at least 50,000 m^2, with the following conditions required.

(a) The site should be convenient for receipt of raw materials, namely close to the raw material supplier.

(b) The site should be close to the consumer zone.

(c) Electricity, water and other utilities should be readily available.

(d) Manpower should be easily mobilized.

(e) Land price should be low.

(f) The site should not infringe any other projects, city development plans, and the like in Thailand.

Although all these requirements cannot fully be satisfied with ease, they must be taken into consideration collectively in selecting the site.

The project town gas area is as shown in Fig. 3-1-4. The 'Industrial Region' where the construction of plants is permitted under the 'Town and Country Planning' established by the Ministry of Interior is as shown in Fig. 2-2-10.

Since Bangchak Oil Refinery is the only raw material supplier of Thailand, the plant site will be inevitably limited to the vicinity of the refinery.

Consequently, three areas shown in Fig. 3-2-1 were preselected for the site, so that either one of them be selected as the final plant site in accordance with the following equation which satisfies the minimum requirement.

Total sum = cost of land to be aquired + cost of road construction + cost of power receiving cabling + cost of raw material transport piping + cost of drain construction.

Total sum for each of Areas 1, 2 and 3 calculated by the equation are,

Area 1:	84,000,000 bahts
Area 2:	20,000,000 bahts, and
Area 3:	38,000,000 bahts.

Therefore, Area 2 was selected as the gas making plant site.

III-2-3 Electricity

III-2-3-1 Present Situation of Electricity

Consumption of electricity has also been sharply increasing, as referred to above, with a 23 per cent rise in the whole Thailand, and a 21 per cent rise in the Greater Bangkok Area, per year over a period from 1966 through 1972.

To cope with this situation, EGAT is planning to strengthen the existing hydraulic and thermal power plants and to construct new ones, including future development of a nuclear power station.

Voltages are categorized as follows:

Low voltage	110V (single-phase) 220V (three-phase) 380V (three-phase)	50 Hz 50 Hz 50 Hz
High voltage	12,000V (three-phase) 24,000V (three-phase) 69,000V (three-phase)	50 Hz 50 Hz 50 Hz

Electricity is largely classified by use into household, commercial and industrial uses. The latter two are further subdivided by peak value of continuous 15 minutes as follows, each subjected to different electric rate system:

Less than 30 kW	Small business
30 - 499 kW	Medium business
500 kW or more	Large business

Besides, a special rate system is applied to such a private business or State-owned enterprise as is operated at a high rate during off-peak hours. The project town gas service is also one of the State-owned enterprises. In the final scale of the service, its peak power consumption is predicted to reach 6,000 kW.

The special rate will, therefore, be applied to it. The table of special electric rates is as shown in Table 3-2-6.

Table 3-2-6 Special Electric Rates (For the case of Soda Ash Industry)

Demand charge:		
	First 5,000 kW	45.00 bahts/kW
	Over 5,000 kW	40.00 bahts/kW
Energy charge:		0.333 bahts/kWh

III-2-3-2 Receiving of Electricity

Consumption of electricity at the project gas making plant in the final project year is estimated to be 6,000 kW for a peak hour. Electricity should be supplied from the Samrong Substation of MEA by the 69 kV aerial line, the route of which is as shown in Fig. 3-2-1.

III-2-3-3 Power Supply System and Categorized Voltages

In-plant power supply system should comprise, as shown in Fig. 3-2-2, the super-high tension substation and the No. 1 and No. 2 substations. Power should be supplied mainly through No. 1 substation to gas making equipment, utilities and offices, while thorugh No. 2 substation to compressors, gas cooling equipment, etc. The in-plant voltages are as categorized below:

3,300 V	Three phase	Motors over 150 kW
380 V	Three phase	Motors between 10 - 150 kW
220 V	Three phase	Motors below 10 kW
220 V	Single phase	Instrumentation, illumination, etc.

III-2-3-4 Stability of Power Supply

For the project gas making plant, the stability of power supply is very important. If power supply is interrupted, gas making and distribution will become impossible. Therefore, some countermeasures are mandatory to properly meet the situation of the power supply.

Presently power is transmitted within the standard allowance of

Voltage:	± 10%
Frequency:	± 5%

The greatest outstanding problem is power failure. One or two instantaneous power interruptions are said to usually occur in a month, seemingly due to frequent lightning in Thailand.

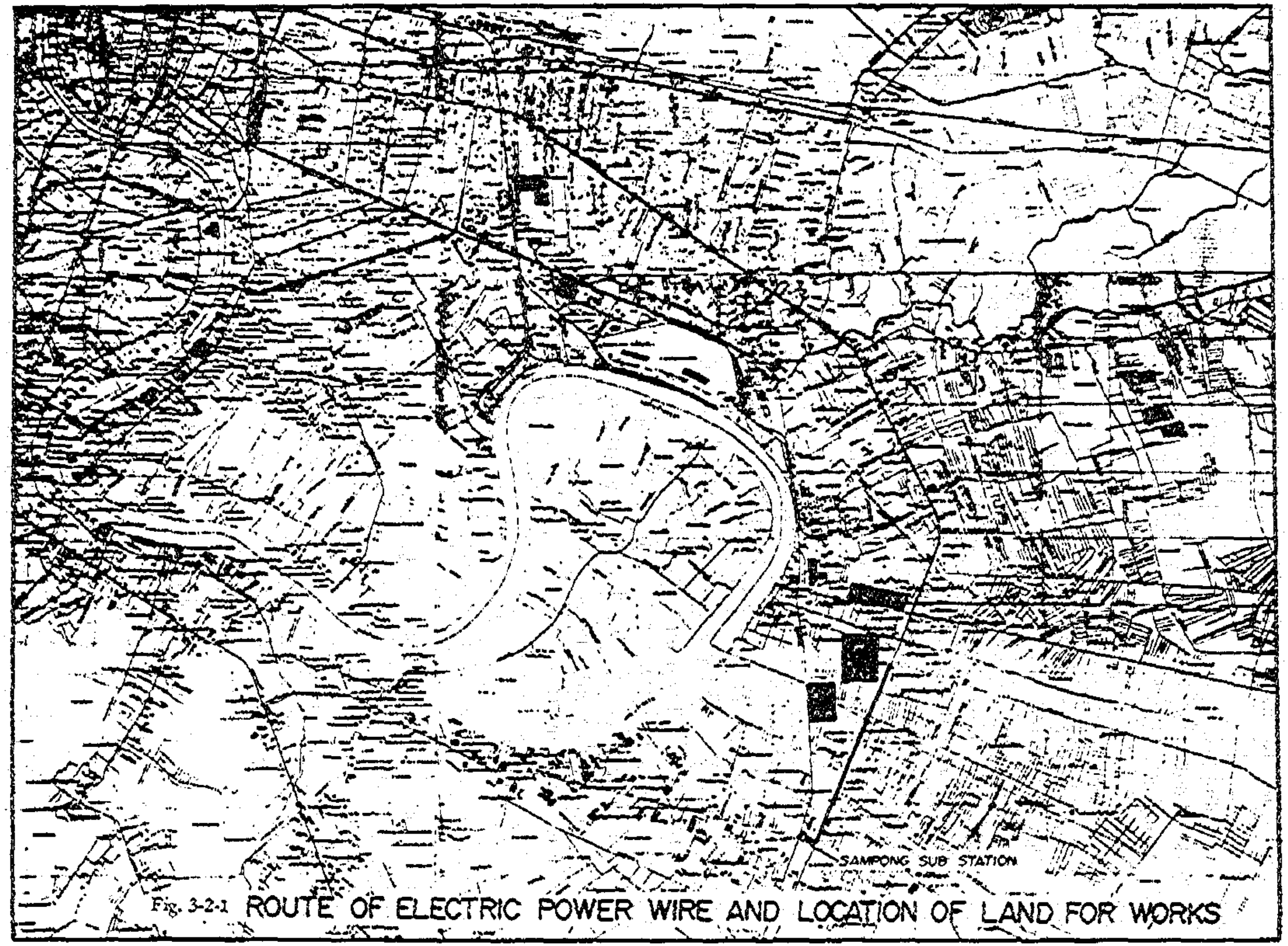
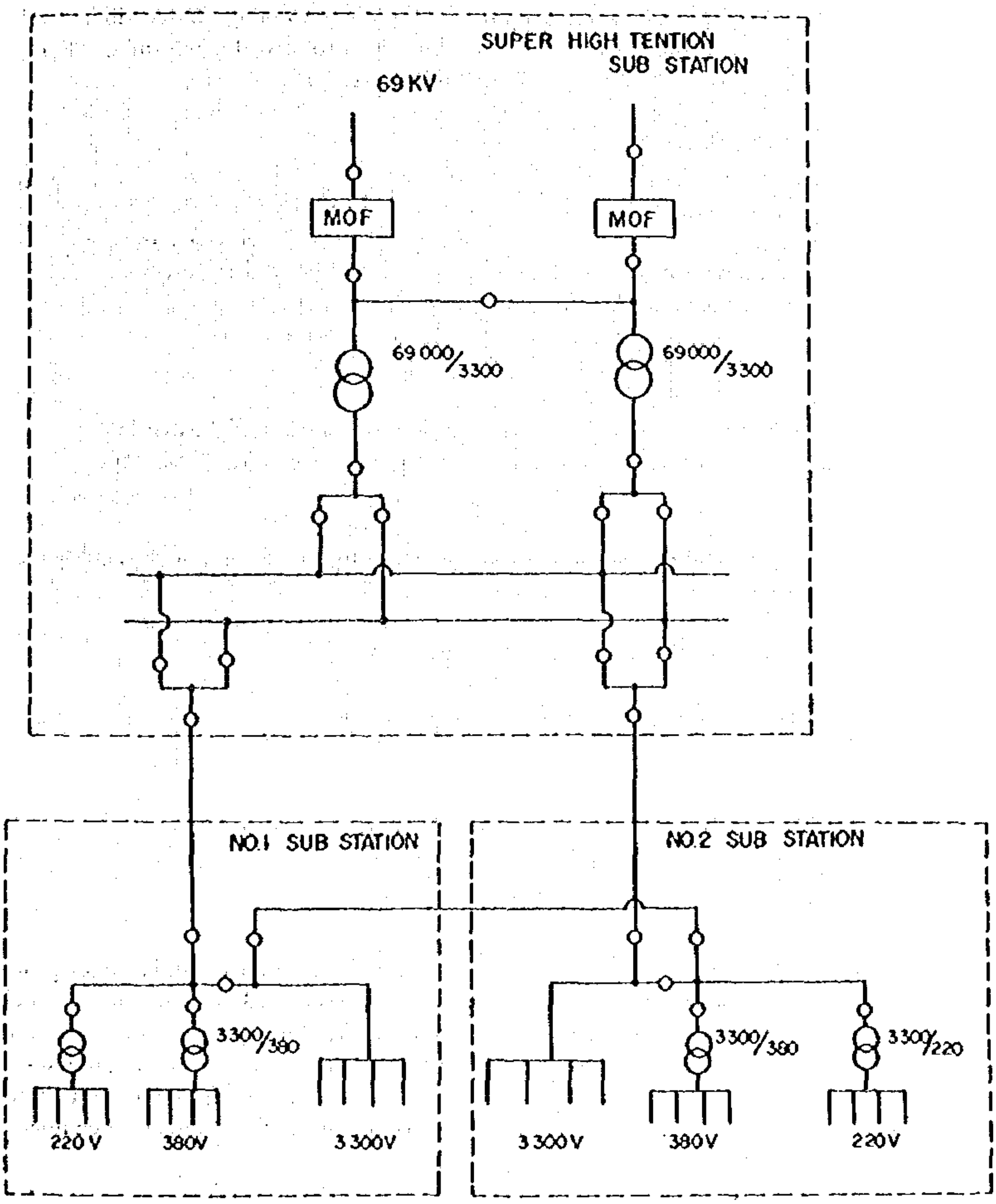


Fig. 3-2-1 ROUTE OF ELECTRIC POWER WIRE AND LOCATION OF LAND FOR WORKS

Fig. 3-2-2 Flow Sheet of Electric Power System



III-2-4 Water

The water in the gas making plant not only serves the life of employees working therein, but also will function as a hydrogen source for naphtha reforming. Water will be used not in the original from, but also vaporized in the boilers to serve for reforming. For these reasons, the quality of such water will naturally be restricted.

III-2-4-1 Water Source

No water supply system is provided in the vicinity of the plant site. The only water sources thought available are the river or deep wells. The river as a water source would require construction of the water intake and piping which will require additional investment, so deep wells should be used as the water source.

III-2-4-2 Water Quality

As a valuable reference, the data concerning the water quality of the existing deep well at Bangchak Oil Refinery located adjacent to the project gas making plant site is shown in Table 3-2-7.

The water quality of this well is satisfactory. The water, therefore, can be readily used as the boiler feed water.

III-2-4-3 Water Supply System (Refer to Fig. 3-2-3)

Uses of water can be classified largely into the following:

Boiler feed water (for gas making)
Cooling water (for gas and compressor)
Drinking water
Fire fighting
Others

Of all these kinds, the amount of cooling water to be consumed will be largest, sharing 94 to 95 per cent of the whole, but it can be easily recovered. Consumption of cooling water will amount to 18,000 tons per day in the final project year, hence, it is recommended that, both for the saving of investment and the prevention of ground settlement, cooling towers be provided for recirculating of the water for reuse instead of providing many deep wells. Table 3-2-8 shows comparison of the amount of equipmental investments for both cases.

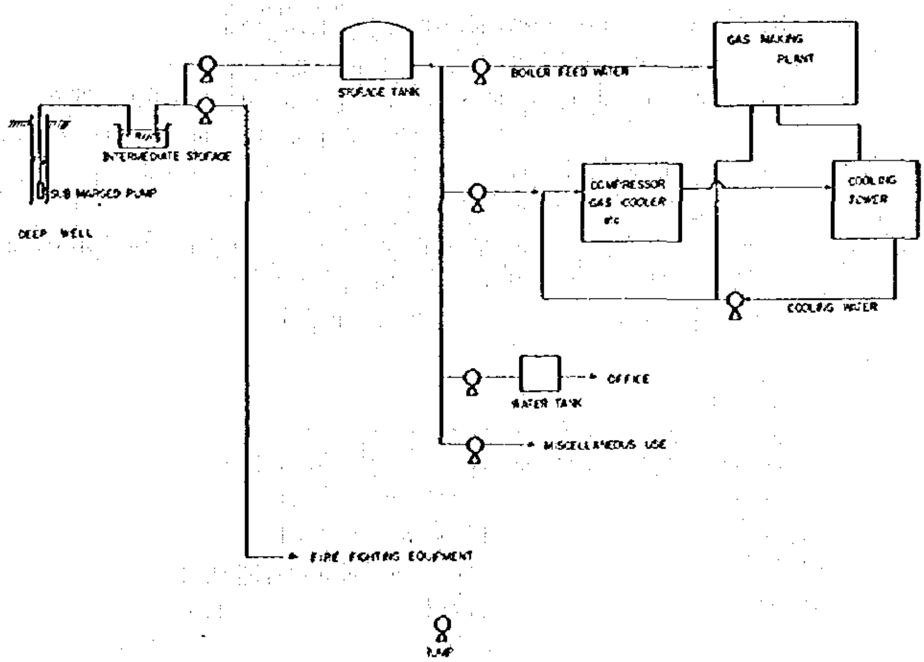
Table 3-2-7 Quality of Deep Well Water

Item		Analysis value of deep well water	Water quality standards for boiler feed water
pH		8.6	7 or more
Turbidity	ppm, silica scale	1.8	
Hardness	ppm, as $CaCO_3$	56.0	Less than 60
Silica	ppm, as SiO_2	35	Less than 150
Chlorine ion	ppm, as Cl^-	27	Less than 400
Alkalinity	ppm, as $CaCo_3$	135	Less than 500
Total solid	ppm	310	Less than 2000

Table 3-2-8 Comparison of Water Supply System

Item	Descriptions of equipments		Total investment
Deep well plus circulating water	Deep well:	200 t/D x 1	10,342,000 bahts
		400 t/D x 3	
	Cooling tower:	5000 t/C x 6	
Deep well alone	Deep well:	400 t/D x 68	24,752,000 bahts

Fig. 3-2-3 Water Supply System Flow Sheet



III-2-5 Gas Making and Distribution System

III-2-5-1 Gas Making and Distribution System

In order to select a gas making and distribution system, assessment should be made in relation to,

(a) Easiness of operation

(b) Cost of equipment

(c) Variable expenses (including gasification efficiency and electric power charge)

(d) Flexibility

(e) Safety and maintenance

(f) Given environmental conditions (raw materials, electric power, etc.)

Since the high pressure distribution system of town gas is employed in this project, feeding of gas from the plant should be at high pressure as well.

For this reason, the following two systems may be envisaged in general.

(a) High-pressure continuous reforming system, and

(b) Combination of low-pressure reforming system and compressor.
Comparison of these systems with respect to the aforementioned points is as shown in Table 3-2-9.

The high-pressure continuous reforming system is superior to thw low-pressure reforming system in variable expenses, but inferior in equipmental investment, for the former is extremely costly and is not suitable for this project because of the performance of its catalyst.

Inconclusion from the comprehensive assessment of these factors, the combination of the low-pressure reforming system and compressor should be selected.

The low-pressure reforming equipment has two kinds of systems: the cyclic type and the partial continuous combustion type. It is recommended that the cyclic type be employed in consideration of the factors such as operation and flexibility.

Table 3-2-9 Comparison of High-Pressure Continuous Reforming System and Low-Pressure Reforming System with Compressor

Check point \ System		High-pressure continuous reforming system	Combination of low-pressure reforming system and compressor
Easiness of operation		Difficult to operate. Skillful operators are required.	Simple
Flexibility		10 days are required for start from a cold state. More than 2 hours are required for restart after emergency shut-down.	3 days are required for start from a cold state. 10 to 15 minutes are required for restart after emergency shutdown. Hot standby is possible.
Maintenance		High level of technique is required. Repair takes long time.	Medium level of technique is required. Repair can be done in short period.
Cost of equipment (x bts 10^3)		486,667	74,595
Variable expenses	Gasification efficiency	87%, 0.224 bahts/1,000 Kcal	82%, 0.23 bahts/1,000 Kcal
	Electric power charge	0.07 KWH/Nm^3	0.12 KWH/Nm^3
Environmental conditions	Raw material	Naphtha from Bangchak Oil Refinery cannot be readily reformed.	Naphtha from Bangchak Oil Refinery can be used without reforming.
	Electric power	A non-utility generator is needed because restart after power service interruption takes more than 2 hours.	No non-utility generator is needed because restart takes only 10 to 15 minutes.
Miscellaneous		Restart after a long period of shut-down requires reduction of catalyst, for which pure hydrogen and other auxiliary materials are needed.	No reduction of catalyst is required even after a long period of shut-down.

The cyclic type reforming equipment is still invided into two systems: one is the system which employs thermal cracking of hydrocarbon at 800° - 900° C in the presence of water vapor; and the other which uses catalyst to actively accelerate reforming.

The thermal cracking process is not desirable because production of tar is generated properly although naphtha is reformed for raw materials. Hence, the catalystic reforming process using catalyst should be selected.

III-2-5-2 Principles of Production

(1) Reaction

Catalysts to be used in the catalytic reforming process are CaO-MgO system and Ni system.

The existence of a catalyst accelerates water gas reactions in a wide range between the low-grade hydrocarbon generated through thermal cracking and the water vapor, thus generating a gas containing much $H_2 CO_2$.

The catalytic reaction of water gasification is expressed by the formulae 2-5-1 through 2.5.3 below.

CnH_2n+2 $CmH_2m+2 + Cm'H_2m'$ ....(2-5-1)
(where, n=m+m')

$CmH_2+2 + Cm'H_2m' + m'H_2O$ $CmH_2m+2 + m'CO + 2m'H_2$ ....(2-5-2)

$CmH_2+2 + Cm'H_2m' + nH_2O$ $nCO + 2nH_2$ ..(2-5-3)

In the case of town gas making, maximum reactions by the partial reforming derived from the formulae up to 2-5-2 are applicable. In order to further decrease carbon monoxide the CO reforming system is incorporated in the process to cause reaction between carbon monoxide and water vapor, changing the carbon monoxide into carbon dioxide and hydrogen to enhance safety to town gas. This reaction, called 'CO reforming reaction', can be expressed by formula 2-5-4, using iron oxide as a catalyst.

$CO_2 + H_2O$ $CO_2 + H_2$ ....(2-5-4)

(2) Gas-Making Process

Gas making process comprises four subprocesses as follows:

1st stage: Heat

Fuel naphtha and combustion air are charged into the upper part of the catalyst layer, then burnt.
Thereafter, waste gas is allowed to pass through the catalyst layer and the waste heat boiler to be exhausted through a stack.

2nd stage: Purge

Air and fuel charging is stopped, the steam from the upper part of the catalyst layer is introduced to purge combustion products out of the stack.

3rd stage: Make

Raw material naphtha, steam and air in the respective specified ratios are introduced to cause themselves to undergo reforming reactions inside the catalyst layer. The gas thus generated is then allowed to pass through the waste gas boiler wash box, and scrubber into gas main.

4th stage: Purge

Introduction of the raw material and air is stopped. The generated gas is then purged completely out of the furnace. Fig. 3-2-4 shows the schematic outline of these stages, and Fig. 3-2-5 shows the flow sheet of the naphtha reforming plant.

All the operations in during these stages are carried out by the automatic control system. Operators are required only to watch the instrument panels.

Safety device includes a system, which is incorporated in the plant equipment, to automatically monitor the pressures of naphtha, steam and air, the state of catalyst layer, the temperature of various parts, etc., and to give an alarm upon any anomalies, and shut down the reforming plant in an emergency.

(3) Properties of Gas

Properties of gas vary with the quality of naphtha, kind of catalyst, operating conditions (including the temperature of catalyst, and the ratio of steam to naphtha). For this project, those listed in Table 3-2-10 are selected as typical.

Fig. 3-2-4 Diagrams Showing Flow During Phase of Operation of Reforming Plant

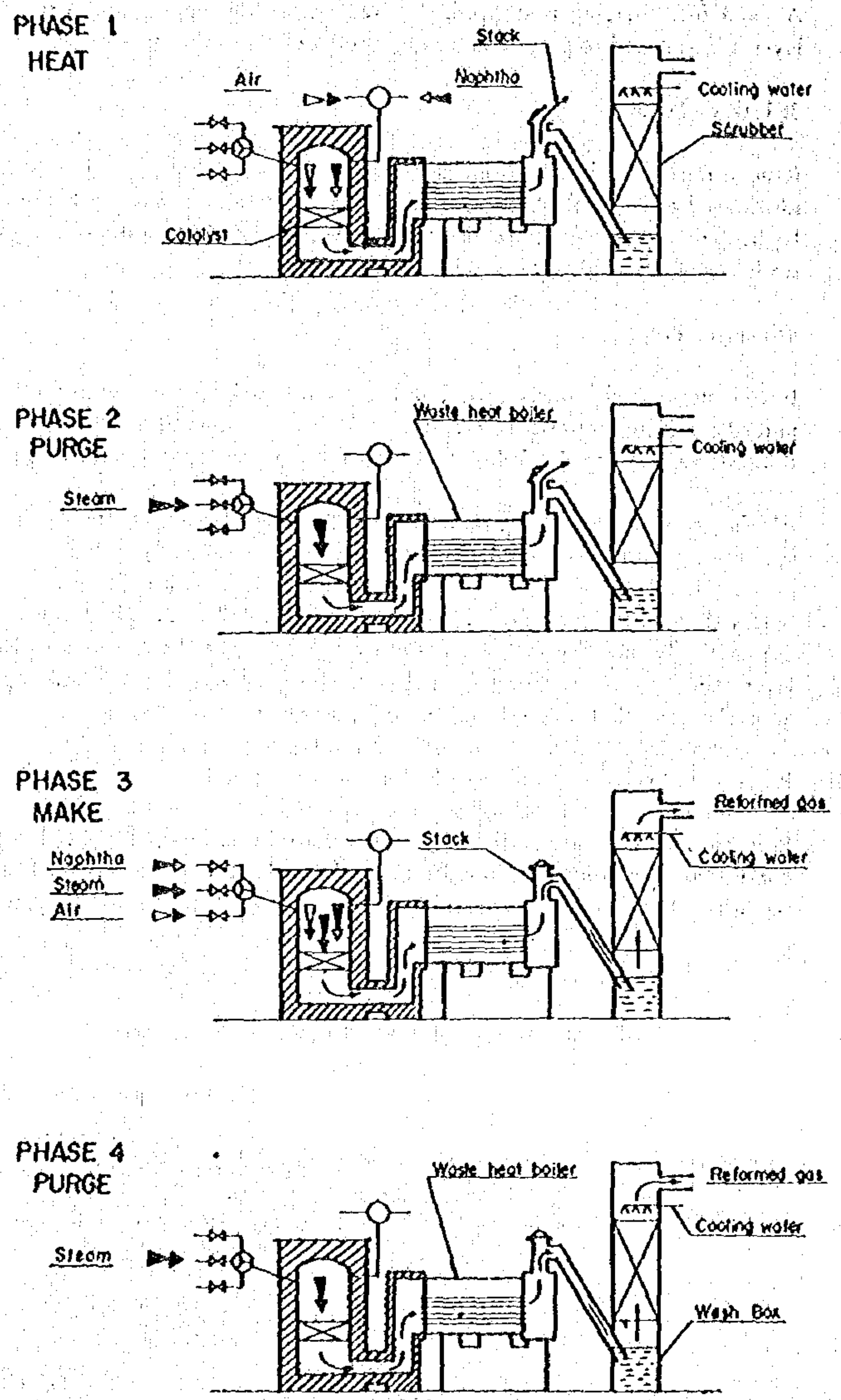


Fig. 3-2-5 Flow Sheet of Naphtha Reforming Plant

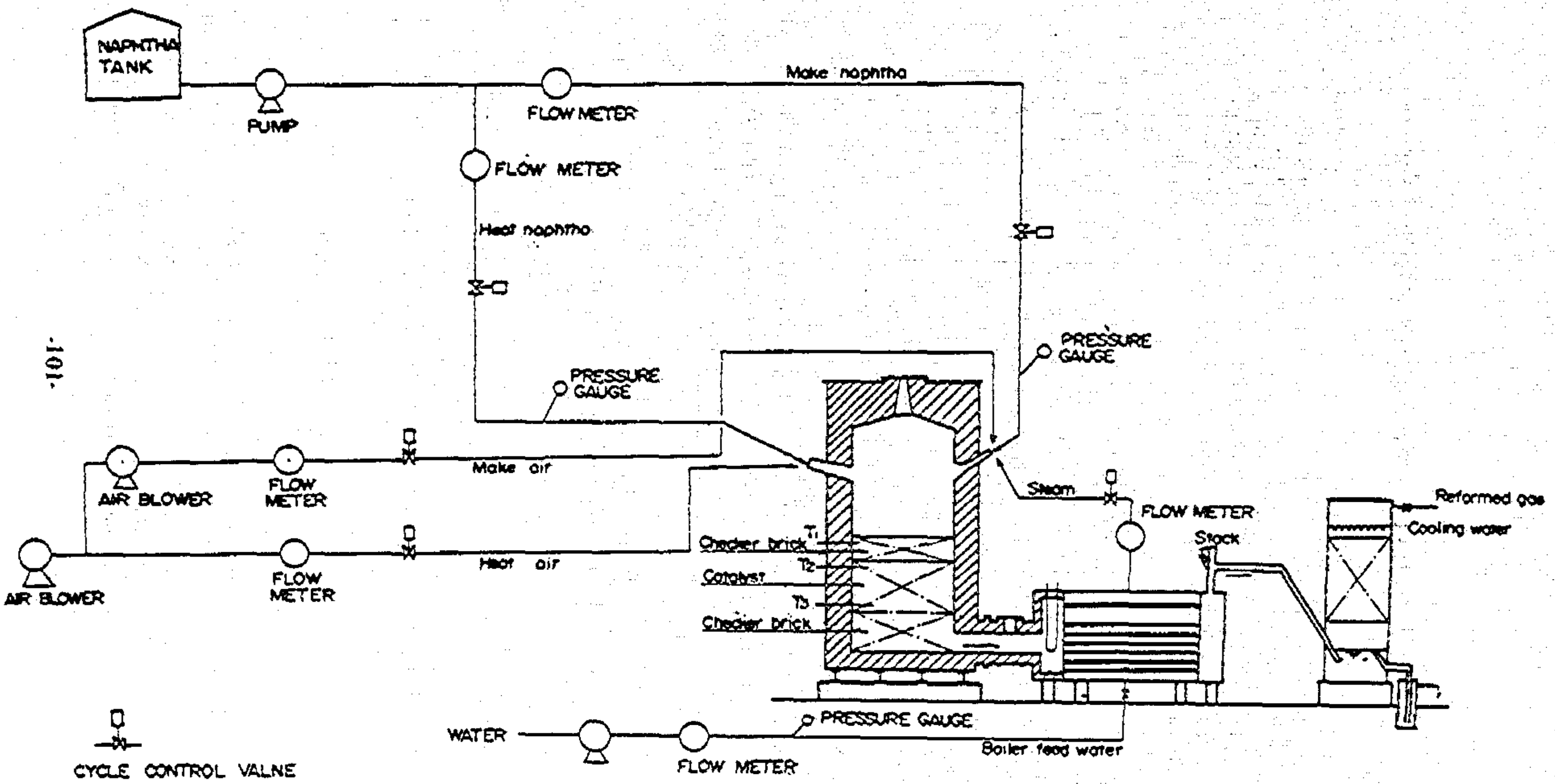


Table 3-2-10 Typical Chemical Composition of Town Gas

Item		Data
Calorific value of naphtha		7,800 Kcal/ℓ
Specific gravity of naphtha		680 g/ℓ
Calorific value of town gas		3,857 $Kcal/Nm^3$
Yield		1,657 $Nm^3/K\ell$
Calorific value		639 JHU
Thermal efficiency		82 %
Town gas chemical composition	H_2	54.1 %
	CH_4	4.5 %
	CO	6.1 %
	C_2H_4	1.0 %
	C_4H_{10}	1.0 %
	C_mH_n	0.3 %
	CO_2	16.6 %
	N_2	12.9 %
	O_2	0.5 %
	Specific gravity	0.599%

Thermal efficiency =

$$\frac{\text{Volume of town gas produced} \quad \times \quad \text{calorific value of town gas produced}}{\text{Volume of raw naphtha} + \text{Volume of fuel naphtha} \times \text{Calorific value of naphtha}}$$

.... (2-5-5)

$$\text{Yield} = \frac{\text{Volume of town gas produced}}{\text{Volume of raw naphtha} + \text{volume of fuel naphtha}}$$

.... (2-5-6)

Heating value =

$$\frac{\text{Volume of town gas produced} \times \text{Calorific value of town gas produced}}{(\text{Volume of raw naphtha} + \text{Volume of fuel naphtha}) \times 10{,}000}$$

.... (2-5-7)

where

Volume of town gas produced:	Nm^3
Volume of raw naphtha:	Kℓ
Volume of fuel naphtha:	Kℓ
Calorific value of naphtha:	Kcal/Kℓ
Calorific value of town gas produced:	$Kcal/Nm^3$

III-2-5-3 Calorific Value and Combustibility of Town Gas

(1) Calorific Value

At present, the calorific values of town gas in Japan are in most cases ranging 3600 $Kcal/Nm^3$, 4500 $Kcal/Nm^3$, 5000 $Kcal/Nm^3$ to 11000 $Kcal/Nm^3$. The higher the calorific value of gas is, the smaller the diameter of gas piping can be to save the amount of investment.

In this project, town gas produced by the naphtha reforming plant is to have a calorific value of 3857 $Kcal/Nm^3$, while refinery-off gases have calorific values of 16200 $Kcal/Nm^3$ for OG1 and 11465 $Kcal/Nm^3$ for OG2. In view of this, the highest calorific value of town gas can be attained by charging these off-gasses in full quantities.

The maximum calorific value can be obtained by solving equations 5-2-8 and 5-2-9 to get y. In the 13th year of the town gas project, when sales is expected to reach 512,000 Nm^3/D, town gas available in volume will be 14370 Nm^3/D of OG 1 and 65,120 Nm^3/D of OG 2.

Hence,

$$\frac{14370 \times 16200 + 65120 \times 11465 + 3857 \times X}{14370 + 65120 + X} = y \qquad \ldots\ldots\ldots (5\text{-}2\text{-}8)$$

$$14370 + 65120 + X = \frac{5000}{y} \cdot 512000 \qquad \ldots\ldots\ldots (5\text{-}2\text{-}9)$$

where, 512000 Nm^3/D is the gas sales when gas calorific value is 5,000 $Kcal/Nm^3$.

Y = 5232

Therefore, town gas calorific value cannot be enhanced more than 5,232 $Kcal/Nm^3$.

It is to be noted, however, that the above value does not consider any allowance for the off-gas supplying capacity. Usually, the project values should have some allowance.

In consideration of this, the calorific value of the town gas should be set at 5000 $Kcal/Nm^3$.

(2) Combustibility of Town Gas

Town gas of 5000 Kcal/Nm^3 is obtained in a mixture of the reformed gas (hereinafter called 'RG'), OG1, OG2 and LPG.

When they are mixed their combustibility must stay within the specified range of interchangeableness (The combustibility and the range of interchangeableness are detailed in Chapter 4.)

Table 3-2-11 shows the results of this calculation, and Fig. 3-2-6 illustrates the results plotted on a Dergurg Chart.

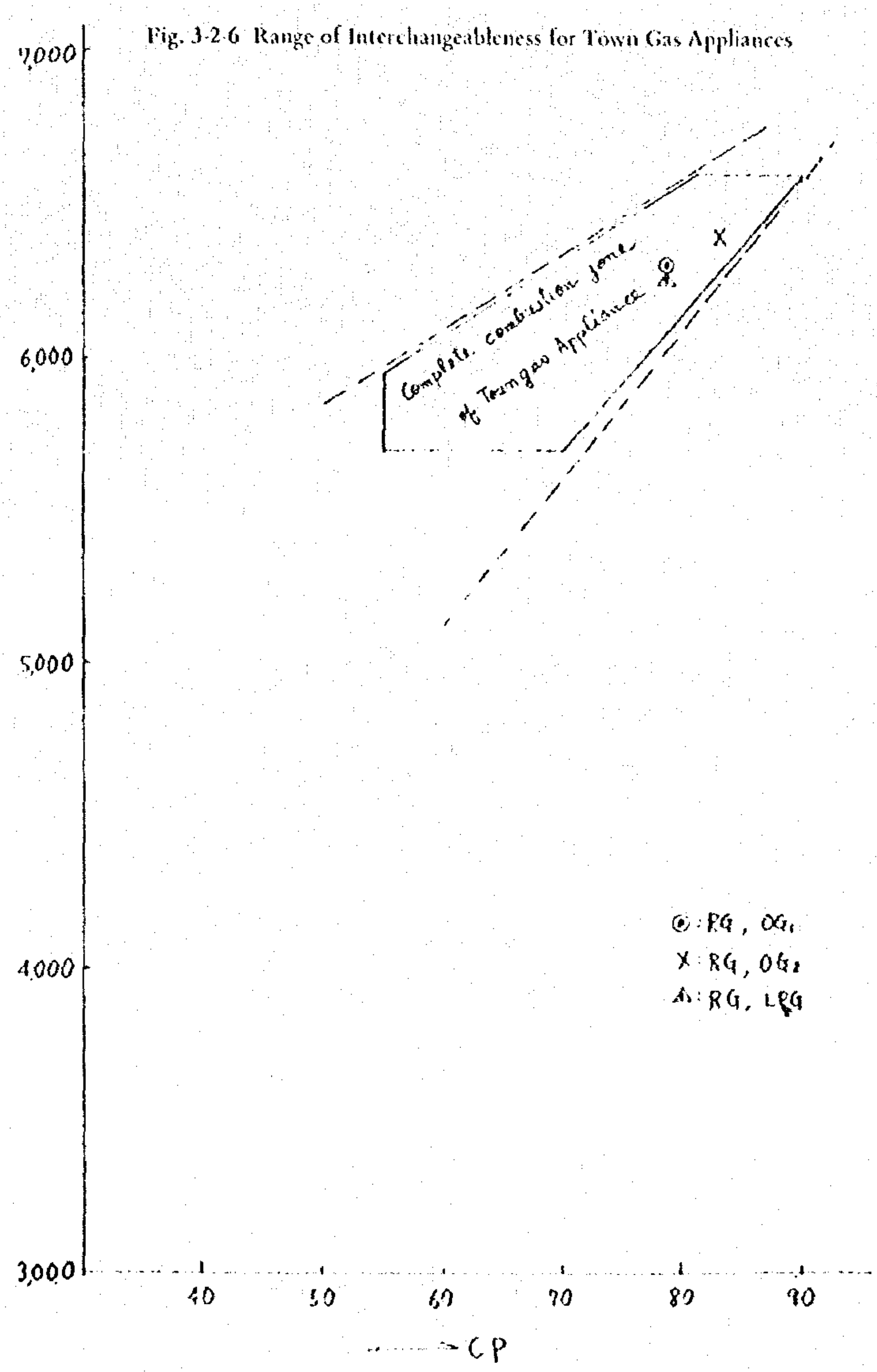
These table and chart clarify that the town gas will have no particular questions in terms of combustibility.

Table 3-2-11 Chemical Composition and Combustibility of Various Kinds of Gasses

Chemical composition \ Combination	RG + OG1	RG + OG2	RG + LPG
H_2	51.4	55.1	50.9
CH_4	5.2	4.9	4.2
CO	5.5	5.2	5.8
C_2H_4	0.9	0.8	0.9
C_4H_{10}	1.1	2.1	0.3
C_mH_n	8.7	6.4	9.6
CO_2	15.1	14.1	15.6
N_2	11.7	11.0	12.2
O_2	0.4	0.4	0.5
Specific gravity	0.63	0.61	0.65
Calorific value	5,000	5,000	5,000
W.I.	6,300	6,410	6,278
C.P.	78	83	78.3

Note: *The specific gravity relates to air (1.293 kg/Nm^3)*

Fig. 3-2-6 Range of Interchangeableness for Town Gas Appliances



III-2-6 Assessment of Holder Capacities and Gas Making Capacities

Close relationships exist between holder capacities gas making capacities, demand in volume, and demand pattern. (Refer to Fig. 3-2-7).

If the gas making plant is to be kept operating for 24 hours a day, it gas making capacity will become the minimum, while the holder capacity will become the maximum.

On the contrary, if the gas making capacity is set to satisfy the peak hour delivery outflow, the holder will be needless theoretically, but the gas making capacity will stand at the level of the peak delivery outflow times 24 hours, requiring tremendous gas making facilities. According to the load survey of the Study Team, the peak hour outflow was 12 per cent of the total demand of the day (0.12 x 24 = 2.88). In other works, without holder, the gas making capacity approximately three times that of the case of 24-hour operation + holder would be necessary.

Besides, without holder, the operation would have to be changed frequently to follow demand patterns, and would have entirely no protection against power service interruptions or other accidents.

Therefore, provision of holders of a considerable capacity is the general practice.
In this background, preconditions are here set for the assessment, requiring that:

Gas-making equipment be kept operating at a given level during a given period of hours.
For instance,
Under a 24-hour continuous operation
Required gas making capacity = demand ÷ 24
Under a 18-hour operation:
Required gas making capacity = demand ÷ 18

Then, the following expressions of relationships exist among the demand, demand patter, required gas-making capacity, and required holder capacity.

$$V_o \geqq Q_o \quad \cdots\cdots\cdots \quad (2\text{-}6\text{-}1)$$

$$\theta + v \geqq \beta \quad \cdots\cdots\cdots \quad (2\text{-}6\text{-}2)$$

$$H_o \geqq \left[\sum_{i=1}^{24} (v_i - q_i)\right]_{max} - \left[\sum_{i=1}^{24} (v_i - q_i)\right]_{min} \cdots\cdots \quad (2\text{-}6\text{-}3)$$

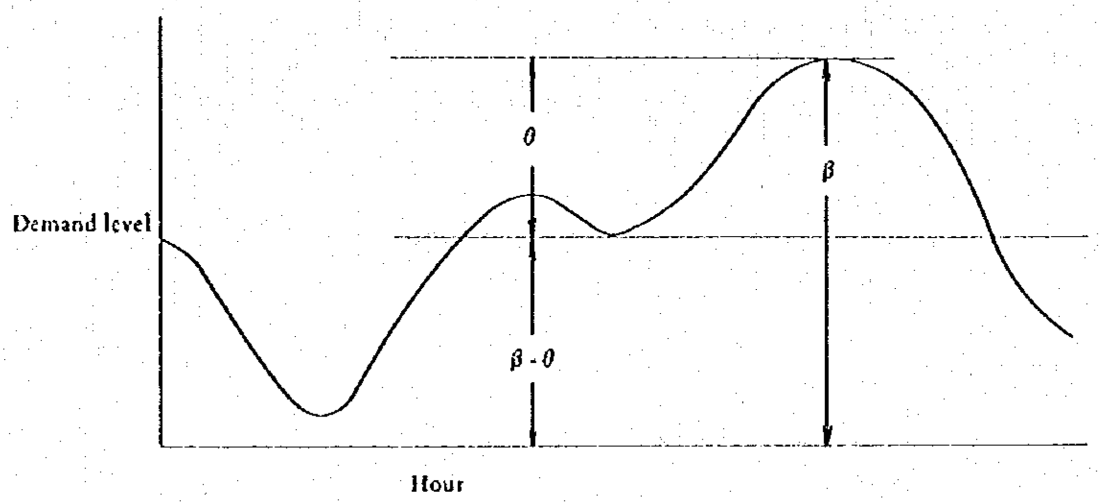
V_o: Gas making capacity — Nm^3/D
Q_o: Peak day gas demand — Nm^3/D
θ: Gas outflow per hour from holder — Nm^3TH
v: Gas outflow per hour from plant — Nm^3/H
β: Peak-day peak hour gas demand — Nm^3/H
H_o: Holder capacity — Nm^3
q: Demand per hour — Nm^3/H

$[\ ]_{max}$: Maximum value of [ ] — Nm^3

$[\ ]_{min}$: Minimum value of [ ] — Nm^3

t: Suffix to indicate time

Fig. 3-2-7 Relationship between Demand Level and Required Gas Making Capacity



The results of the load survey were applied to equations 2-6-1, 2-6-2 and 2-6-3. Table 3-2-12 shows the calculated results for the cases of operating for 24 hours, 18 hours, 17 hours, 16 hours and 15 hours, provided that unequality symbols in the expressions were replaced with equality symbols, and demand is taken as 100 per cent. The demand pattern of weekend was selected because it exceeds by 17 per cent on a weekday.

Table 3-2-12 Gas Making Capacity and Holder Capacity by Operation Mode

Operation mode	Required gas-making capacity	Required holder capacity
24-hour operation	100%	32.5%
18-hour operation	133%	15.2%
17-hour operation	140%	14.0%
16-hour operation	150%	16.0%
15-hour operation	160%	19.0%

The table shows thar the holder capacity in 24-hour operation is largest, and smallest in 17-hour operation. Therefore, the amounts of equipmental investment are compared of the cases of 24-hour operation and 17-hour operation with a view to selecting the case requiring less investment amount.

Table 3-2-13 shows the results of calculations to substitute the symbols with real quantities, and develop them for the individual project years.

Table 3-2-14 shows the amount of equipmental investment.

Table 3-2-14 Comparison of Equipmental Investments by Operation Mode

Operation mode	Gas making capacity	Holder capacity	Total amount of equipmental investment
24-hour operation	810,000 Nm^3/D	240,000 Nm^3	330 x 10^6 bahts
17-hour operation	110,000 Nm^3/D	120,000 Nm^3	430 x 10^6 bahts

Note to the table:

Beside these gas making capacities, a spare capacity of 15 per cent is allowed, and a standby unit of 100,000 Nm^3/D is reserved. The same provision is to be made for other types of equipment.

Each holder is to have a spare capacity of 40,000 Nm^3, that is, to have a working capacity of 60,000 Nm^3 in a geometrical capacity of 10,000 m^3.

As shown in Table 3-2-14, the 24-hour operation is lower in investment amount.

In this context, however, a further overall assessment will have to be made including the analysis of investment for the distribution pipeline, the result of which (as detailed in Paragraph 3 of Chapter) will lead to the same conclusion.

Hence, the 24-hour operation should be selected for this project.

Table 3-2-13. Required Gas Making Capacity and Holder Capacity Developed for Individual Project Years

Item / Year	Peak day outflow Q	Peak day peak hour gas demand $\beta = Q \times 10^{12}$	Required gas making capacity V_0		Holder capacity H_0		Gas outflow per hour from holder in peak hour θ	
			17-hour operation $Q \times 0.059$	24-hour operation $Q \times 0.042$	17-hour operation $Q \times 0.14$	24-hour operation $Q \times 0.325$	17-hour operation $\beta - V_0$	24-hour operation $\beta - V_0$
	Nm^3/D	Nm^3/H	Nm^3/H	Nm^3/H	Nm^3	Nm^3	Nm^3/H	Nm^3/H
1979	13,100	1,600	800	600	1,900	4,300	800	1,000
1980	30,500	3,700	1,800	1,300	4,300	10,000	1,900	2,400
1981	57,500	6,900	3,400	2,500	8,100	18,700	3,500	4,400
1982	107,800	13,000	6,400	4,600	15,100	35,100	6,600	8,400
1983	178,000	21,400	10,500	7,500	24,900	57,900	10,900	13,900
1984	252,100	30,300	14,900	10,600	35,300	82,000	15,400	19,700
1985	328,700	39,500	19,400	13,800	46,000	106,900	20,100	25,700
1986	401,800	48,300	23,800	16,900	56,300	130,600	24,500	31,400
1987	479,000	57,500	28,300	20,200	67,100	155,700	29,200	37,300
1988	565,600	67,900	33,400	23,800	79,200	183,800	34,500	44,100
1989	590,800	70,900	34,900	24,800	82,700	192,000	36,000	46,100
1990	607,800	73,000	35,900	25,600	85,100	197,600	37,100	47,400

III-2-7 Operation of Gas Making Plant

III-2-7-1 Main Equipment and Flow Diagram Sheet of Gas Making Plant

Off-gas is fed from the oil refinery through the pipeline at 4.2 kg/cm^2 pressure and its required quantity is charged into the calorie control facilities.

The off-gas holder will be necessary to alleviate the disparity in quantity between gas inflow and consumption as well as to cope with troubles that may happen on the refinery side.

Also naphtha, flowing in through the pipeline, is stored in naphtha tanks, and, after pressure raising, transmitted to the gas making plant, where the naphtha is used both for raw material to be gasified and fuel for heating.

The reformed gas (RG) entering the relief holder, then flows into the calorie control facilities, where it is mixed with off-gas to form a service gas of 5000 Kcal/Nm^3. Its pressure is raised by the compressor up to 9-9.5 kg.cm^2. (The caloric control system is as detailed in Paragraph 2-7-2 of this Chapter.). The function of relief holder is to make smooth gas flow, since the RG is intermittently generated due to the cyclicaly operation of gas making facilities.

The compressed gas, cooled and dehydrated in the gas cooler, is sent through the mixing holder to the distribution piping network. The gas cooler is necessary to prevent the pipeline from clogging (blocking) and corrosion which are caused by the conclensation of moisture in the gas, saturated. At the atmospheric temperature, in the distribution pipeline because of the lower in underground temperature than the atom atomospheric one, i.e. the prior lydration is needed to prevent the condensation in it.

The mixing holder serves for absorbing transitional fluctuation of heating value in the caloric control system, and also to prevent outflow of any off-specification gas into the distribution pipeline.

Fig. 3-2-8 indicates the flow sheet of the gas making plant.

III-2-7-2 Caloric Control System

(1) Principles of Gas Calorific Value Control

The calorific value of town gas is one of the most important items factors for the quality control of the gas, which comprises the control of

1) Gas calorific value, and

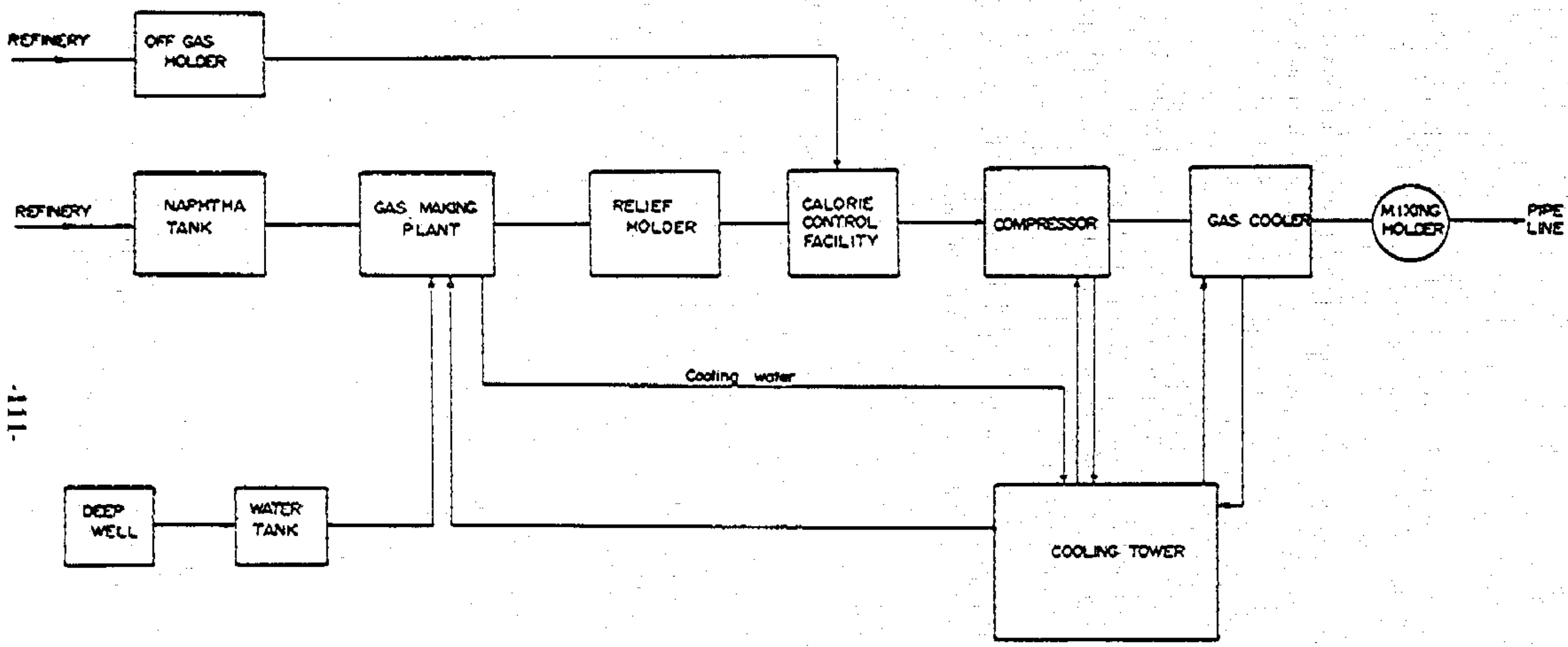


Fig. 3-2-8 Block Daigram of Gas Making Works

2) Gas combustibility

The sales of town gas is made on the basis of Calorific value of gas x gas consumption = total calorific value of gas consumed.

By reason of, sofar, no easy method to measure the total calorific value of gas, the gas flow is measured in the assumption that the gas calorie is constant and used as the basis for transaction. Consequently, the calorific value of town gas must be maintained constant.

Combustibility of town gas is important for a assurance of stable burning. As for the gas to be used under this project, no question will remain if a level of 5000 $Kcal/Nm^3$ be maintained, unless conspicuous fluctuations will occur in the chemical composition of the gas.

Flow sheet of the gas caloric control system is shown in Fig. 3-2-9. The general formulae gas calorie control can be expressed as follows:

$$\frac{\sum_{i=1}^{n} Q_i V_i}{\sum_{i=1}^{n}} = Q_o \qquad \text{.............. (2-7-1)}$$

$$\frac{Q_1 V_1 + \sum_{i=2}^{n} Q_i V_i}{V_1 + \sum_{i=2}^{n}} = Q_o \qquad \text{.............. (2-7-2)}$$

$$Q_1 V_1 + \sum_{i=2}^{n} Q_i V_i = Q_o \left(V_1 + \sum_{i=2}^{n} V_i\right) \qquad \text{.............. (2-7-3)}$$

$$V_1 = \frac{Q_o \sum_{i=2}^{n} V_i - \sum_{i=2}^{n} Q_i V_i}{Q_1 - Q_o} \qquad \text{.............. (2-7-4)}$$

where

Q_i: Calorific value of individual gases $Kcal/Nm^3$
Q_o: Calorific value of the desired mixed gas $Kcal/Nm^3$
V_i: Flow rate of the individual gases Nm^3/H
V_1 and Q_1: Calorific value and flow rate of the gas to be an operator

In the case of the actual gas making plant, n is approximately 2 to 8. If n is numerous, an analog computer may be used, but in the case of this project, n = 2, small enough to permit the control of ratio. Assuming that the calorific value of the individual gases is constant (n = 2),

$$V_1 = \frac{Q_0 V_2 - Q_2 V_2}{Q_1 - Q_0} \quad \cdots\cdots\cdots\cdots\cdots \quad (2\text{-}7\text{-}5)$$

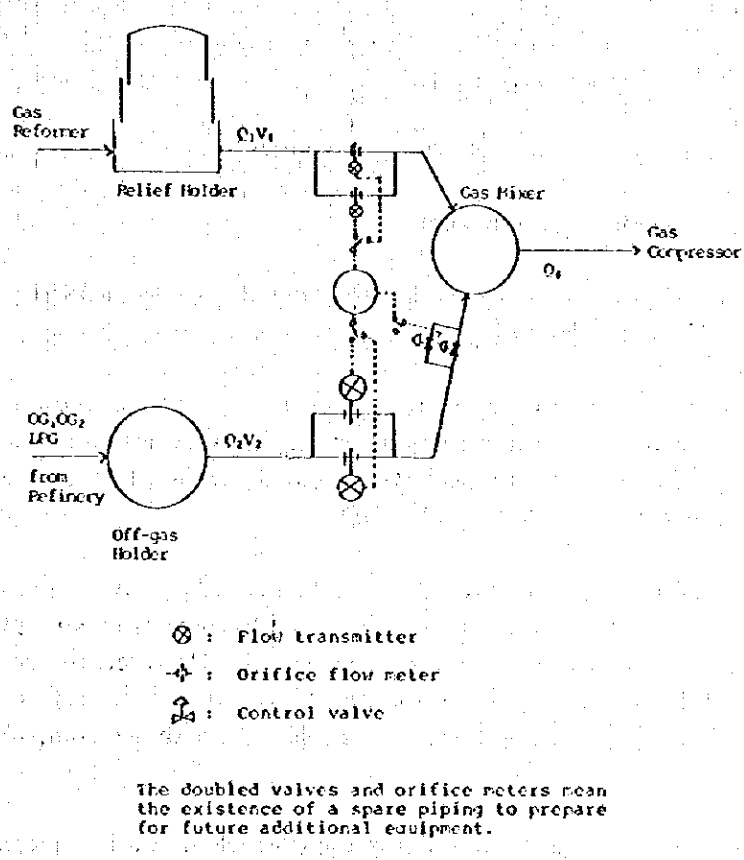
$$V_1 = \frac{Q_0 - Q_2}{Q_1 - Q_0} \cdot V_2 \quad \cdots\cdots\cdots\cdots\cdots \quad (2\text{-}7\text{-}6)$$

$$= k \cdot Ve$$

where, k: constant

Q_0: 5,000 Kcal/Nm^3

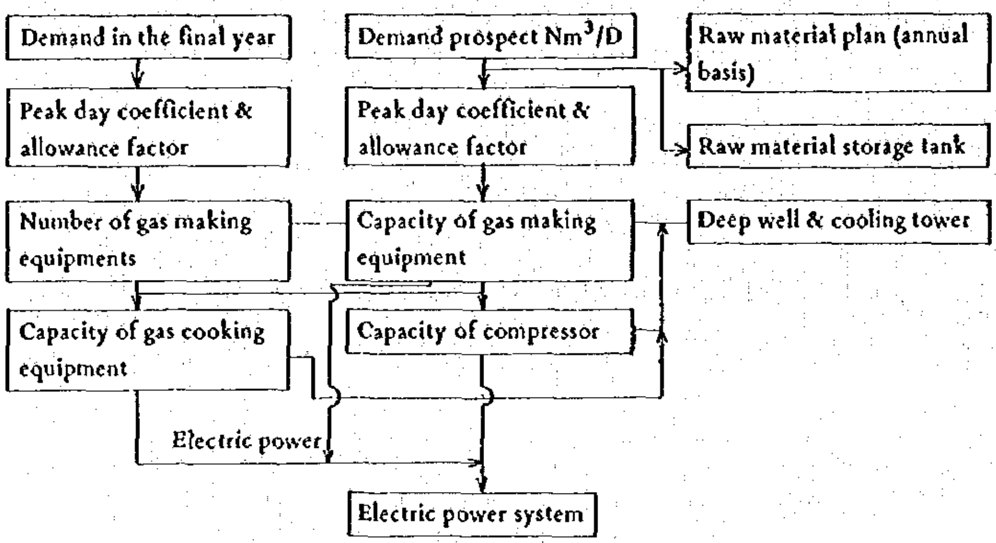
Fig. 3-2-9 Caloric Control System Flow Sheet



III-2-8 Equipment Plan

The equipment plan of the gas making plant is worked out on the basis of demand prospect for the individual project years and in accordance with the gas appliance conversion program. The flow sheet of the equipment planning is as shown in Fig. 3-2-10.

Fig. 3-2-10 Flow Sheet of Equipment Planning of Gas Making Plant



III-2-8-1 Gas Making Equipment

The demand forecast indicates that the annual gas sales in 1991 will be 187 x 10^6 Nm^3/year, or 512 x 10^3 Nm^3/day.

The gas making capacity of the plant must have an allowance of 15 per cent in preparation for service interruptions or incidental accidents in the plant. Besides, a 17% additional in demand on a peak day (at weekend) must be covered. In all, the required gas making capacity is 689,000 Nm^3/D.

This capacity level is required to be accomplished by any combination of the low-calorie reformed gas of 3,857 Kcal/Nm^3 produced by the gas making plant, and other calorie-adding gases such as OG1, OG2, propane, etc. However, the volume of the service gas obtained by combining some calorie-adding gas and the reformed gas varies with the sources of the calorie-adding gas. Table 3-2-15 shows comparison between different sources.

Amount of service gas produced is in the least when caloric is increased by means of LPG, and in this case the required capacity of the gas making equipment is 650,000 Nm^3/D. However, 700,000 Nm^3/D will be more convenient if the standby unit for the regular

Table 3-2-15 Ratio of Service Gas to Reformed Gas by Calorie-Adding Source

Calorie-adding source	Service gas/reformed gas
OG1	110.0%
OG2	116.7%
Propane	106.1%

maintenance is taken into consideration.

Hence, the capacity of the gas making equipment is set at 700,000 Nm^3/D.

The capacities of the individual units should have the levels of

50,000 Nm^3/D x 2 units
100,000 Nm^3/D x 7 units (including 1 standby unit)

Fig. 3-2-11 shows the relation between these units. The dotted line in the chart is a curve determining the periods during which one of the units may undergo the periodical maintenance while being replaced with the standby unit. Periodical maintenance will be served only while the gas making capacity is exceeding this curve.

Specifically, the periods for possible periodical maintenance come immediately after installation of an additional unit every year, and during the addition of calorie by OG2 after the year 1990.

The employment of the standby unit is based on the demand structure in Thailand, where no four-season cycle exists. In Thailand, temperature is so high that no room heating is employed throughout the year. The demand for town gas, derived mainly from cooking use, will be almost constant throughout the year.

For this reason, no periodical maintenance season can be established (unlike Japan, where this season is May through September). Overall suspension of the gas making plant will be impossible, and the units should be given the periodical maintenance service alternately per annum. (Assuming that gas making units are 9 and period necessary for the regular maintenance service for a unit requires one month, the total service period will be 9 months a year.)

This maintenance principle should also be applied to the compressors and similar types of equipment other than the gas making equipment.

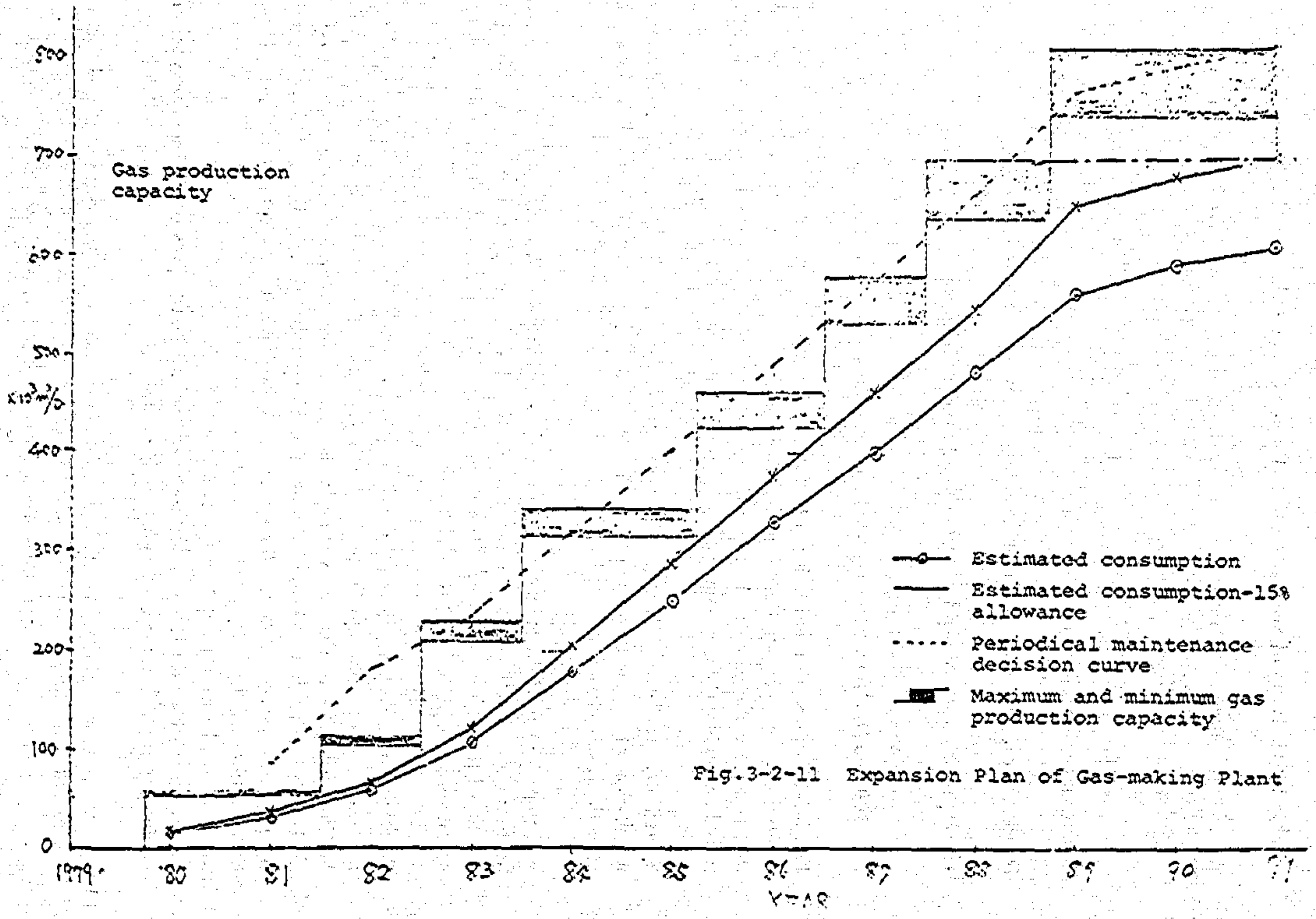


Fig.3-2-11 Expansion Plan of Gas-making Plant

III-2-8-2 Basic Concept for Main Equipments

(1) Naphtha Tank and Inflow Pipeline

The capacities of the naphtha tanks can be minimum, because naphtha will be delivered from adjacent Bangchak Oil Refinery through pipeline. Their capacities should meet 3-day's consumption with a delivery of every other day, amounting to 800 kℓ. The naphtha pipeline should be of Class 6B.

(2) Off-Gas Holder and Inflow Pipeline

The capacities of the refinery-off gas holders can be minimum, because off-gas will be delivered through pipeline similarly as that of naphtha. Their capacities should meet approximately 3-hour's consumption, taking into consideration the troubles that may happen in the refinery or the gas making plant.

The capacities of the holders should be 800 Nm^3 (geometrical capacity 2,000 m^3). The off-gas pipeline should be of Class 8B, capable of withstanding an inflow pressure of 4 kg/cm^2G.

(3) Deep Well

In consideration of the final year water consumption in 1,000 tons/day and of the peak day consumption, the capacities of the deep wells should be set at,

400 t/D x 4 units, and
200 t/D x 1 unit

(4) Cooling Tower

On the condition that the peak day consumption in the final stage will be 25,000 tons/day, the capacity of the cooling tower should be set at,

5,000 t/D x 6 units (including a standby unit)

(5) Water Tank

The capacity of the water tank should meet a half day's consumption, with

500 kℓ x 1 unit

(6) Gas Making Equipment

Refer to Subparagraph 2-8-1 of this Chapter.

(7) Gas Compressor

The types of compressor consist of reciprocal compressor and turbo compressor. In a town gas service in the project scale (2,500 to 5,000 Nm^3/H),the turbo compressor is inferior to the reciprocal compressor because more expensive by 60 to 80 per cent, and less efficient by 5 to 10 per cent. Hence, the reciprocal compressor should be selected.

The capacity of each compressor should sufficiently meet the capacity of each corresponding gas making unit related to it. Specifically they should be,

2,500 Nm^3/H x 2 units and
5,000 Nm^3/H x 7 units (including a standby unit).

(8) Gas Cooling Equipment

Assuming that the peak day outflow is 700,000 Nm^3/D, and taking into consideration further annual progressive increase, the capacity of the gas cooling equipment is set at,

120,000 Nm^3 x 1 unit and
200,000 Nm^3 x 4 units (including a standby unit).

(9) Relief Holder

In consideration of its controllability, the capacity of relief holder should meet 1-hour's consumption, i.e.,

10,000 Nm^3/D x 2 units.

III-2-8-3 Layout of the Gas Making Equipments

Refer to Fig. 3-2-12.

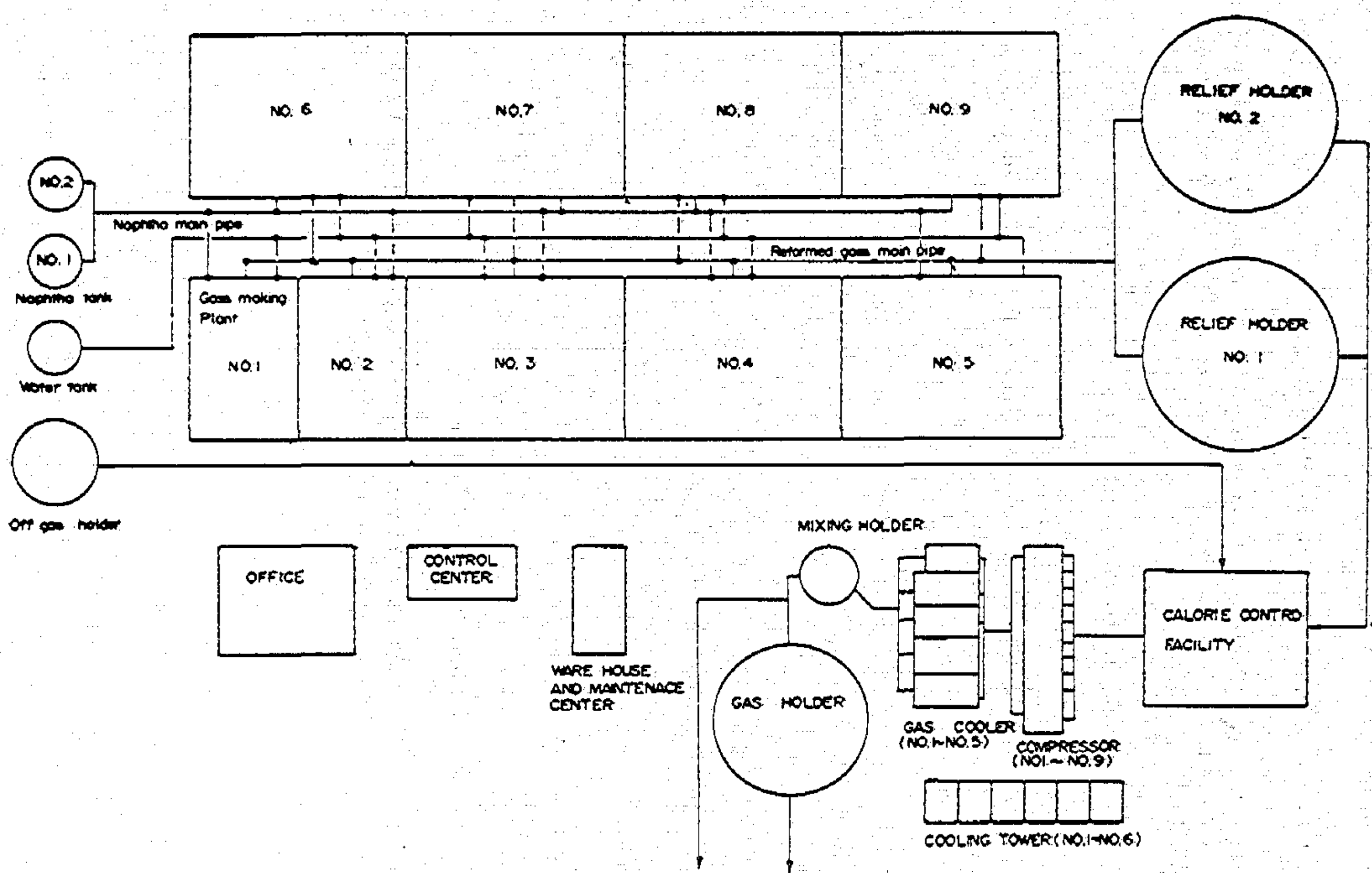


Fig. 3-2-12 Layout and Mainpipe Route of Gas Making Works

III-2-9 Construction Work and Investment Plan

III-2-9-1 Procurement of Construction Materials

With a view to fully utilizing local manpower which can enormously save the project cost, the construction work should be divided as shown in Table 3-2-16, with estimates made accordingly.

Table 3-2-16 Procurement of Construction Materials

Type of equipment	Imported	Locally procured
Gas making equipment	Design and fabrication of pressure vessels and towers	Foundation, erection of equipment, and piping works
Gas compressors	Design and manufacture of compressor proper	Foundation, installation and piping works
Gas cooling equipment	Design and manufacture of heat exchanger	Foundation, erection and piping works
Cooling tower	Design and fabrication of the tower proper	Foundation, erection and piping works
Tanks and holders	Design and fabrication of steel materials	Foundation, fabrication and piping work
Pumps	Design and fabrication	----
Blowers	Design and fabrication	---
Pipeline	4B or larger pipes	4B or smaller pipes and all piping works
Electrical appliances	All equipments	Local works only
Civil works	----	Complete as required

III-2-9-2 Prices and Specifications of Equipments

Table 3-2-17 shows the prices of various types of equipment. Table 3-2-18 shows the equipments and their specifications in the final project scale.

Table 3-2-17 List of Equipment Prices

Type of equipment	Capacity of unit	Price
Gas making equipment	50,000 Nm^3/D	6,046,000 bahts/unit
		8,929,000 bahts/unit
Gas compressor	2,500 Nm^3/D	4,913,000 bahts/unit
	5,000 Nm^3/D	7,951,000 bahts/unit
Gas cooling system	120,000 Nm^3/D	4,400,000 bahts/unit
	200,000 Nm^3/D	5,000,000 bahts/unit
Cooling tower		1,496,000 bahts/unit
Deep well	200 t/D	274,000 bahts/unit
	400 t/D	364,000 bahts/unit
Naphtha tank	300 kℓ	428,000 bahts/unit
	500 kℓ	832,000 bahts/unit
Off-gas holder		6,731,000 bahts
Relief holder		9,341,000 bahts/unit
Water tank		1,007,000 bahts
Electric power supply facilities	Incoming line and accessories	520,000 bahts
	Extra-high tension incoming station	13,386,000 bahts
	Substation	6,270,000 bahts/station

Table 3-2-18 List of Major Equipments in the Final Project Scale

Type of equipment	Number of units	Specification, etc.
Gas-making equipment	50,000 Nm^3/D x 2 100,000 Nm^3/D x 7	Cyclic type naphtha reforming system with CO reforming unit. Total calorific value produced: 3,857 $Kcal/Nm^3$
Gas compressor	2,500 Nm^3/H x 2 5,000 Nm^3/H x 7	Reciprocal compressor. Suction pressure 30 - 50 mm water head Discharge pressure 9.5 kg/cm^2G
Gas cooling equipment	120,000 Nm^3/D x 1 240,000 Nm^3/D x 4	Inflow temperature: 50°C Outflow temperature: 20°C
Cooling tower	5,000 t/D x 6	Inflow temperature: 50°C Outflow temperature: 30°C
Deep well	200 t/D x 1 400 t/D x 3	140 m deep
Naphtha tank	300 kℓ/D x 1 500 kℓ/D x 1	Cone roof tank
Off-gas holder	2,000 m^3 x 1	Spherical holder
Relief holder	10,000 Nm^3 x 2	Water-type holder
Water tank	500 kℓ x 1	Cone roof tank with lining on inner surface
Electric power supply facilities	1 set	2 circuits of 6,000kW incoming line 2 substations

Gas producing capacity: Nominal: 742,000 Nm^3/D
Maximum: 800,000 Nm^3/D

Outflow pressure: 9 kg/cm^2G

Calorific value of gas: 5,000 $Kcal/Nm^3$

III-2-9-3 Investment Plan

Table 3-2-19 shows the investment plan by types of facilities for the individual project years.

Table 3-2-19 Investment Plan of the Gas Making Plant (in the 1974 prices)

(10^3 bahts)

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Machinery & equipment	101,321	8,435	22,247	34,512	21,750		44,507	28,250	24,353	21,750
Building	8,430			1,703			1,320			
Land	11,000									
Total	120,751	8,435	22,247	36,215	21,750		45,827	28,250	24,353	21,750
Extension	120,751	129,186	151,433	187,648	209,398	209,398	255,225	283,475	307,828	329,578

III-3 Town Gas Distribution System

III-3-1 Outline of Other Facilities Related to Town Gas Distribution Facilities

Gas distribution facilities except for gas holders and governors mostly utilize roads, waterways, railways and other public spaces.

These public spaces have been used by underground power cables, telephone cables, water supply pipelines, sewerage facilities, etc. buried underground or electric poles, manholes, and other facilities installed thereon. Before constructing the gas distribution facilities, their future relations with the existing and planned facilities of these utilities should be first clarified. Our survey results on these facilities are as follows:

III-3-1-1 Road

(1) Road Network

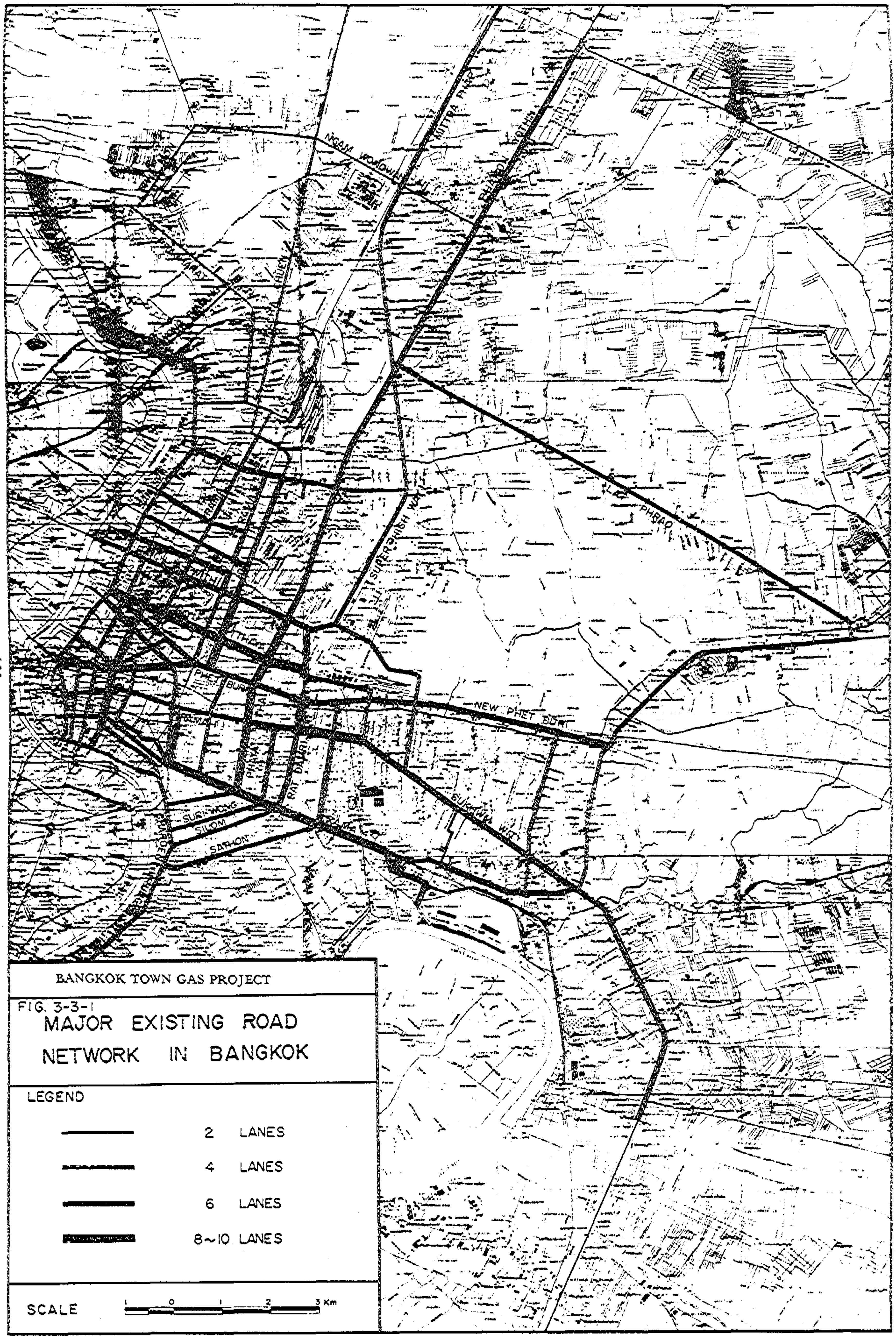
The arteries in Bangkok are Phetburi, Sukhwm Wit, Rama 4, and other roads to the eastwest of Bangkok, and Phahon Yothon, Super highways, Rama 5, Samsen and other roads to the northsouth of Bangkok.

The outline of the major road network is shown in Fig. 3-3-1.

(2) Surface Traffic Status

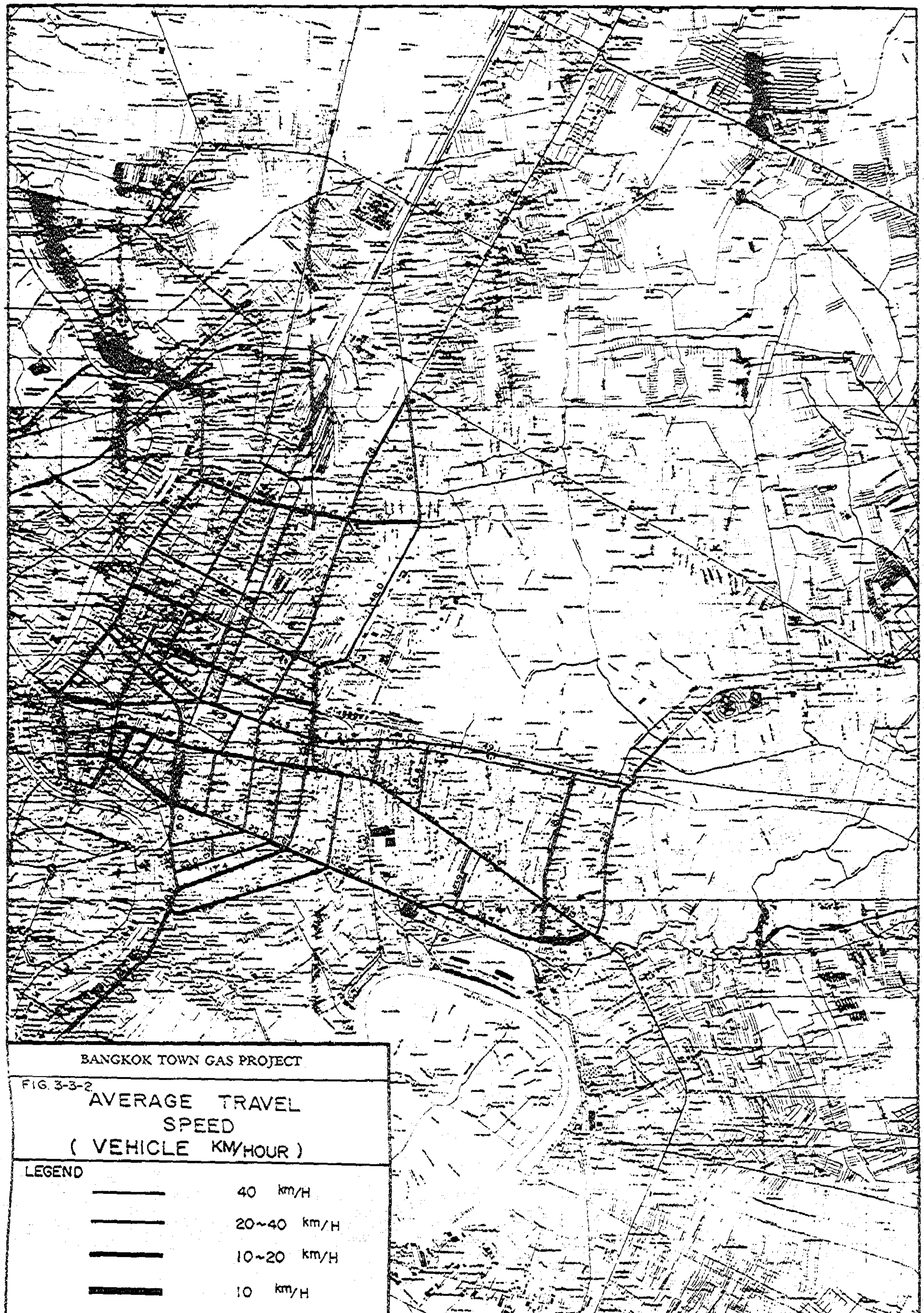
Surface traffic is very congested. Besides, as shown in the map of road network, the shortage in connection roads between the northsouth and eastwest routes is conspicuous, causing a trend to concentrate congestion on certain limited sections. These traffic situations have been roughly clarified by the surveys carried out in 1972 by the Metropolitan Traffic Planning Board and other instituteions, covering trip direction surveys, transverse traffic volume surveys and these at intersections.

The results of these surveys are shown in Figs. 3-3-2 and 3-3-3.



BANGKOK TOWN GAS PROJECT

FIG. 3-3-1
MAJOR EXISTING ROAD NETWORK IN BANGKOK



BANGKOK TOWN GAS PROJECT

FIG. 3-3-2
AVERAGE TRAVEL SPEED
(VEHICLE KM/HOUR)

LEGEND

40 km/H
20~40 km/H
10~20 km/H
10 km/H

SCALE 1 0 1 2 3 Km.

BANGKOK TOWN GAS PROJECT

FIG. 3-3-3
TRAFFIC VOLUME
SELECTED ROAD SECTIONS
OBTAINED BY CROSS SECTION
COUNTS AND INTERSECTION
STREAM COUNTS
(AM 6:00~AM9:00) DIVIDED BY THREE

SCALE 0 1 2 3Km

BANGKOK TOWN GAS PROJECT

FIG. 3-3-4

MAJOR KHLONGS IN BANGKOK

SCALE 1 0 1 2 3 Km

III-3-1-2 Khlong and Flood

(1) Khlong (waterway)

Bangkok, located near the mouth of the Chao Phraya River, is often influenced by delta formation. This has helped having developed numerous networks of khlongs, and artificially excavated khlongs, depending on the purposes of irrigation, flood prevention, canal traffic, etc.

Khlongs may be crossed by aerial gas pipelines through underwater. Most of the other existing utilities employ the aerial crossing method. In this method, the bottom of a pipeline crossing over a khlong with ship traffic must be at least 5.80 m above MSL. Main khlongs in the vicinity of Bangkok are shown in Fig. 3-3-4.

(2) Flood

In gas pipeline construction work, the greatest caution must be taken against a flood. Underground water level in Bangkok is very close to the ground surface. Even in the dry season, the underground water level is 100 mm scarecely below the ground surface. When it rains, partial flood occurs.

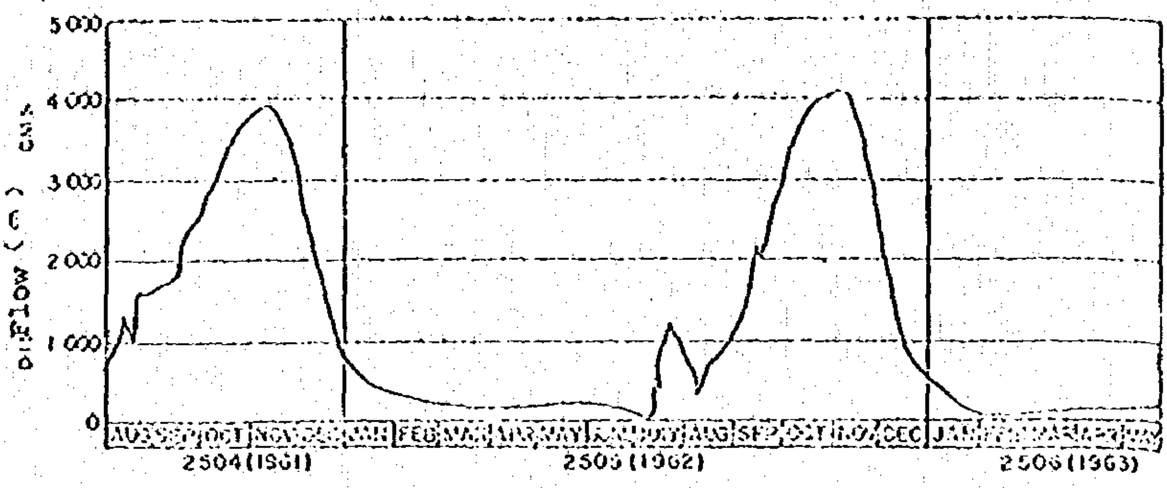
Flood in Bangkok may be classified into the internal and external flood. The internal flood, like the one mentioned in the previous paragraph, is seen at low lying areas during a rainfall surpassing the drainage capacity. This will be alleviated, as the existing sewerage system is undergoing improvement and strengthening.

The external flood is often caused either by an increase in the flow rate of the River Chao Phraya, or the high tide of the Gulf of Thailand. In Thailand where monsoon brings about frequent rains, the flow of the river is closely related to the seasons, as shown in Fig. 3-3-5. When the flow exceeds 3,300 m^3/sec at Chai Nat, flooding is feared. Deliberate provision is required against floods during progress of construction work.

III-3-1-3 Railway

Existing railways of Thailand, constructed and operated by the State Railway of Thailand, are in most part of single track. In general, the right of way is occupying extensive lands, some of which are utilized by water supply lines and other facilities. There is still ample area left for installation of the project gas pipelines. The electrification of the State Railway lines, which closely relates to maintenance of gas pipelines, is not planned currently but the State Railway is deeply interested in the electrification.

Fig. 3-3-5 Discharge Hydrograph of Chao Phraya River at Mouth



III-3-1-4 Water Supply System

(1) Outline of System

In order to meet the demand for the rapidly increasing population, Water supply system in the Bangkok Metropolitan Area has been experiencing expansions, in 1958 the establishment of the 1966 master plan, and the reshuffling and the execution of expansions of the basic plan.

Particularly the Trunk Main Project, which was started in 1971, and is scheduled to be completed in another two or three years, which is divided into ten plans, with their outlines shown in the table below.

Pipes used	Diameter in mm	Total length in m
Steel pipes	500-1500	13,902
Prestressed concrete pipes	400-1200	28,705
Asbestos cement pipes	250-300	16,350

By implementation of the Trunk Main Project, the water supply system has been extensively improved. Principal parts of the water distribution network around Bangkok is shown in Fig. 3-3-6.

(2) Water Pipe Installation Criteria

Town gas distribution pipelines and water supply distribution pipelines have many similarities. For information, some of the water pipe installation criteria of MWWA is presented below.

1) Standard locations of underground pipe.

300mm dia. and less: Sidewalk
400mm dia. and more: Roadway

2) Preparation of trench bed

The trench bed shall be prepared using sand or gravel to a layer depth of 200 to 300mm, on which the pipe is to be laid.

3) Excavation criteria

Pipe diameter in mm	Trench width in m	Earth cover in m
150	0.55	1.00
200	0.60	1.00
250	0.65	1.00
300	0.70	1.00
400	1.00	1.30
500	1.00	1.30
600	1.20	1.30
700-900	1.50	1.50
1000	2.00	2.00

4) Steel Pipes

Steel pipes are generally used for main crossings over or under khlongs, railroads, highways, and the like. About 11km of steel pipe is used for the trunk mains. In the deposited areas where soil is not stable, steel pipes are often used, and recommended to be used for water supply trunk mains of a large diameter, as well. More frequent use of steel pipes is foreseen in Bangkok for such large diameter water supply pipelines.

III-3-1-5 Sewerage System

The Bangkok Sewerage System Master Plan was reported in 1968 by Camp Dresser & Mckee. The report recommends 3 systems comprising,

Waste-water sewerage system
Flood protection system, and
Storm-water drainage system.

Based on the master plan, the first stage was implemented.

Thus, a sewer line of approximately 2,000 m in length was completed, and in now operated between the Rama 4 Road and the Chao Phraya River, with a new pumping station, and a connection with the existing sewerage system completed.

Outline of this construction work is shown in Fig. 3-3-7. Besides, storm-water drainage pipelines are installed under the main roads, or gradually expanded, but mostly of the gravity flow type. Water flow gradient is so small in the flat land like Bangkok and in its vicinity that the drainage lines cannot fully function at the time of vehement rains or the Chap Phraya River reaches the high water level.

Fig. 3-3-8 shows sewerage system plans having relations with the project gas pipelines.

BANGKOK TOWN GAS PROJECT

FIG. 3-3-6

MAJOR WATER DISTRIBUTION PIPE LINE NETWORK IN BANGKOK (DIAMETER 300 φ UP)

ALL DIMENSIONS IN M.M

SCALE 0 1 2 3Km

III-3-1-6 High-Tension Power Transmission Lines

High-tension power transmission lines in operation are either of the aerial or underground type. The aerial extra-high tension power transmission lines (of 230,000V) are on the outskirt of this project area, but they have little relation with this project.

Underground transmission lines in Bangkok are under the control and operation of the Metropolitan Electricity Authority, and are classified into the following three cases:

(1) Cables for power and motor circuits which are led into buildings, etc. are short in length and not using much road space, but are extremely numerous.

(2) High-tension transmission lines of 69,000V, which are existing.

(3) Extra-high tension transmission lines of 230kB, which are under consideration to be implemented for 1974.

The location of the lines of Cases (2) and (3) are shown in Fig. 3-3-9.

As the demand for electricity increase in the future, extra-high tension transmission lines of both the aerial and underground type will be improved and expanded. Therefore, the gas pipelines project must be insulated and protected from these electric lines.

III-3-1-7 Telephone Network

Today, the total length of telephone cables in and around Bangkok stands at approximately 200km, and is scheduled to exceed 300km under the 1979 plan. Telephone trunk lines are mostly laid underground.

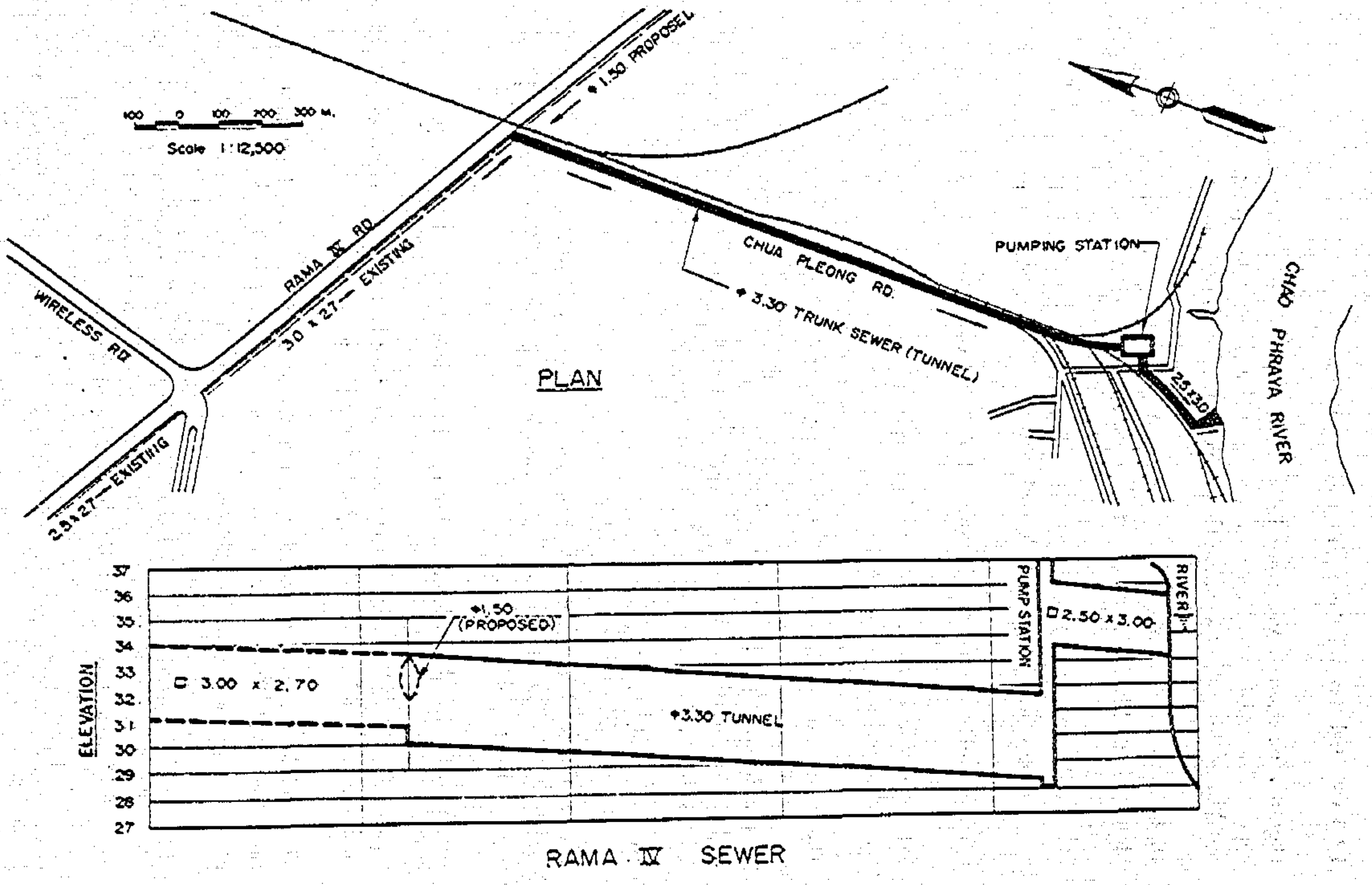
Fig. 3-3-10 shows the underground telephone cable line network.

Apart from the above, secondary cables are directly buried underground, while other cables are laid underground through conduit pipes, by T.D.T.

These works are being executed in compliance with the 'Technical Code for Communications and Civil Works'. Main points relevant to the installation of the gas pipelines project may be as summarized below.

(1) Cable protecting conduits shall generally use asbestos cement pipes but shall use galvanized iron pipes for those cables lines laid across railroad tracks, on and along bridges, and running from switch panels up electric poles.

Diameters of the cable protecting conduits shall be '4' for main lines and '3' for other lines.



ALL DIMENSIONS IN METERS

Fig. 3-3-7 Rama IV Sewer

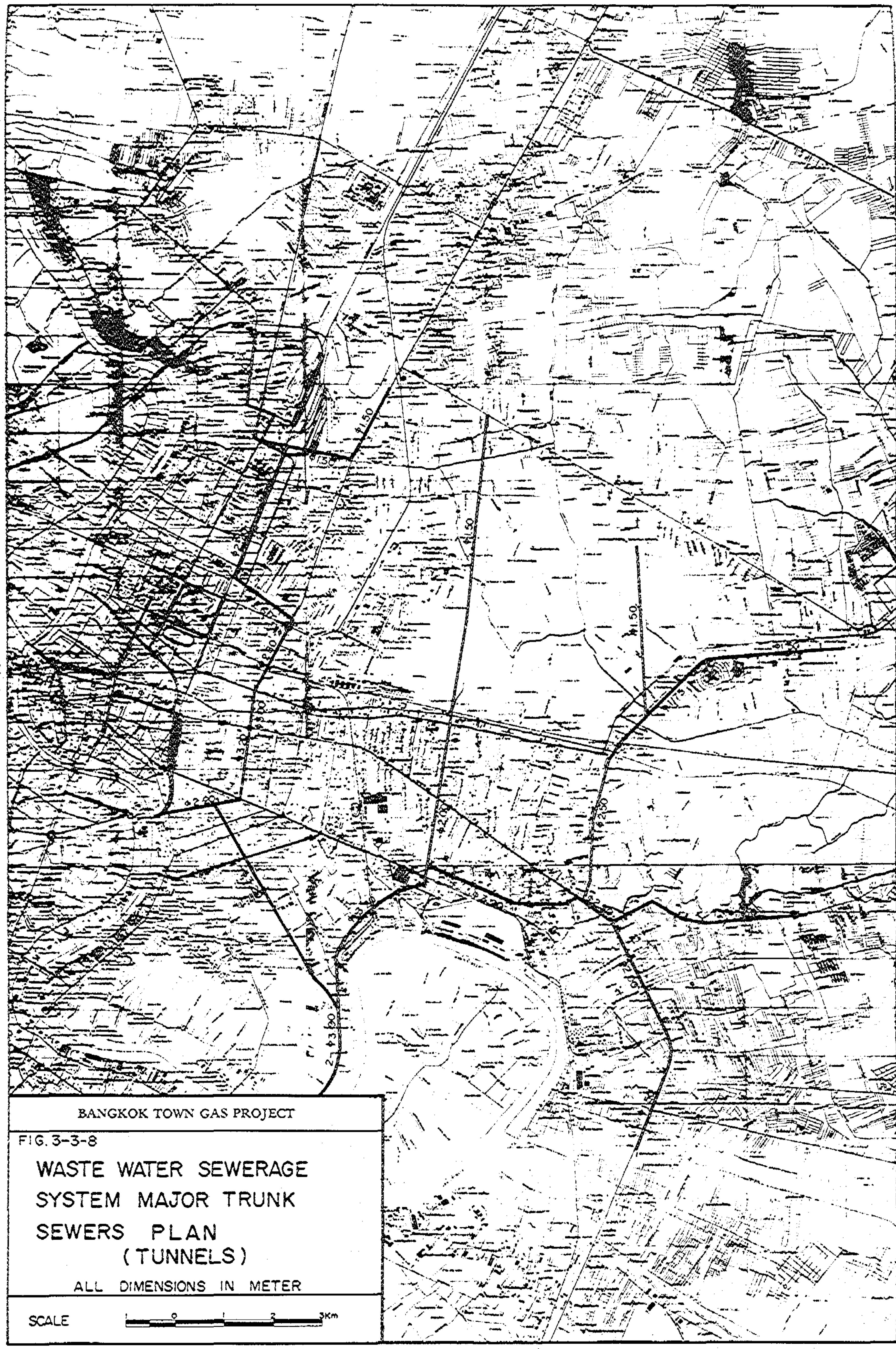
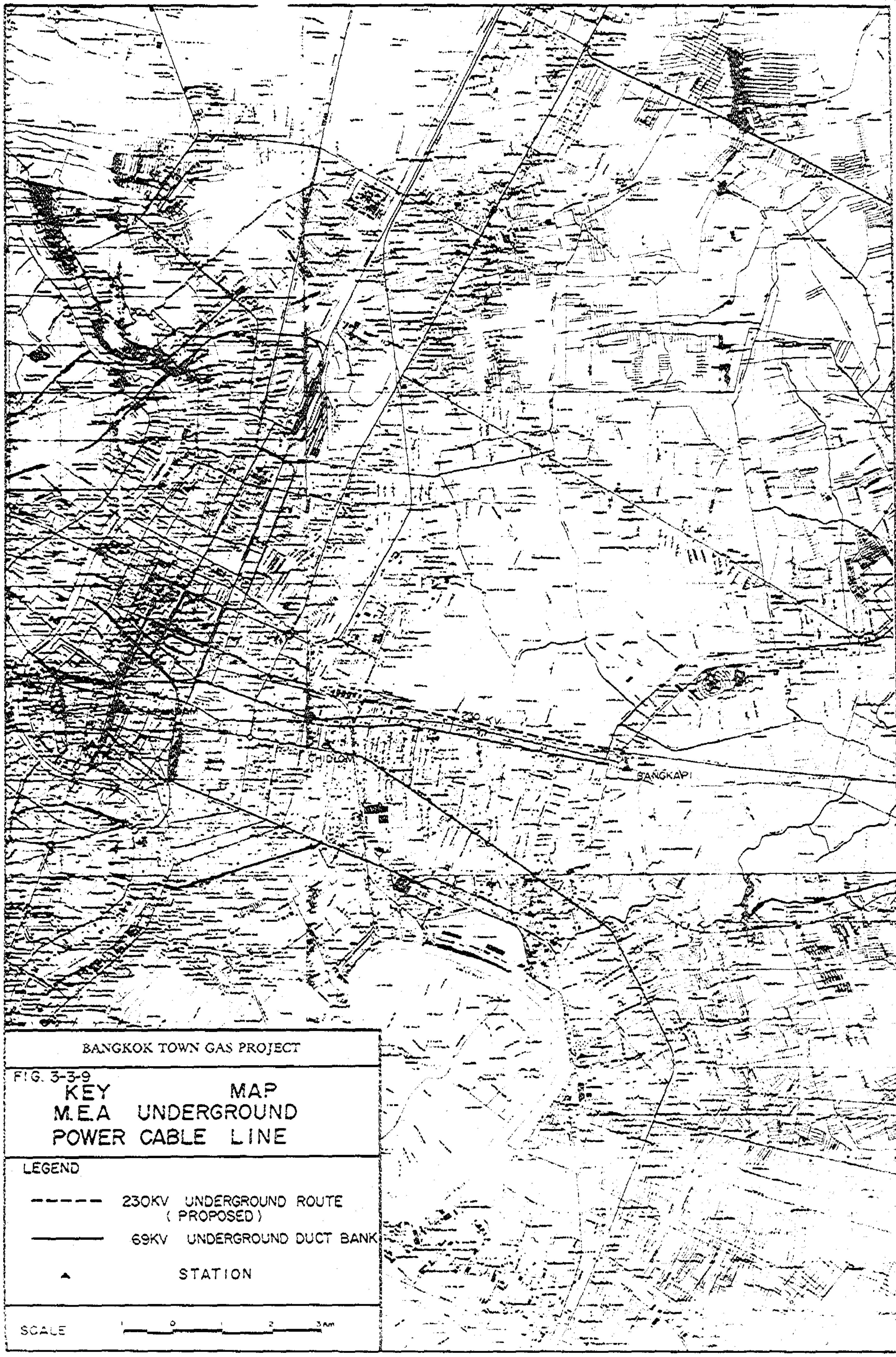


FIG. 3-3-8
WASTE WATER SEWERAGE SYSTEM MAJOR TRUNK SEWERS PLAN (TUNNELS)
ALL DIMENSIONS IN METER


230 KV
CHIDLOM
BANGKAPI
BANGKOK TOWN GAS PROJECT
FIG. 3-3-9
KEY MAP
M.E.A UNDERGROUND
POWER CABLE LINE
LEGEND
230KV UNDERGROUND ROUTE (PROPOSED)
69KV UNDERGROUND DUCT BANK
STATION
SCALE
1 0 1 2 3km

BANGKOK TOWN GAS PROJECT

FIG. 3-3-10

TELEPHON UNDERGROUND CABLE LINE MAP (T. O. T)

LEGEND

EXISTING UNDERGROUND CABLE LINE

PROPOSED LINE

SCALE 0 1 2 3Km

(2) The standard depth of laid piping shall be 1.8 to 2.3m from its bottom to the ground surface.

(3) Conduit pipes shall in all cases be set under sidewalks, if any and close to houses, when no sidewalks exist.

(4) For protection of conduit piping, an asbestos cement pipe shall be in all cases encased with reinforced concrete.

(5) Manholes shall be provided at a maximum interval of 215m.

(6) The existing primary and relay cables shall be sealed against entry of gas, their maintenance, waterproofing status and existence of moisture shall be checked with pressurized gas.

III-3-1-8 Survey of Roads and Typical Areas

The Study Team conducted site survey on roads, houses, and other factors in the gas project distribution area to collect information necessary for installation of gas pipelines.

The detailed survey of all the areas is desirable, but often impracticable, and so some typical area blocks and key check points were selected. The surveyed areas are shown in Fig. 3-3-11.

The selected typical areas comprised blocks of 0.5-1 km^2, each area representing the high-class, middle-class and common residential blocks as well as commercial blocks and concrete office building blocks. The Study Team mainly surveyed on road conditions. Besides, subblocks were selected from among the areas (as shown in Figs. 3-3-12 (1) through (4) to actually measure the plan composition of housing sites, configuration of buildings and layout of houses.

For the key check points, detailed road cross sections, types of pavement, degree of traffic volume, and outline of environmental conditions for neighboring residents were investigated.

The types of main road pavement are as shown in Fig. 3-3-13. Roads within the Bangkok City, with some variations in pavement types depending on when they were constructed, are generally of concrete in many cases. The concrete-paved roads, around road intersections or on shoulders are overlaid with asphalt. Both asphalt and cement are mass-produced in Thailand, and the construction techniques thereof are highly advanced. Some asphalt-paved roads so far constructed in Thailand are of thin asphalt layers, some having deteriorated sublayers caused by dense traffic or floods.

When a gas pipelines are laid under such deteriorated roads, influences by the restoration work must be fully taken into consideration.

The number of surveyed spots are as tabulated below.

	Number of roads or area blocks	Number of spots on the roads
Main road	36 roads	67
Typical area	8 areas	137
Main check points	-	256

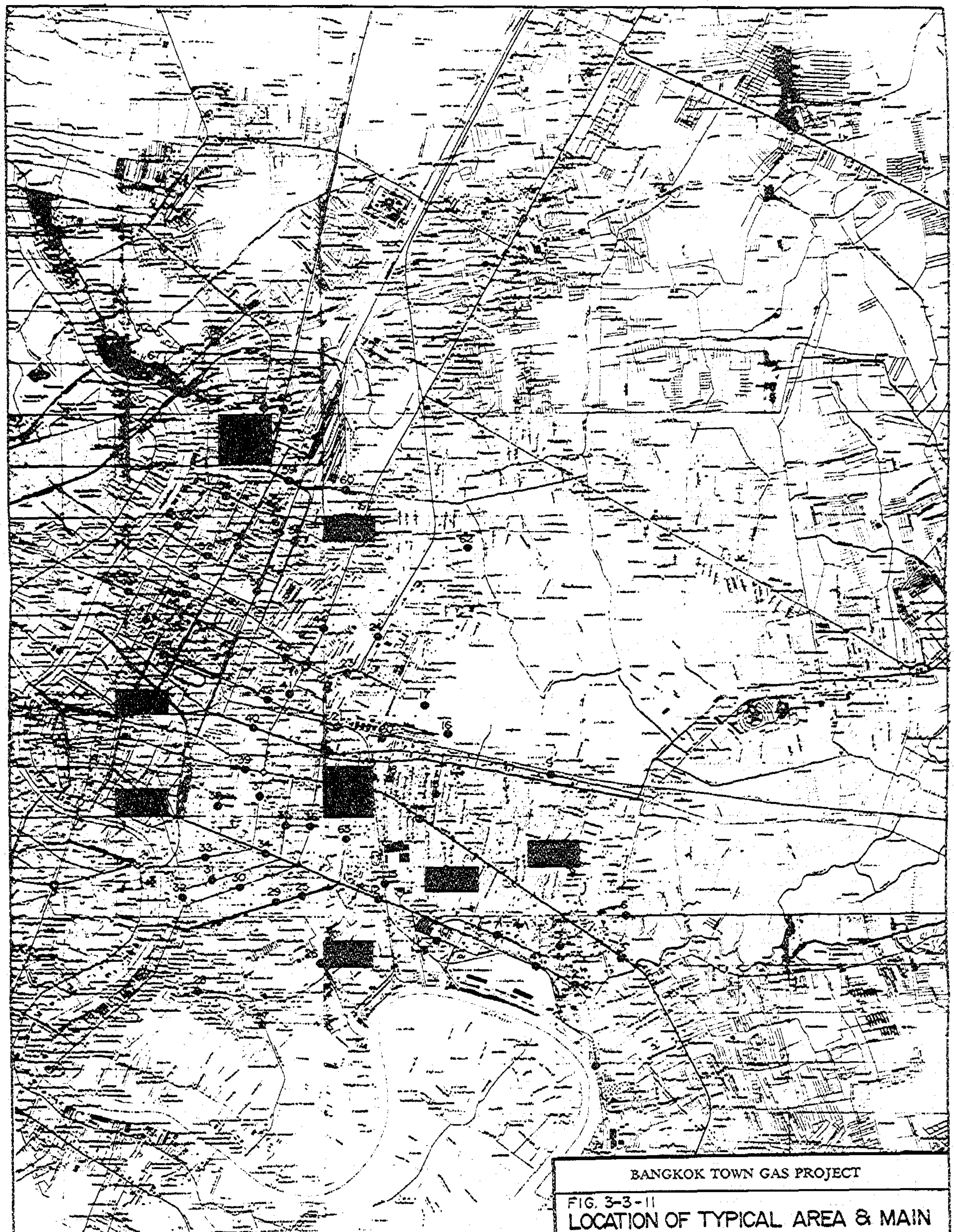


FIG. 3-3-11
LOCATION OF TYPICAL AREA & MAIN ROAD SURVEY

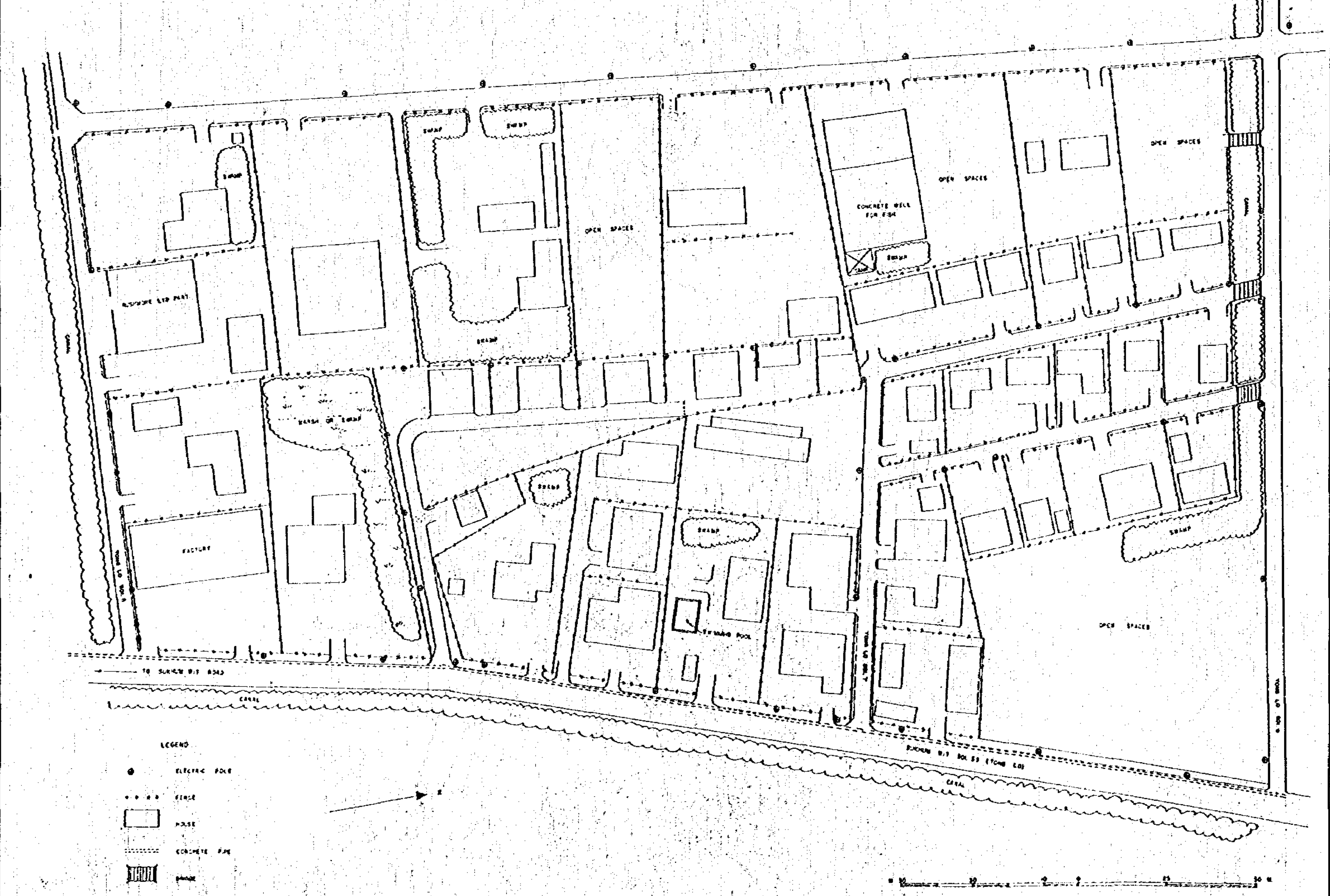


FIG. 3-3-12-(1) PLANE TABLE OF TYPICAL AREA (1)

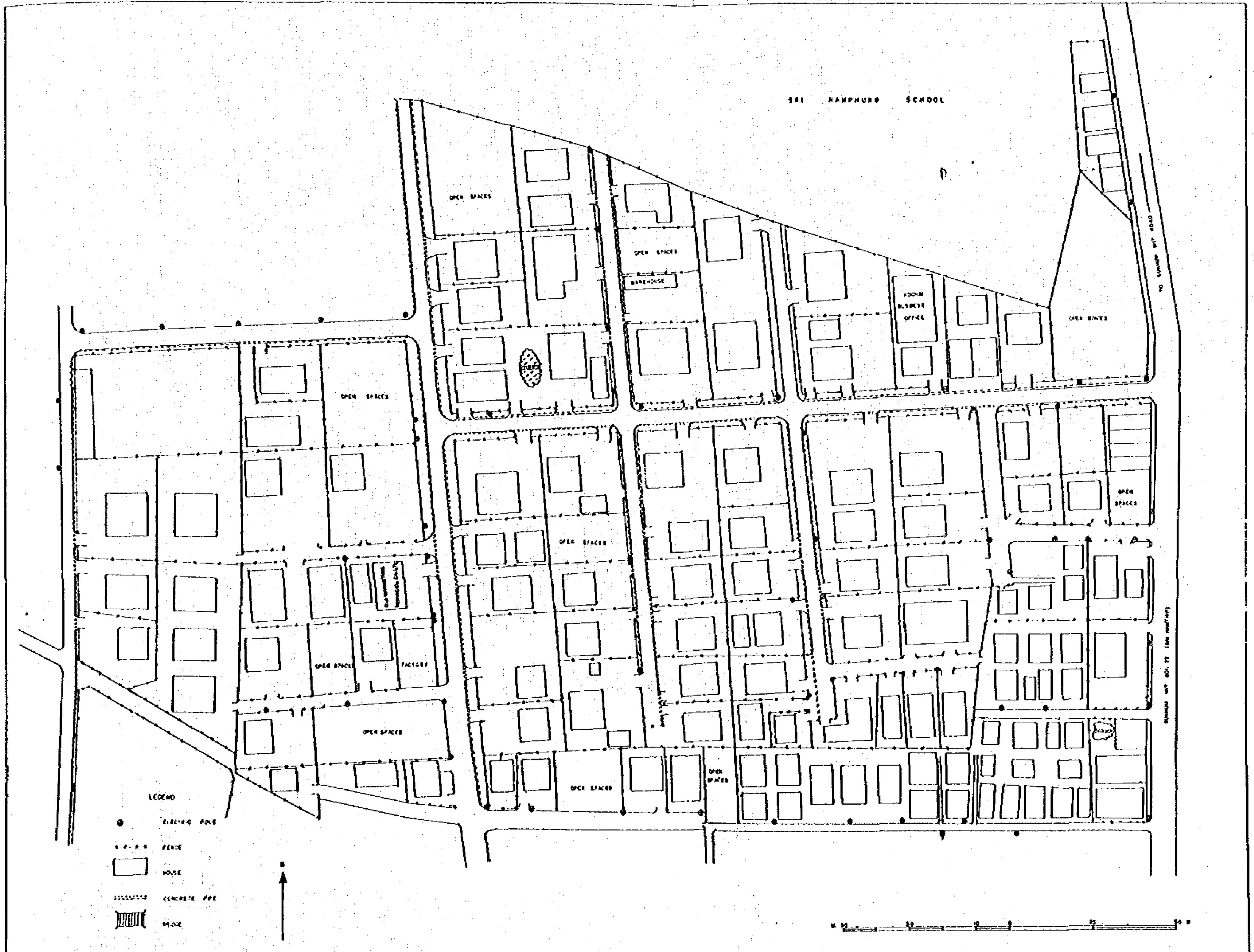


FIG. 3-3-12-(2) PLANE TABLE OF TYPICAL AREA (3)

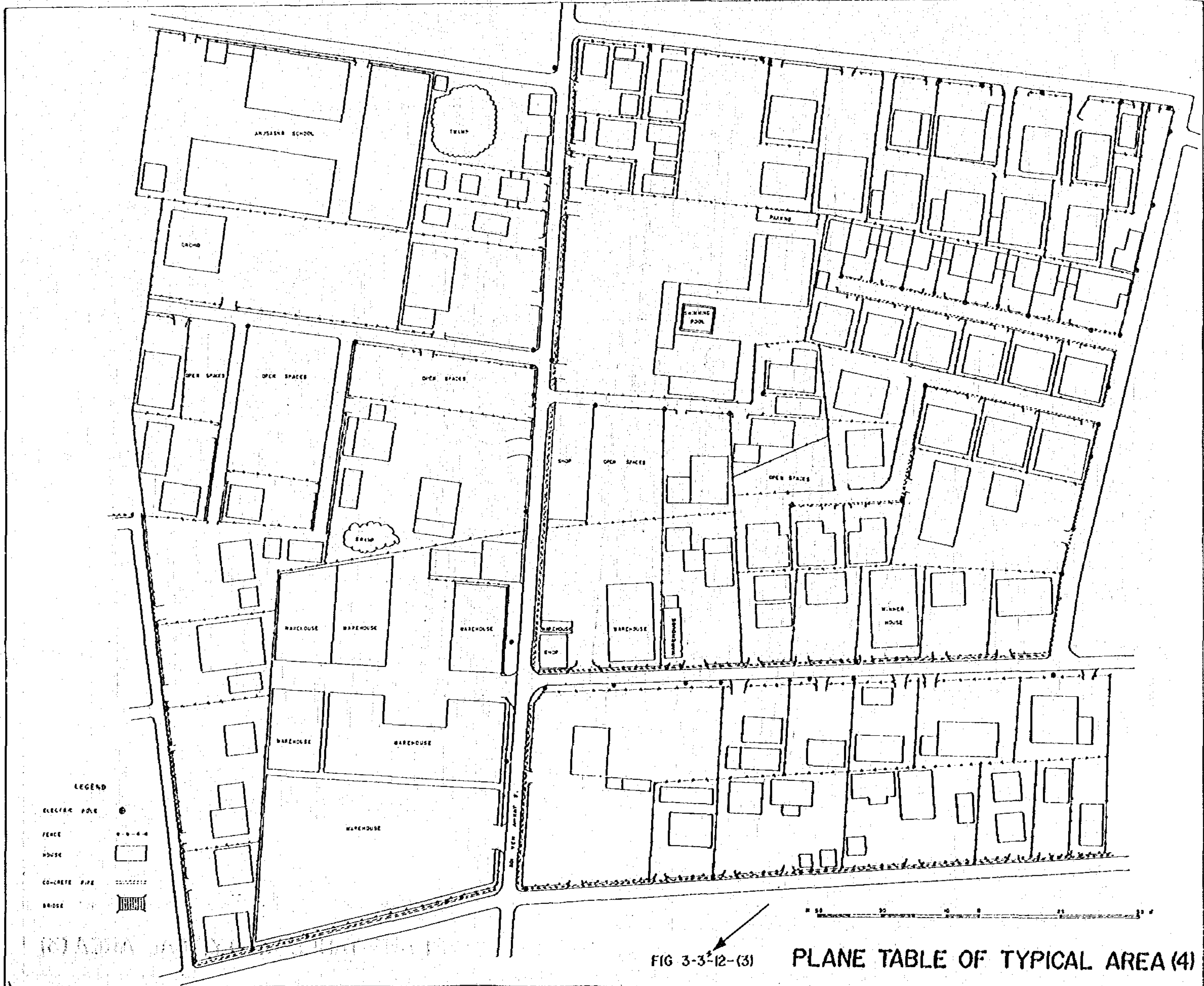


FIG 3-3-12-(3) PLANE TABLE OF TYPICAL AREA (4)

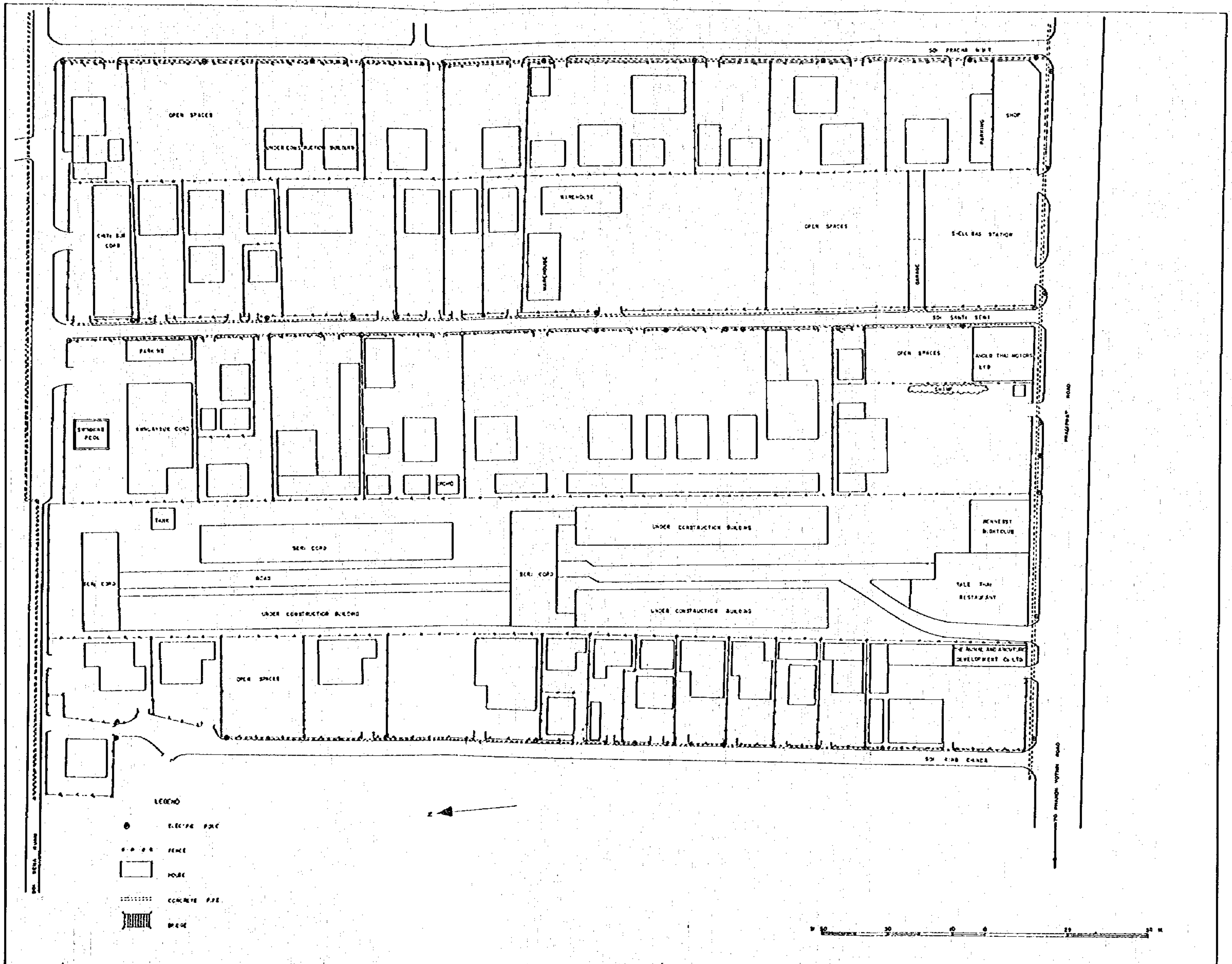


FIG. 3-3-12-(4) PLANE TABLE OF TYPICAL AREA (7)

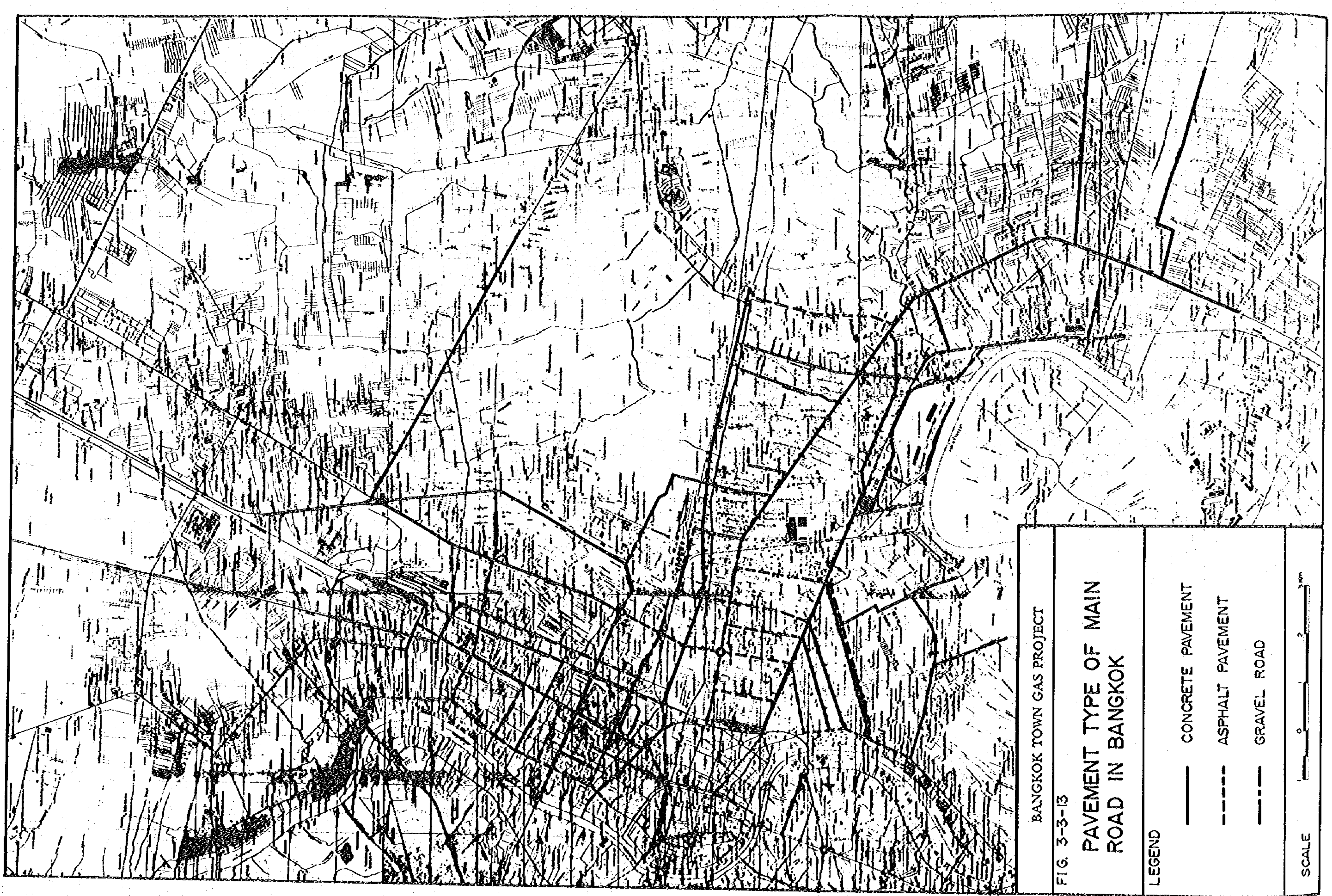


FIG. 3-3-13 PAVEMENT TYPE OF MAIN ROAD IN BANGKOK

III-3-2 Physical Conditions Related to Gas Supply Facilities

III-3-2-1 Soil of Bangkok

Soil profiles of Bangkok and its adjacent areas is as shown in Fig. 3-3-14, particularly flat in and around Bangkok. The soil outlined below is classified into four categories.

(1) Weathered surface layer varying in thickness from 1 to 3m consists of hard clay mottled with grey and brown, partly cracked due to repeated dry and wet actions. In some spots, various types of fill (generally of clayey type) exist as top layer. Underground water level is +1.0 to +1.5 above the Mean Sea Level.

(2) Soft and highly consolidatable soil called 'Bangkok clay', wich ranges from very soft to medium one, having a color of dark grey. This clay usually reaches M.S.L. -12±2m.

(3) A layer of clay ranging from stiff to very hard one having a color of grey or yellowish brown. Thickness varies with locations, reaching M.S.L. -20±2m.

(4) A layer of sand and gravel of high density containing sandy clay. Its thickness reaches down to at least 200 or 300m in depth.

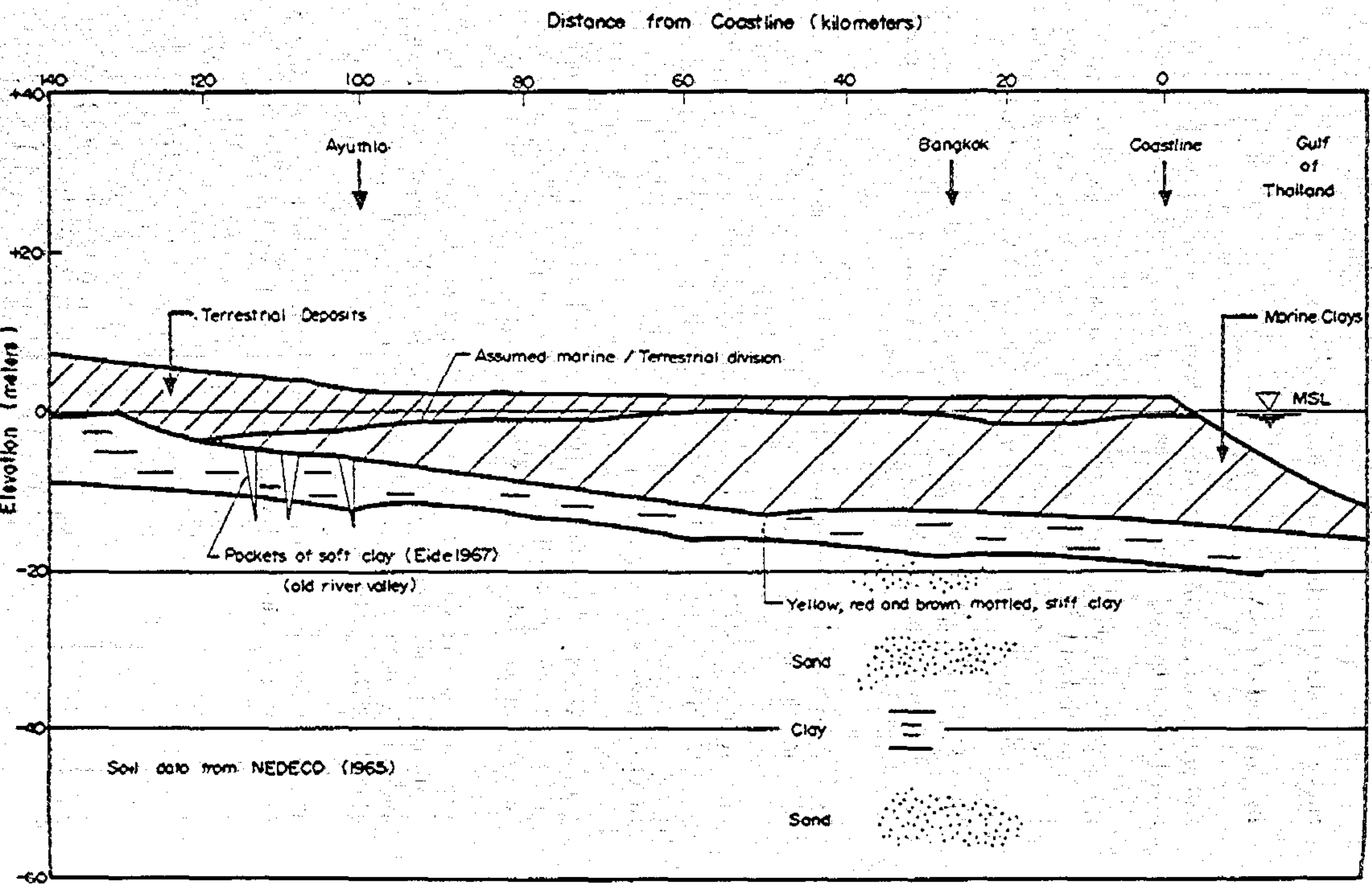
NOTE: The Mean Sea Level (MSL) = EL. + 35.03m

Bangkok clay, (or the second layer) is generally homogeneous, but its thickness is not uniform, containing a certain amount of sea shells, implying that the current land used to be at the bottom of the deep sea. (Chai et. al., 1966).

The hard clay (or the third layer) is considered to have been created by drying and weathering actions when the sea level used to be very low and the strata having relatively uniform elevations were created through the upheavals of the sea corresponding to those of the land. (N.G.I., 1967).

The sand layer (or the fourth layer) is an alluvial layer of Pleistocene, drifted from an ancient river in the Chao Phriya plane. (Chai et. al., 1966).

Fig. 3-3-14 Cross Section Through Chao Phraya Delta, Thailand
(after Cox. 1968)



III-3-2-2 Soil

III-3-2-2-1 Process of Survey

This survey mainly aimed at investigating the overall soil conditions, foundations, and influences on pipes, within the project gas distribution area. Boring and laboratory tests were conducted for this survey in 1974 by the Asian Institute of Technology (AIT), the report of which is presented in the Appendix.

III-3-2-2-2 Engineering Properties of Soil

In order to establish the gas pipes and foundations for gas making plant, the engineering properties of the abovementioned four strata must be comprehended.

(1) Surface layer

The surface layers of Bangkok and around it are featured by the hard and cracked dark grey strata, which are 1.0 to 3.0m thick on the average, as shown in Fig. 3-3-15. It contains organic matters of approximately 1.74%. Besides, in some places, fill material brought in from other various suburban areas are observed and it is of brown or brown-grey color.

The bearing capacity of such surface layers are 2.0 t/m², and its California Bearing Ratio (CBR) is approximately 4 per cent. If a paddy field or similar land is to be used during execution of construction work, soil within at least 1.5m below the ground surface should be replaced with sand or other materials.

(2) Soft Clay

Fig. 3-3-16 shows the non-drained shearing stress by depth. These data were obtained from the results of unconfined compression tests performed in conjunction with the boring tests conducted at ten spots by the Study Team, and from those performed in the past.

According to this survey, this highly consolidatable clay lies in depths from GL-2.0m to -15.0m, and most of the unconfined compression test results marked values below 10 t/m². The sensitiveness ratio of this clay can be presumed to be 2 to 4 from other data collected.

Consolidatableness of clay is determined generally by the relationship between the void ratio and pressure. In this survey, tests were conducted for the soft clay and hard clay separately, the results of which are presented in the Appendix. The results show that their coefficiency of consolidation (Cv) is 2.0-8.0 x 10^{-4} cm²

/sec, and compression index (Cc) is 1.0-2.5. Overconsolidation value estimated from an e-log p curve shows that most of the clays have not been subjected to any vertical pressure other than the one given by the existing soil on top of it.

(3) Stiff to Hard Clay

This hard clay layer has an unconfined compressive strength of 10-40 t/m², and generally functions as a layer to bear piles for medium-size structures. This survey has clarified that the clay layer lies in depths from GL-15.0m to 30.0m in some places with an average thickness of 7 to 8m. Natural moisture content is approximately 40 per cent, a value lower than the soft clay layer lying above it, but voids are completely saturated with moisture.

As can be seen from the results of this survey, the standard penetration resistance (N value) rapidly increased as soon as boring into this clay layer started, indicating an N value of 20 to 40.

(4) Densely consolidated sand and gravel layers

A densely consolidates yellow sand layer lies under the hard clay layer. In some places, a clayey sand layer of yellowish grey is found lying between the sand layer and the clay layer above it and is considered to be the transition zone between them. This sand layer has sufficient bearing capacity to support piles and caissons which will be used for supporting large, heavy structures.

III-3-2-3 Various soil engineering problems

III-3-2-3-1 Influences of uneven settlement

Bangkok clay is extremely soft and has very high compressibility. Although there is such an advantage that the underground pipe is protected from the influences of external loads and temperature fluctuations by the vicinity earth and sand, it has such a disadvantage that it undergoes the influences of the deformation of the ground because it directly contacts the ground.

Particularly, an unexpected stress is generated at the time of designing and execution of works, and it sometimes breaks underground pipes and causes great troubles. The following factors may be considered as causes for uneven settlement of the ground.

1) When the underground water level partially lowers due to filling earth for the road or the housing land construction and others, above or near the underground pipe after the execution of piping work, consolidation settlement in the clay layer causes an uneven settlement of the ground, and further causes uneven settlement

Fig. 3-3-15 Soil Profile Along Pahol Yotin Highway

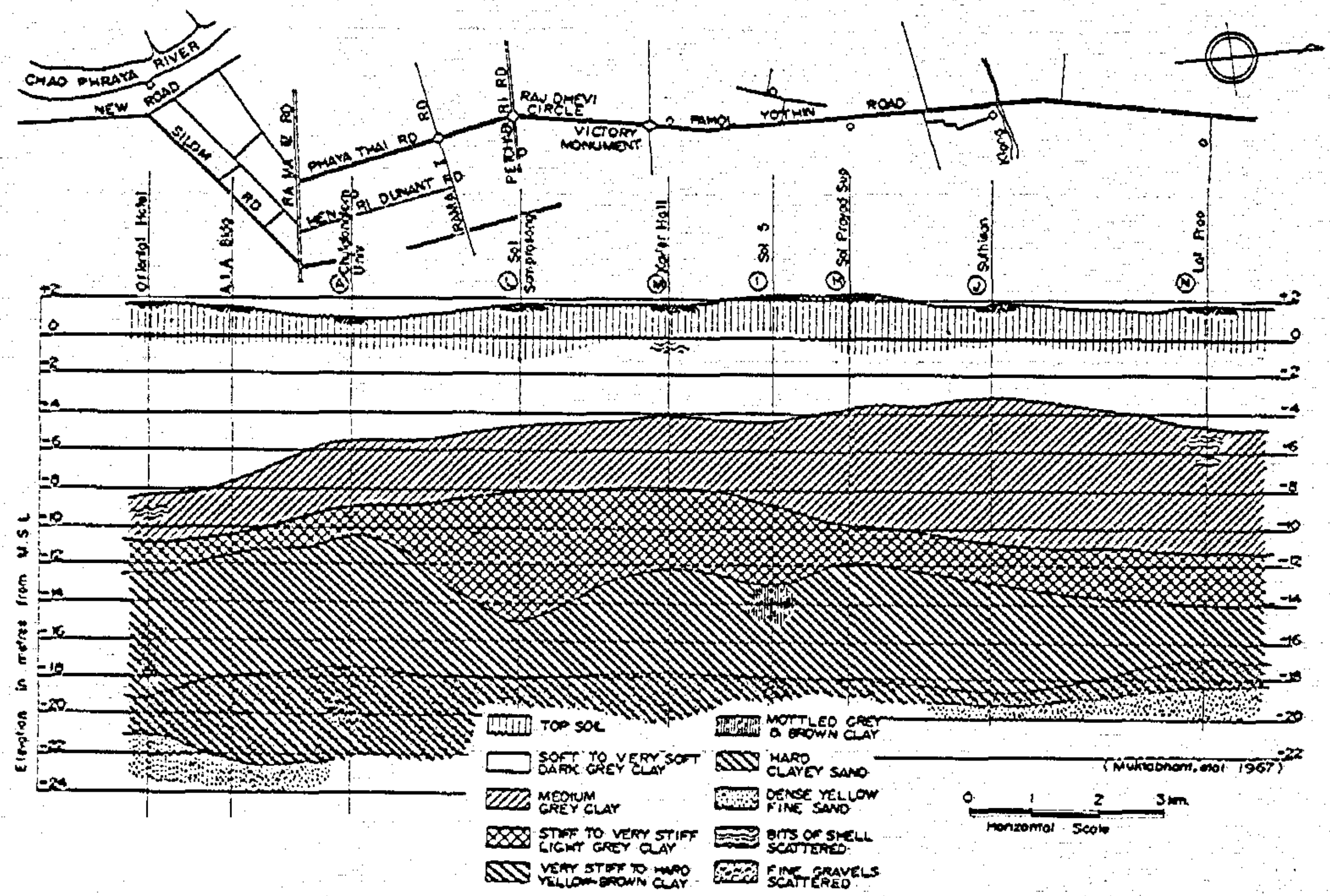
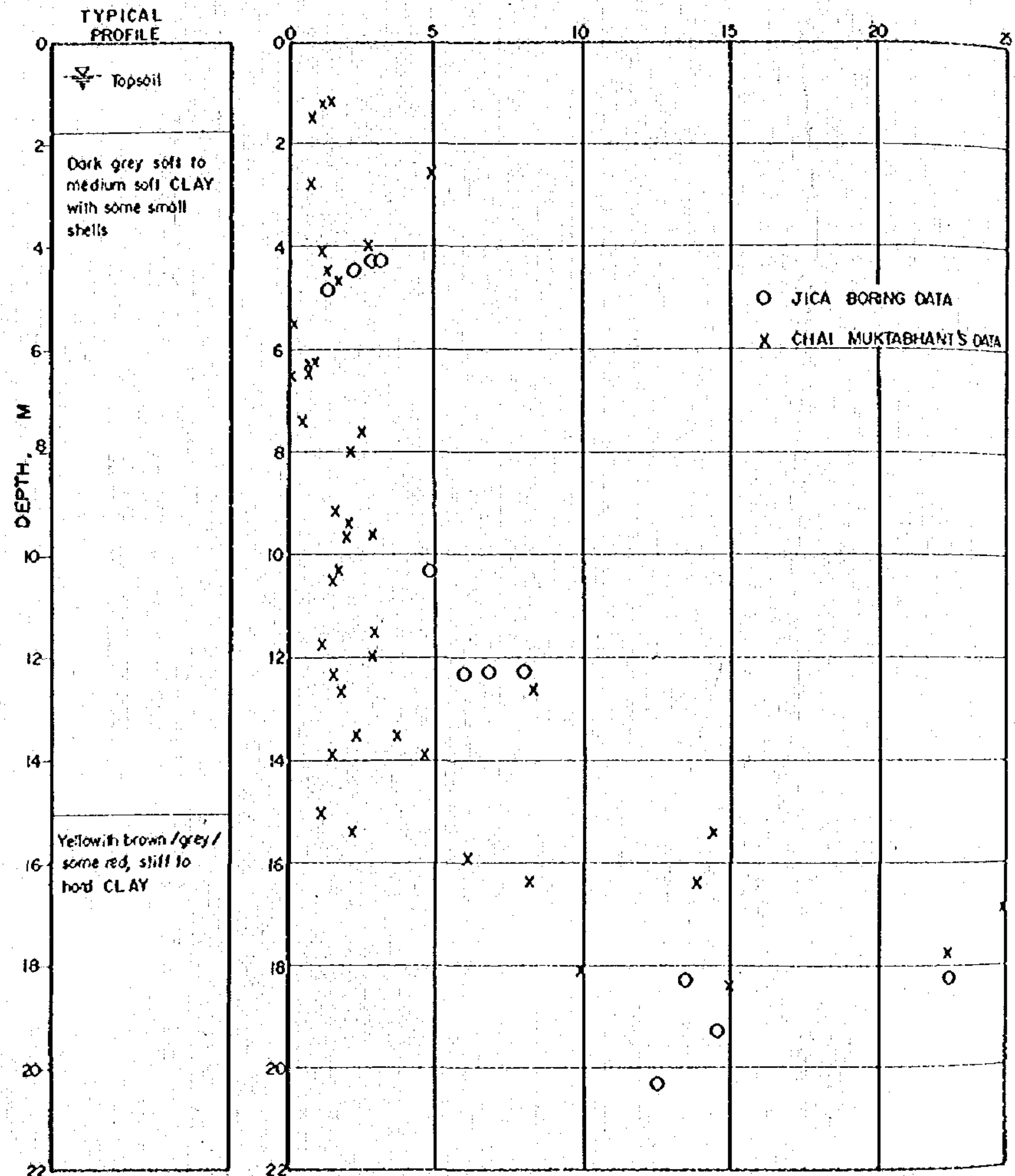


Fig. 3-3-16 Typical Unconfined Strength Data on Bangkok Clay



of the underground pipe and uneven settlement stress to occur.

2) Even in the case where substantially uniform settlement of the ground is caused by lowering of the underground water level, when the underground pipe is connected to a non-settlement structure such as abutment of a bridge or valve pit supported by piles, a great stress occurs in the border of such connection.

3) In the vicinity of the border between the hard ground and soft ground, when any settlement is caused in the soft ground it causes uneven settlement of the ground and a stress occurs in the underground pipe.

It is presumable that the uneven settlement stress occurs in the above-described states in Bangkok. Examples of the uneven settlement and uneven settlement stress are shown in Appendix.

III-3-2-3-2 Foundation of the structure

Of the project town gas service faciliteis, there are only a small number of structures which require large-scale foundations. However, since Bangkok clay is very soft and has a high compressibility, any structure having a contact pressure of more than 2.0 t/m^2 requires a deep foundation capable of transmitting the load to the supporting layer having sufficient bearing capacity and low compressibility.

With respect to relatively light loads, such as valve pits, intermediate piers of a river bridge, of gas pipelines and light-load facilities of gas manufacturing plant, etc. wooden piles and/or precast concrete piles are driven into the hard clay layer, as friction piles. Wooden piles each having a length from 5 to 6m are driven for valve pits and light-load facilities of the plant, and precast concrete piles each having a length from 15 to 16m are driven into the hard clay layer for piers at the river crossing parts.

Since gas holders, naphtha tanks, compressor and houses in the plant or the gas supply station have relatively heavier loads, friction piles are insufficient but bearing piles are required.

For these installations, prestressed concrete piles each having a 23 m length and a 35 cm square section must be driven down to a layer having a standard penetration resistance of 30. The bearing power of each of these piles is 30 to 40 ton/piece.

In this manner, the foundation of the structure must be, as a general rule, of a pile structure, and no improvement of the ground must be carried out.

However, the construction site of the plant and the gas supply station are partially in soft and marsh land, and therefore the construction works are difficult to be carried out if it is subject to construction works in its original condition. Accordingly, replacement by sand is required for such sites as having soft ground and high underground water level.

III-3-2-4 Corrosive environment

III-3-2-4-1 General

In general, the following matters may be considered as factors from which corrosiveness of soil can be inferred,

(1) soil resistivity
(2) pH value of soil, and
(3) redox potential of soil

(1) Soil resistivity

Of these factors from which corrosiveness of soil can be inferred, there are many scholars who consider that the soil resistivity is a factor that gives the largest influence across the soil. In general, the soil resistivity and the corrosion extent of iron and steel has relations shown in Table 3-3-1. It is found from this table that soil having a soil resistivity of less than about 2,000Ω-cm has a heavy corrosiveness. The soil resistivity is influenced by water content and dissolved salts.

When the contents of water and salts in soil increase, the resistivity becomes low.

(2) The p^H value of soil:

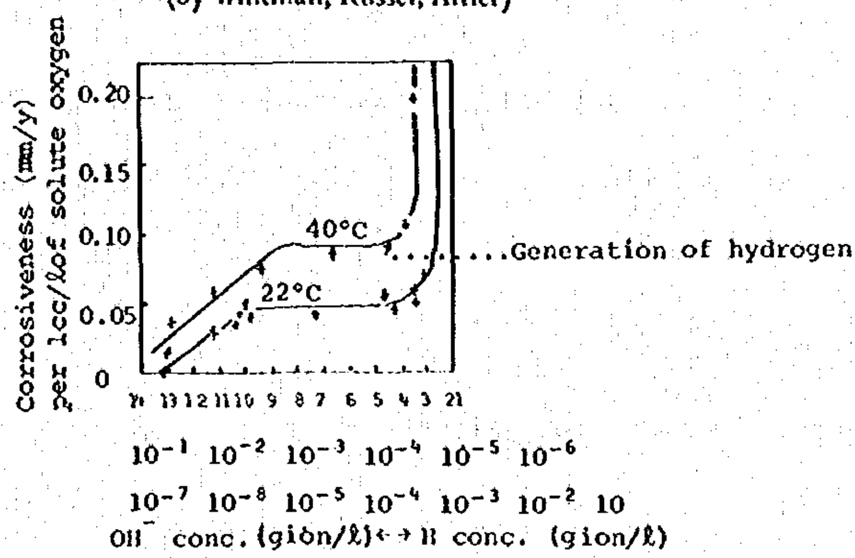
Since the p^H value does not indicate the full amount of acid but indicates the concentration of hydrogen ions in the soil it is insufficient to mention the corrosiveness only by p^H value but it is important as a factor.

Generally speaking, iron is weak in acidity, and lead is weak in both acidity and alkalinity. The relationship between p^H value and corrosiveness in water is shown in Fig. 3-3-17.

Table 3-3-2 Soil resistivity and extent of corrosiveness of untreated pipe

Extent of corrosiveness of iron and steel	Life of untreated pipe	Soil resistivity (Ω-cm)
Very heavy	Less than 10 years	Less than 1,000
Heavy	Less than 10 years	1,000 -2,000
Medium	10 - 17 years	2,000 - 5,000
Slow	17 - 25 years	5,000 - 10,000
Very slow	More than 25 years	More than 10,000

Fig. 3-3-7 Influence of pH on the corrosion of soft steel
(by Whitman, Russel, Altier)



(3) Redox potential of soil:

When an aerobic sulfate reduction bacteria is propagated in the impervious soil containing sulfate, the cathodic reaction formulates, and rapid corrosion occurs.

In the general corrosion mechanism (V. Wolzogen Kühr - 1934), that is,

anodic reaction $4Fe \rightarrow 4Fe^{++} + 8e$
cathodic reaction $8e + 8H_2O - 8H + 8OH^-$,

the cathode side is depolarized by bacteria as follows:

$$H_2SO_4 + 8H \rightarrow H_2S + 4H_2O$$

Therefore, iron sulfide and di-valent iron hydroxide are produced as corrosion products by the following reaction:

$$Fe^{++} + H_2S \rightarrow FeS + 2H^+$$
$$3Fe^{++} + 6OH \rightarrow 3Fe\ (OH)_2$$

Also FeS acts as a corrosion agent against metallic iron. This tendency of bacteria corrosion can be inferred by measuring the redox potential.

The relationship between the redox potential and bacteria corrosiveness is indicated in Table 3-3-2.

The corrosion of this kind occurs frequently in low damp land such as march land, reclaimed land, etc. and particularly occurs very frequently in sludges on the sea bottom.

TAble 3-3-2 Relationship between redox potential and bacterial corrosiveness

Redox potential (mV)	Bacterial corrosion tendency
Less than 100	Furious
100 - 200	Middle degree
200 - 400	Slight
More than 400	None

III-3-2-4-2 Corrosiveness of soil in Bangkok

Table 3-3-3 indicates the result obtained by measuring and investigating in Bangkok on three items as the factors from which abovementioned corrosiveness of soil can be inferred. Fig. 3-3-18 indicates the locations of measurement and investigation. The soil resistivity is in the range from 280Ω - cm to 3,500Ω - cm. Soil having heavy corrosiveness less than 2,000Ω - cm cover more than 80% of the fully investigated location, and therefore it indicates that soil is in environments of heavy microcellar corrosion.

With respect to the soil nature, as mentioned above, generally a hard clay layer covers up to the depth of 3m from the ground surface. However, there is partly found viscous sandy soil. Therefore, when fluctuations of soil resistivity are taken into consideration, microcellar corrosion due to the difference in soil quality or microcellar corrosion in the vicinity of underground water surface is also considered.

In the redox potential, almost no tendency of bacterial corrosiveness is observed except that middle degree tendency of bacterial corrosion is observed at several places. However, when inferred from the soil conditions mentioned above, the actual redox potential is considered to be slightly low.

The p^{H} value of soil is in the range of from 6.4 to 8.8, and there is found no strong acidic soil of particularly heavy corrosiveness.

In addition to the abovementioned corrosiveness factors, the temperature of soil is as high as 25 to 28°C, and therefore accelerates corrosion.

In conclusion, Bangkok soil can be said soil for which thorough measures for the prevention of corrosion is necessary for the piping works.

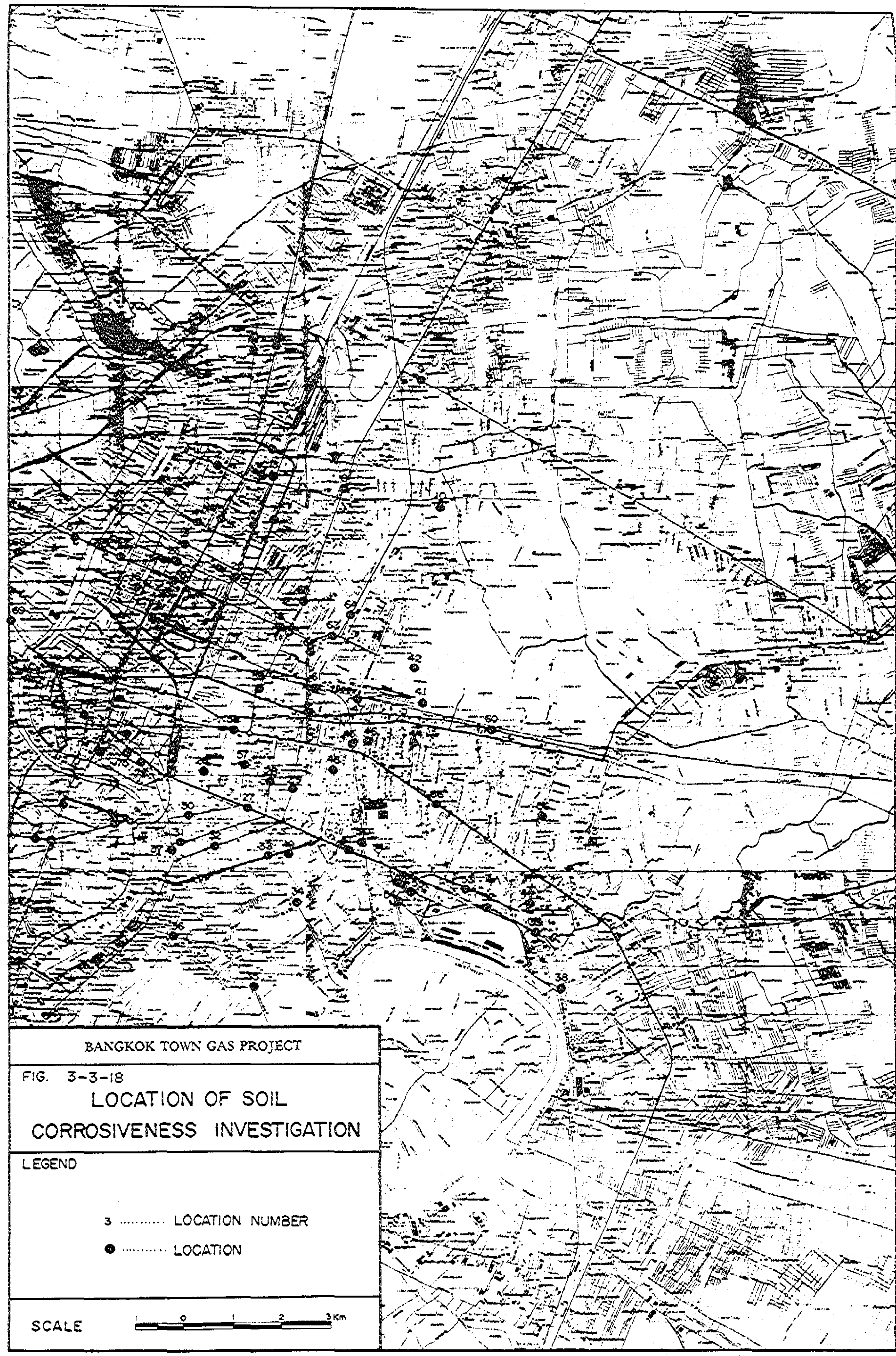

BANGKOK TOWN GAS PROJECT
FIG. 3-3-18
LOCATION OF SOIL CORROSIVENESS INVESTIGATION
LEGEND
3 .... LOCATION NUMBER
● .... LOCATION
SCALE
1 0 1 2 3Km

Table 3-3-3 Corrosiveness Investigation of Soil

Location Number	Location	Depth	Date	Measured Valves		
				Soil Resistivity	Redox Potential	P-H Valve
4	Amnuai Songkhram Rd.	0.9		1,500 Ω-cm	449 mV	8.2
8	Phahon-Yothin Rd.	1.0		3,500	471	8.4
12	Pracha Chuen Rd.	1.0		270	481	7.9
15	Ratchawithi Rd.	0.7		1,400	501	7.9
19	Nakhon Chaisi Rd.	1.0		860	491	8.4
24	Si-Ayutthaya Rd.	0.8	Nov.14 1974	530	455	7.8
32	Silom Rd.	1.0	:	770	433	7.1
39	Khlong Toey Rd.	1.0	:	450	491	8.4
43	Soi Phrakhanong-Latphao Rd.	1.0	:	2,000	479	7.2
46	Soi Nana Nua	1.0	Nov. 25 1974	620	501	7.9
51	Rama IV Rd.	1.0		750	482	7.5
54	Sun Thon Kosa Rd.	1.0		220	503	7.6
57	Phayathai Rd.	1.0		540	441	7.4
66	Sukhumvit Rd.	1.0		2,400	511	8.4
75	Soi Mangkon Rd.	0.8		1,450	475	7.1