KINGDOM OF THAILAND

MASTER PLAN REPORT
OF
ELECTRIC DISTRIBUTION SYSTEM
IN
BANGKOK
(1982—2001)

ANALYSIS OF PRESENT SITUATION

AUGUST 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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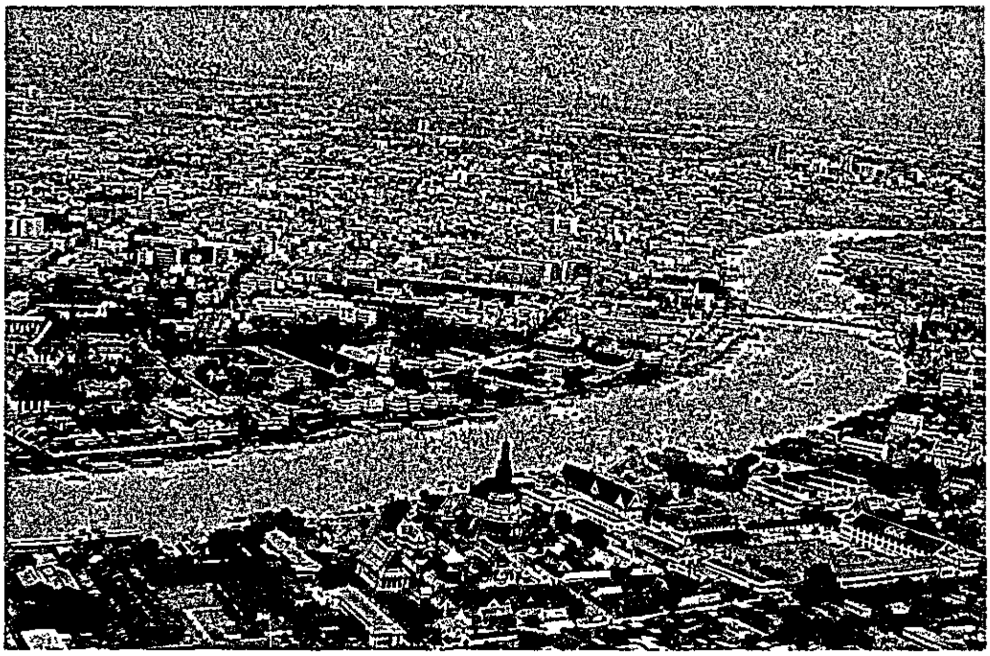

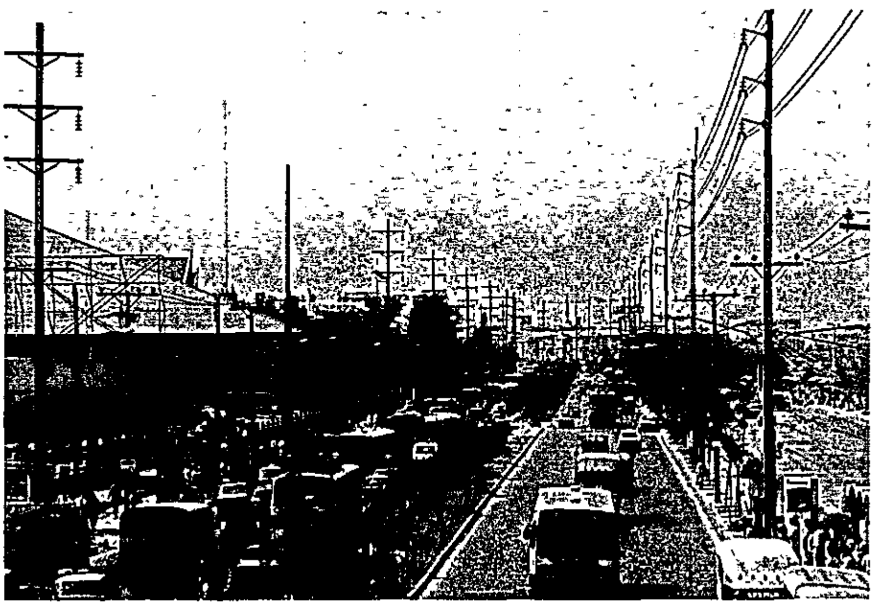

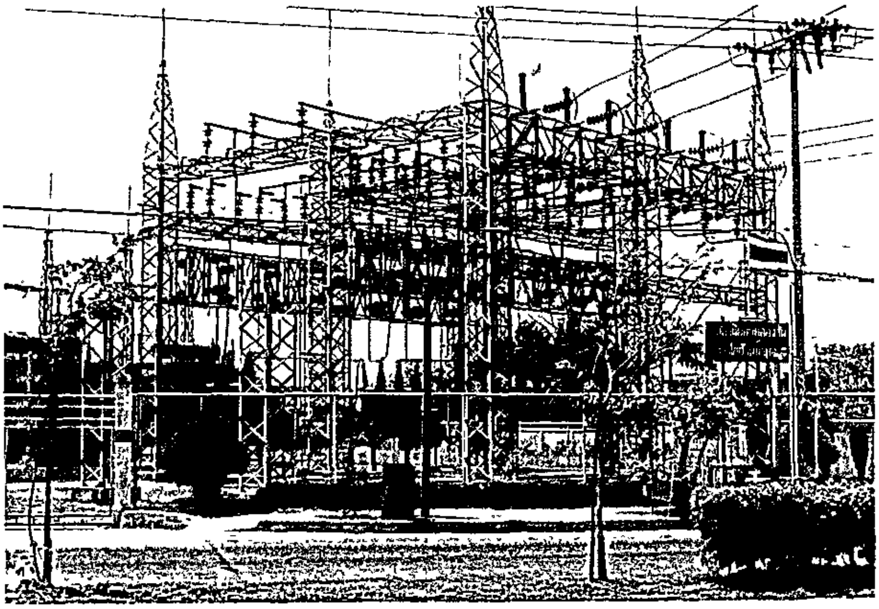

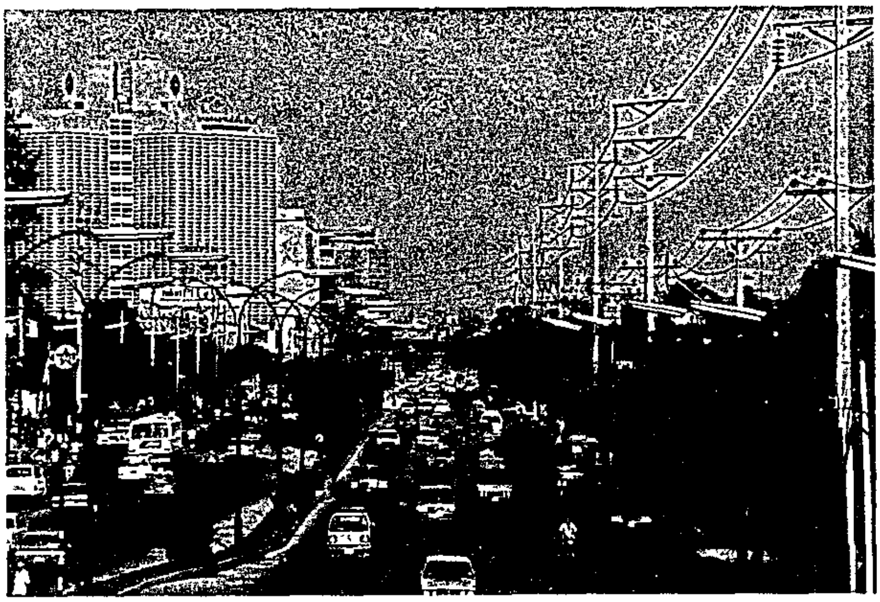

PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Government of Japan decided to conduct a study on the 20-Year Master Plan for MEA's Electricity Distribution System and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Thailand a study team, headed by Mr. Toshinori HOMMA four times in the 1981—1982 period.

The team exchanged views with the officials concerned of the Government of Thailand and conducted a study in MEA's distribution area, Bangkok. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the above System, and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

Tokyo, August, 1982

Keisuke Arita
President
Japan International Cooperation Agency

CONTENTS

IV. APPENDICES

I. INTRODUCTION

I. INTRODUCTION

This report on analysis of the existing condition of power system in the Metropolitan Electricity Authority is a summarization of the results of analysis studied by the Japan International Cooperation Agency (JICA) as the first step in compilation of the MEA's 20-year master plan.

JICA dispatched a team consisting of 5 engineers to Bangkok at the request of the MEA, and the team carried out field investigations and collected relevant data. Upon returning to Japan, the team made analytical studies of the details of these investigations with the help of experts in various fields.

Deepest gratitude is expressed to the unselfish and wholehearted cooperation of the MEA counterparts, without their help it would not have been possible to prepare this report.

II. RECOMENDATIONS

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II-1 Improvement of facility utilization factor

The utilization factor of the existing facilities of the MEA is considerably low compared with those in other countries. For instance, utilization factor of transformers in distribution substations is 55.7% and utilization factor of distribution feeders is 62.0% in average at year 1979. Since improvement of utilization factor of the facilities is directly tried to reduction of the amount of investment, the most important point is to take certain action from an engineering and economic standpoint.

Low utilization factors in the MEA come from the following reasons;

- Standardized facilities are installed irrespective of the diversity of regional characteristics (load density, growth rate).
- The system composition is of radial type, and dual facilities are usually installed for maintaining a required level of reliability.

If facilities were continuously expanded based on these two criteria, half of the installed capacity will always be maintained as spare facilities. This may be permissible as far as the scale of the system is small, but as load increases, an enormous amount of spare capacity will be required in the future and this will be a reason for deterioration in economic efficiency of investment for facilities.

The investment for facilities must be studied with the purpose of finding the minimum amount of investment with which the required level of reliability can be maintained. For such purpose, the existing standard and design criteria must be improved so that new systems, equipments and materials effective for improving reliability can be adopted on a case by case basis.

Since the MEA's distribution system has a considerable surplus capacity, power interruption time to customer can be minimized, if necessary distribution switches are operated quickly. For this purpose, we recommend that a study be made to improve the interlinking system of distribution lines and adoption of new type of distribution switches.

The conclusion is that, strengthening of the function of load interchange by distribution lines will lead to improvement in the utilization factor of the distribution lines and the transformers in the distribution substation. Detailed description is given in paragraph III-10.

Note. Interlinking system is a system that two or more distribution lines are connected each other by the automatic load break switches, if power interruption occurred on one distribution line, this line is supplied by another distribution lines.

II-2 Establishment of reliability criteria by district

Investment in facilities will vary according to reliability level. If it is the intention to maintain the same high level of reliability for all districts in the service area of the MEA, it will require a huge amount of investment. It is evident that there is a big difference in the power demand structures between the central district of Bangkok and the surrounding rural districts. In general, there is the tendency to think of maintaining the same reliability level being bound by the ethics of "fairness", but this is not realistic.

The MEA has a complete set of standards for facilities which are well maintained, but does not have the flexibility to select equipment and materials according to necessary level of reliability. The maximum load density in the central district of Bangkok at present is about 20,000 kW/km^2, but the difference between this district and rural districts will become much greater when the load grows to many times more in the future, and it will become much more difficult to supply power in both areas at the same level of reliability. We recommend that the MEA must establish the reliability criteria by district. An example is shown in Table 1.

In establishing the reliability standards by district, the problem will be what are the indices that should be selected as representing the importance by district. Examples conceivable as indices are population, existence of important customer, overall living standard, electric power load density, etc. From the standpoint of the electric power supplier, index which is the easiest and the most effective to adopt is the electric power load density.

As a result of processing by computer of the massive data collected in the field survey, an electric power load density map is shown for every unit mesh (Appendix 16). With these as the bases, we recommend that the MEA service area be divided into three zones, with different reliability levels established for the each zone. The central part of Bangkok will provisionally be called area A, the surrounding part area B, and the outlying remote district area C. Regarding the method of determining the boundary between A and B, and that between B and C, it can be decided by thoroughly investigating the actual status of demand in the various areas.

The MEA uses MW-min as the index for reliability. [See III-8-(1)] It may be a good index under the present situation where data on the interrelation of customer and distribution facilities are not yet available. At a stage in the future when a management system combining customer data and facilities data is adopted, it will be advisable to contemplate the use of Σ(H x C) employed in Japan.

Table 1 Reliability Standard

– Sample of a Japanese utility

Basic conditions in planning power system facilities are described below:

Every facility should be planned to satisfy the condition that service interruption time should not extend beyond the following value at occurrence of fault and at scheduled maintenance interruption.

(1) Unexpected interruption time by fault

Facility	Situation of fault	Unexpected interruption time		
		A area	B area	C area
Transmission transformer	1 bank fault	Within 15 min	Within 90 min	Within 90 min
Generator	1 unit fault	No interruption		
Transmission line	1 circuit fault	Within 2 min	Within 15 min	Early as possible
Distribution transformer (SS)	1 bank fault	Within 30 min	Within 120 min	Within 480 min

Notes

1. A area. . . . . Town area of main big city
   B area. . . . . Town area of other city
   C area. . . . . Provincial area
2. Required operation
   No interruption . . . . Automatic recovering
   2 min . . . . Transfer 1 circuit by circuit breaker
   15 min . . . . Transfer 2 circuits by circuit breaker
   30 min . . . . Transfer to another bank of same substation or of adjacent substation by distribution line
   90 min . . . . Transfer to spare transformer
   120 min, 480 min . . . . Supply by portable transformer

(2) Expected interruption time by scheduled maintenance

Facility	Condition	Expected interruption time	
		A & B area	C area
Transmission transformer	1 bank out	No interruption	Within 8 hours, but important load will be transferred to another substation (once a year)
Generator	1 unit out	No interruption	
Transmission line	1 circuit out	No interruption	
Distribution transformer (SS)	1 bank out	No interruption	Within 4 hours, but important load will be transferred to another substation (once a year)

II-3 Reviewal of facility standards

The MEA has set up good, harmonious standards for its facilities. Existing facilities were built up in an orderly manner in accordance with these standards. It is certain that these standards have adequately demonstrated their effectiveness in the process of the build-up until the present.

However, as Bangkok further expands as a modern large metropolis, it will become subject to various changes in conditions not previously experienced, and it is anticipated that MEA cannot follow such changes through application of the existing standards only. We therefore recommend a review and up-grading of the facility standards in order to carry out enormous expansion while preventing a decline in reliability. (See Appendix 15)

First, the distribution substations are each of 30 (40) MVA x 2 banks with 5 feeders (12 kV) or 3 feeders (24 kV) per bank. This capacity is slightly small for Area A, but is too large at times for Area C. From the standpoint of reliability, 3 banks will be more advantageous than 2 banks.

Second, bigger capacity equipment should be used according to increase of load. Consequently, sizes of conductors, strength of concrete poles and capacity of switches must be reviewed.

Third, facility standards must be established in accordance with the level of reliability required for each district. At present, the service area is divided into a network area and others, but we recommend that it be divided into 3 ranks, A, B and C. An example of standards in Japan is given in Table 1 as reference.

Fourth, it is necessary to review the current standards periodically to follow the new technology, and technical committee should be established for this purpose.

As urbanization has progressed, there have arisen problems which are different from traditional ones both quantitatively and qualitatively. There are many problems needing study in connection with aesthetics, land required, etc., such as increasing 230 kV substations inside the city, changing from overhead transmission and distribution lines to underground cables in some areas, stringing of transmission lines on expressways and bridges, and adopting thermo-resisting AAC.

Especially, thorough study of underground facility is needed taking into consideration the peculiar natural conditions in the Bangkok area.

II-4 Power system voltage

To cope with the actual demand, there is no problem at the present in the system voltages of the MEA. But as problems in the long future, system voltages of transmission and distribution are important items to be studied.

As a result of our analysis of existing condition and load forecasts, there is no need to change the existing system voltages for coming 20 years.

(1) 230 kV transmission system must be expanded into the city area to transmit bulk power to the load center of Bangkok city.

(2) 69 kV system will be utilized effectively as subtransmission line voltage to distribute the power to each distribution substation.

(3) 115 kV system will be used in the rural area in the same way as the existing pattern.

(4) 12 kV primary distribution system does not need to be stepped up 24 kV. But, to supply power to new spot loads, 24 kV system should be adopted in the Bangkok city area in addition to 12 kV system. (See Appendix 14)

As for stepping up of the distribution voltage from 12 kV to 24 kV, it is better to make an early start to study the step up procedure.

In the remote area, 24 kV system will be used in the same manner as the existing pattern.

(5) Four different kinds of secondary system are used at present, but 3-phase 4-wire 240V/416V system is adequate as the secondary distribution system voltage. Unification to 3-phase 4-wire 240V/416V system is needed.

In very long future after 2001, up-rating of primary distribution system voltage from 12 kV to 24 kV may be taken into consideration.

But, changing of distribution system voltage requires big amount of investment and complete consensus with public society.

It is so big project that the MEA must prepare a basic plan of this project with careful attention.

II-5 The secondary network distribution system

The MEA is operating a secondary network distribution system using low-voltage overhead lines, covering 8.5 km^2 in the service area of Sapandam and Watlieb substations which comprise a very crowded urban district in Metropolitan Bangkok. Corresponding to the rapid growth of demand in this district, the distribution facilities need to be expanded year by year.

Secondary network distribution system is a good system to maintain the highest level of reliability in a stable demand area, but if the load increases rapidly, maintenance and operation of the system becomes very complicated. Furthermore, network protector, which is required to be attached to every distribution transformer has become extremely expensive so that the MEA has serious difficulties to keep up with requirements.

Under such prevailing situation, we recommend that a study be made of the method of changing the existing network system into conventional radial type distribution system. Nevertheless, thorough consideration must be given in he reliability of the new radial system.

To maintain the high level of reliability in the area after dismantling of the network system, improvement must be made to the 12 kV underground distribution system by means of installation of line switches, change of line connection, etc. Such improvement works will need a considerable amount of investment. Therefore, it is necessary to establish a basic plan for dismantling of the network system from the viewpoint of economic consideration.

Detailed description is given in paragraph III-6-2.

II-6 Watt-hour meter calibration system

The MEA has supply contracts with approximately 700,000 customers with a watt-hour meter installed at every customer's terminal for measuring electric energy consumption. The characteristics of a watt-hour meter changes with time. Normally, the changes become apparent with minus errors, although there are cases of plus errors. As a government enterprise which should carry out fair transactions, controlling errors of meters is of extreme importance. We recommend that MEA's calibration system be reviewed.

Detailed description is given in paragraph III-6-5.

II-7 Contract kW and supply voltage

Usually, customers who contract less than 300 kVA are supplied at voltages of 240V/416V. Especially in secondary network area, customers who contract less than 500 kVA are supplied at 240V/416V. For this reason the MEA is forced to install many stepdown transformers on its own poles.

Corresponding to the rapid urbanization of town area, installation space of transformers becomes one of serious problems of the MEA. To minimize such difficulty, increasing of the number of transformers must be suppressed as much as possible.

For this purpose, it is recommended to curb the upper limit of contract kW which is supplied at 240V/416V. By this means, customers who are supplied at 12 kV or 24 kV will increase. It is desirable that such customers install their own stepdown transformer.

If the installation of transformers by customers themselves is impossible, they must provide or lease land or building as installation space of transformers.

This is a matter concerning contracts between customers and the MEA. We recommend that a study be made of this matter including the MEA's tariff regulation.

Detailed description is given in paragraph III-2-5 and III-6-2.

II-8 Improvement of load management for distribution transformers

As distribution demand has increased, the number of distribution transformers has increased rapidly, and the number of transformer stations has come to exceed 20,000. As a result, the MEA has difficulty to locate overloaded transformers by the existing manual methods.

The very same situation was seen in Japan in the past and the difficulties were eliminated through application of electronic computers. The computer calculates the load at present and one year hence for each transformer by inputting the monthly consumption of each customer.

This computer system is an important and fundamental measure in coping with rapid increase in demand, and we recommend that the MEA make efforts for the realization of such a system.

II-9 Modernization of distribution facilities

1. Distribution line switch

Distribution system must be composed considering the interlinkage among distribution feeders as a measure to minimize interruption of service to customers. In order to supply the interchange power in a short time, it is necessary to operate distribution line switches. But the MEA is presently using knife-type switches which open and close one phase at a time. For 12-kV and 24-kV distribution lines, good-quality switches which can open and close 3 phases simultaneously are being marketed, and we recommend that the MEA successively change over to these new type of switches. Especially, for the district inside the city which requires high service reliability, the MEA must consider automation and remote control of these switches.

2. Underground cable

The MEA's primary distribution lines are mostly overhead lines except secondary network area. Especially in the urban area, installation of overhead lines becomes difficult year by year due to environmental problems, such as right of way, good appearance, safety, etc. To solve these problems, the MEA cannot avoid to promote to install underground cables more and more.

The MEA has had some experiences of underground facilities, but not enough to expand in coping with load increase. Kind and size of underground cable, structure of duct or tunnel in case of multi-circuits on one route, and use of triplex type cable must be studied.

Natural conditions and geological conditions in Bangkok area are very unique ones, therefore those conditions must be taken in consideration carefully in setting up the construction standard of underground cable and necessary facilities.

3. Semi-insulated conductor

The MEA's primary distribution lines are mostly overhead lines, and are usually installed along streets. In the urban area, overhead conductors often locate very near to buildings or trees.

The MEA is using bare wires as primary distribution lines. It causes often grounding fault of distribution circuit and accidents of people by electric shock.

We recommend that the MEA has a serious attention to use semi-insulated conductors as primary distribution lines. It is clear in Japan that frequency of fault and accident decreased apparently by using of semi-insulated conductors.

II-10 Underground facilities

Urbanization of Bangkok city is very rapid, and many problems are encountered in construction of overhead lines, such as right-of-way, clearance of conductors to buildings, aesthetic consideration, safety problems, etc. To cope with such environmental problems, underground facilities should be seriously considered.

Underground facilities provide very high reliability and also big merit of aesthetic problem. But, on the other hand, there are considerable demerits such as high construction cost, delay of repair work, etc. Therefore, even though the MEA should expand underground facilities in the future, investment for expansion must be scheduled after careful attention to economic conditions.

We recommend that the MEA study and establish standards of underground facilities including transmission line, distribution line and substation. Natural conditions in Bangkok area are very unfavorable for construction of underground facilities. Thus, the MEA must have a specific standard which cope with such natural conditions.

The MEA already has considerable experience of underground work, for instance, underground distribution feeders in secondary network area, 230 kV underground cable in downtown area, incoming cable and outgoing cable in several substations, etc. Such experiences will be sufficient to set up the MEA standard of underground facilities.

II-11 Improvement of facility operation and maintenance

The functions and capacity of a facility can be maintained over a long period through proper maintenance, and it must be the aim for the functions to be demonstrated perfectly through proper operation of the facility. The MEA has not yet established complete maintenance standards, and management is being done through temporary patrols and measurements. Maintenance standard must be set up regarding patrol, inspection and measurement methods, and intervals to perform each maintenance work must be decided by thorough analyses of fault statistics in the past.

In connection with operation and control, load dispatching is done through communication by radio, and to maintain a high level of reliability of a system which will become increasingly complex in the future, manual operation will be inadequate, and it is necessary at least to make preparations for remote control and automatic control of main facilities, including utilization method of electronic computer.

Detailed description is given in paragraph III-9-4.

II-12 Application of computer

The MEA has a computer system, and billing is the main job of this computer. Technical calculations are not yet applied.

The peak load of the MEA's power system has already reached to 1,300 MW in 1980. 20 years later, it will reach to four times of existing peak demand. At that time, number of equipments and materials which compose such big-scaled power system will be of enormous quantity.

To manage and maintain each element of such big power system, extremely complexed and many works are required to be executed. That's why computer is necessary to execute such works.

At same time, the MEA should develop and grade up the computer programs to execute technical calculations for planning or managing.

Billing, salary calculations, etc. are good subjects as basic load of computer. But we recommend urgent expansion of necessary functions to apply the computer for above-mentioned objectives.

II-13 Strengthening of communication facilities

The MEA owned communication facilities are seemed to be insufficient. Communication for load dispatching is done mainly by VHF wireless system.

To operate every facility effectively, communication facilities with high reliability are indispensable. We recommend the MEA constructs self-owned communication network with high reliability, because these facilities will be used as data transmission lines also. Wire telephone system and wireless telephone system will be used in good combination, taking the communication with EGAT into consideration.

II-14 Training of employee

In accordance with progress of modernization of power system facilities, technical level of every concerned employee must be modernized harmoniously. That's why modernized facilities can display the superb function only when those are operated by qualified personnel.

Technical staff in the office, operator in station, maintenance worker in branch office, each of them must be trained to follow the modernization of facilities.

In the MEA, training is usually done in On the Job Training style. It seems to be not enough in future. We recommend that the MEA set up by himself a systematic training course for each of necessary jobs.

III. EXISTING CONDITION AND RESULTS OF ANALYSIS

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III-1 Existing condition of the MEA

1. Status of the MEA

The MEA is an organization under the jurisdiction of the Ministry of Interior of the Government of the Kingdom of Thailand, and has the responsibility of supplying electric power to a service area consisting of the capital city of Bangkok and two adjacent provinces.

Electric power supply in Thailand is performed through cooperation between three agencies consisting of the Electricity Generating Authority of Thailand (EGAT) which mainly generates electric power, the Provincial Electricity Authority (PEA) which distributes electric power to the entire country other than the capital area, and the MEA. The MEA and the PEA receive energy from power systems operated by the EGAT, and supply the energy to customers in their respective service areas through subtransmission lines, distribution substations and distribution lines which these two agencies operate themselves. Referring to such situation, Fig. 1 shows location of main facilities of EGAT.

The city of Bangkok which comprises the greater part of the service area of the MEA is the capital of Thailand, and as the center of economic activity of Thailand, there is much commercial and industrial demand in the city. Therefore, electric power supply by the MEA of high reliability is of extreme importance not only for Bangkok city but also for the whole of Thailand.

The MEA has handsomely performed its responsibilities for many years in the past through the splendid efforts of its staff. However, the growth of demand in the Bangkok area in recent years has been so rapid that MEA has come to be ceaselessly tied up in expansion of facilities.

Expansion work of facilities has gradually become more difficult to execute, because various restrictive conditions were brought about by changes in the urban environment. On the other hand it is now anticipated that providing adequate management for the vast amount of equipment and line facilities becomes extremely burdensome.

The MEA, taking into account the various conditions which will hereafter rapidly become more complicated and variable, is attempting to establish a 20-year master plan for the future upon carrying out studies of methods of building up facilities, management systems and operation principles suited to the new era. This is considered as being a most timely measure.

2. Organization of the MEA

The MEA is a governmental enterprise under the Ministry of the Interior of the Thai Government. The MEA, with its head office in Bangkok, has branch offices at 11 locations to provide service to customers and maintenance of facilities. But two branch offices, Ploenchit and Daokhanon, had responsibility of financial business only. Fig. 2 shows the MEA's service area devided in 9 distribution areas.

The head office organization has a General Manager as its head, while 3 Deputy General Managers are responsible for administration, operation and technical sectors, and each sector consists of 3 or 4 departments. Each department is made up of a number of divisions or sections. The organizational chart of the MEA Head Office is shown in Fig. 3.

The total number of employees was 9,234 as of September 1979.

3. Outline of the MEA's activity

The indices showing the scale of the MEA's activities are as indicated in Table 2. The indices are all for 1979.

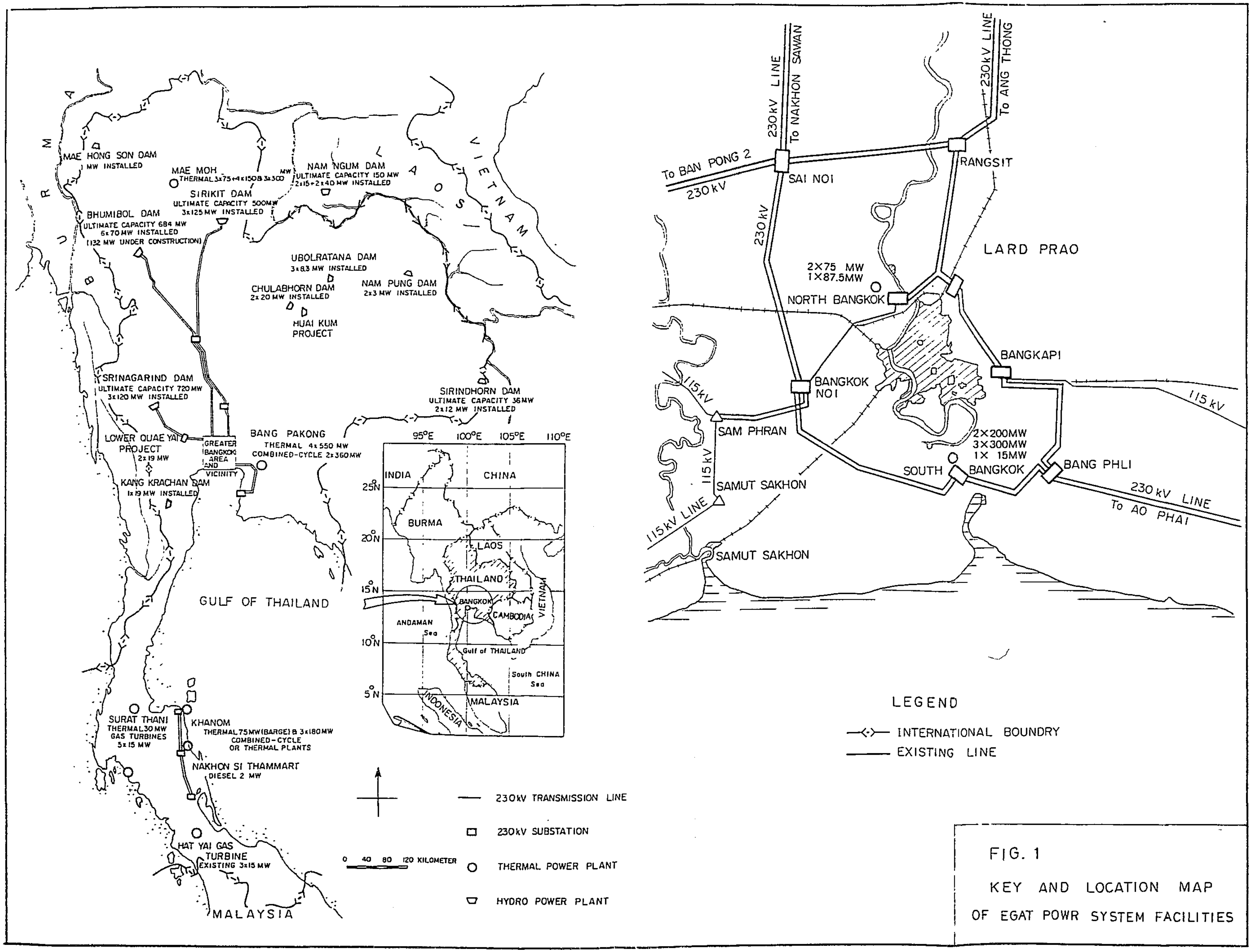


FIG. 1

KEY AND LOCATION MAP OF EGAT POWR SYSTEM FACILITIES

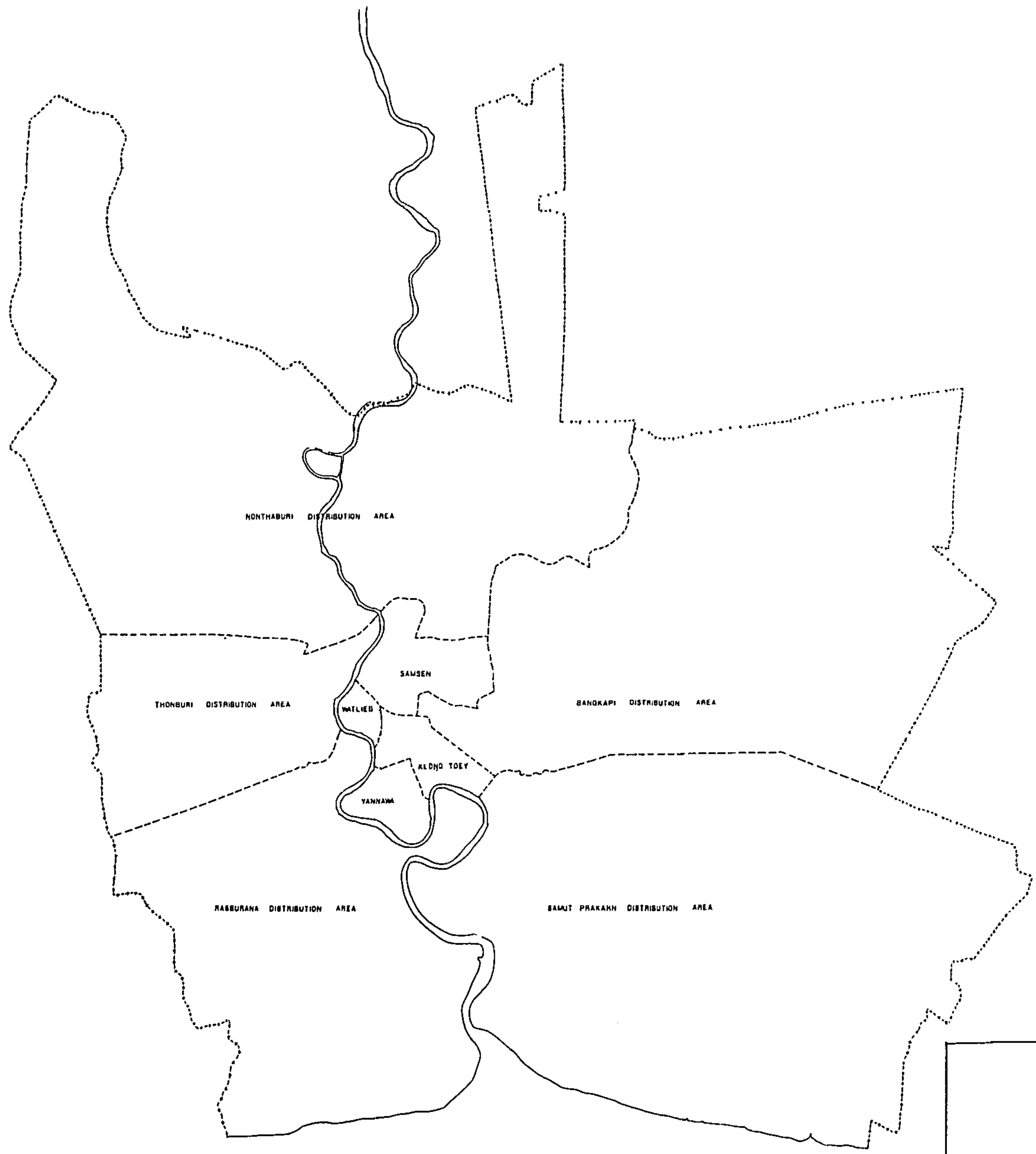


FIG. 2
MEA SERVICE AREA MAP
(9 BRANCH OFFICE)

Fig.3 Metropolitan Electricity Authority Organization Chart

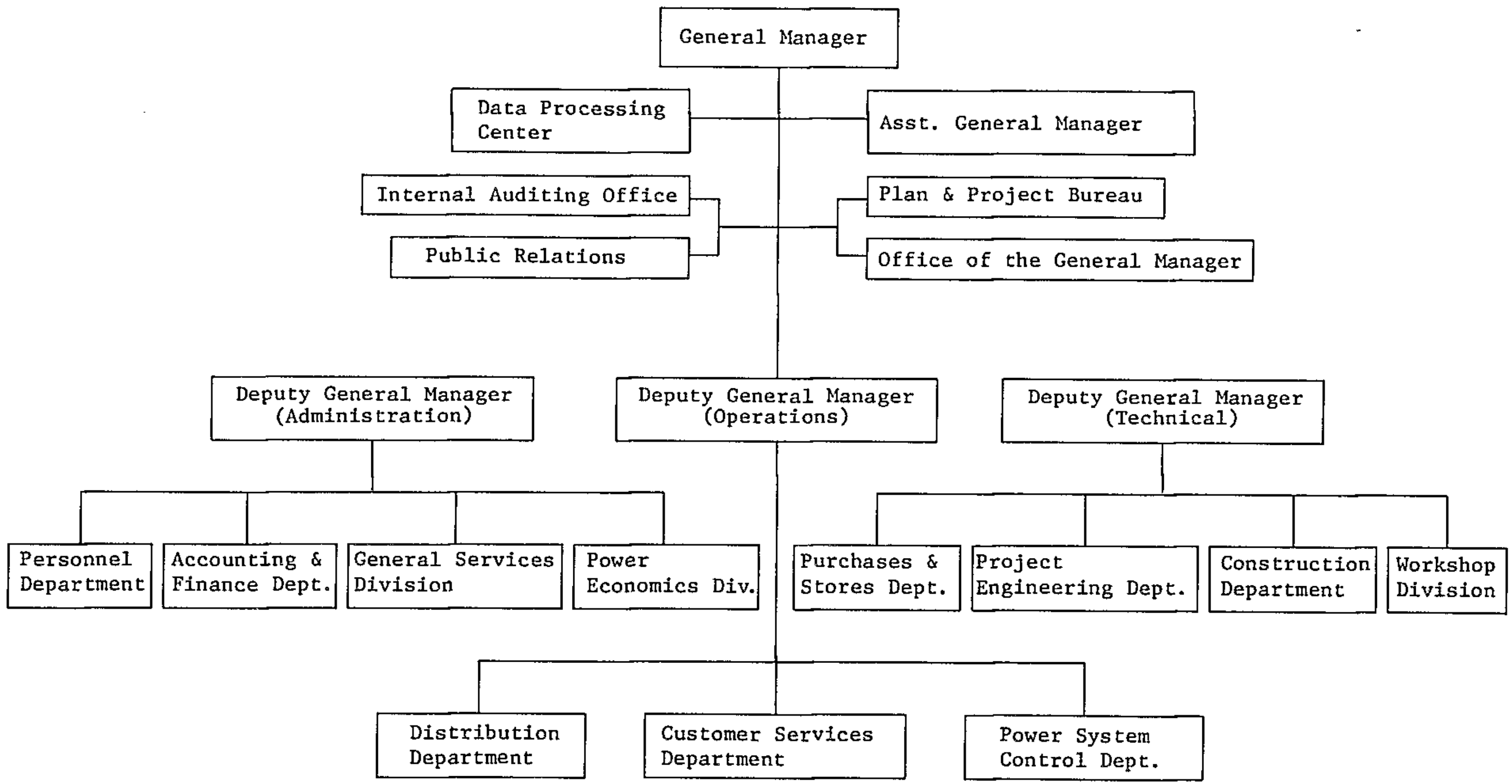


Table 2 Statistics of the MEA in 1979

Index	Unit	Value in 1979
Population in service area (Increase over previous year)	Person (%)	5,884,000 2.8
Number of households in service area	House	924,663
Service area	km^2	3,106
Electrified area (Increase over previous year)	km^2 (%)	1,714 5.4
Electrified area in percentage of service area	%	55.2
Number of customers (Increase over previous year)	Customer (%)	678,801 8.5
Average number of electricity bills issued monthly	Bill	653,327
Energy sold (Increase over previous year)	kWH (%)	7,605,924,380 11.7
Energy purchased (Increase over previous year)	kWH (%)	7,951,086,684 11.3
Power loss	%	4.3
Maximum demand	kW	1,268,000

III-2 Power demand

1. Increase of total demand

(Existing situation)
The energy sales of the MEA have grown immensely during the past decade, the growth rates having been 11% to 19% and, approximately 7,600 GWh of energy were sold in 1979. Accompanying this increase, maximum demand also increased 8% to 16%, and amounted to 1,268 MW in 1979 (Fig. 4 and Table 3).

(Results of analysis)
In the near past there was a decline in the growth rate due to the global oil crisis, but this was a matter of an extremely short period, seen from a long-range viewpoint, and did not affect the trend of increase in demand of the MEA. It is thought that the future deman of the MEA, although subject perhaps to various short-term problems, will indicate a trend of increase in the long future. The load forecast has been made by the MEA including detailed analysis of existing situation, but it is necessary for a long-term investment policy to be studied for such increase of demand.

2. Demand of big customers

(Existing situation)
In energy sales for 1979, large business, OFF-ON peak, and special contract were categories which made up only 8% (366 customers) of the number of customers, but the energy sold was approximately 40% of the whole (Table 4). Only 26 of these big customers were being supplied by 69 kV or 115 kV, the energy sold to them being approximately 13% of the whole. (See Appendix 1).

(Results of analysis)
These big customers are greatly influencing the composition of the electric power system of the MEA as spot loads, but they are concentrated in the 3 planning areas below out of the 25 areas.

Fig 4 Energy Demand and Maximum Demand

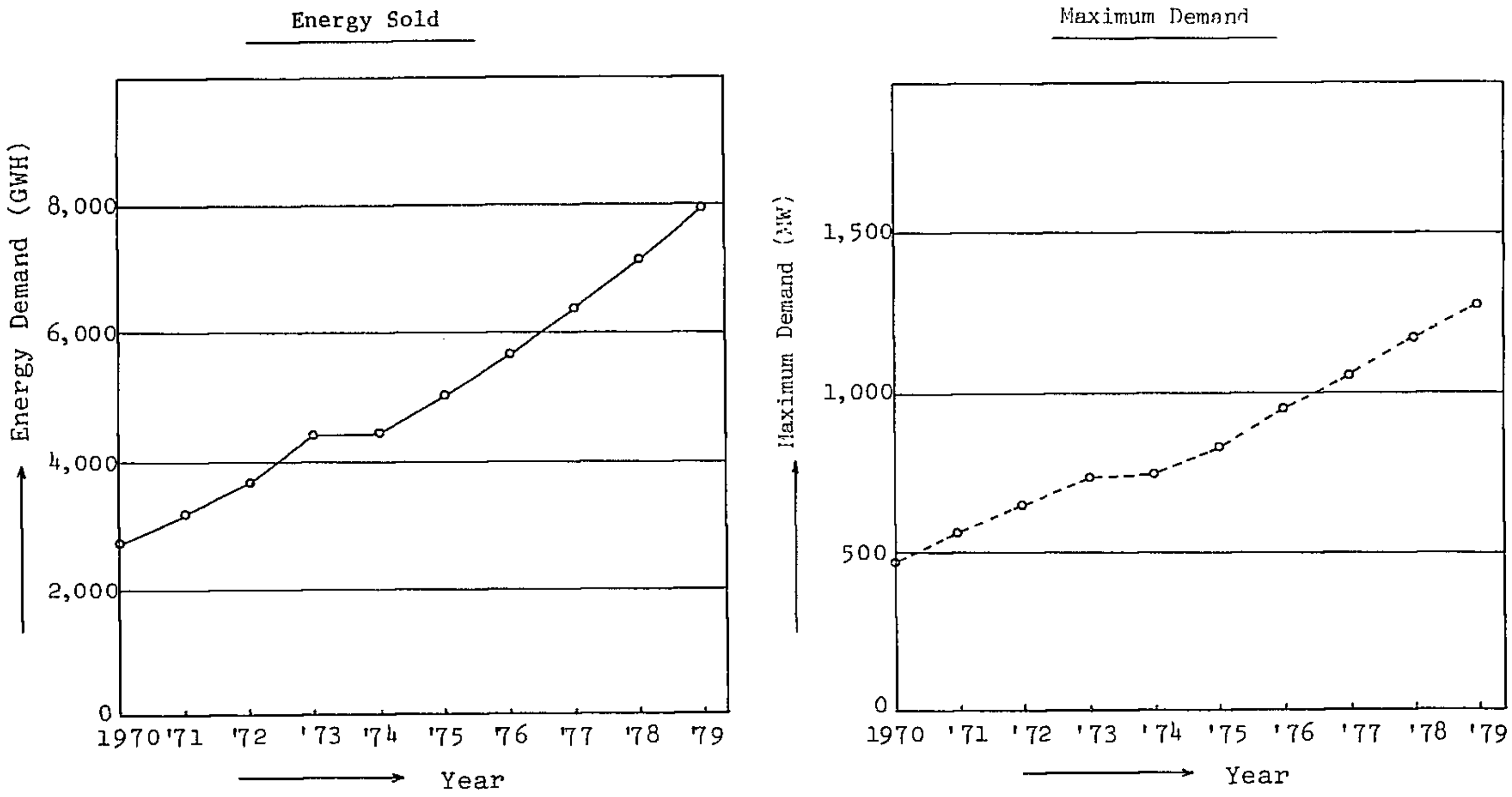


Table 3 Maximum Demand and Energy Sold

	Maximum Demand		Energy Sold		Load Factor (%)
	MW	Growth Rate (%)	GWh	Growth Rate (%)	
1970	484	16.4	2,581	18.0	64.9
1971	561	15.8	3,000	16.2	64.6
1972	647	15.3	3,504	16.8	65.1
1973	739	14.2	4,184	19.4	68.5
1974	752	1.8	4,256	1.7	67.8
1975	834	10.9	4,790	12.5	69.2
1976	958	15.0	5,285	10.3	66.6
1977	1,059	10.5	6,055	14.6	68.9
1978	1,171	10.6	6,807	12.4	69.7
1979	1,268	8.3	7,606	11.7	71.6

Table 4 MEA's Statistical Record

	1978					1979				
	Customer		Energy Sold			Customer		Energy Sold		
	Number	% Increase	GWH	% Increase	% Share to Total	Number	% Increase	GWH	% Increase	% Share to Total
Residential	494,165	9.41	1,240.32	15.27	18.22	538,918	9.06	1,451.22	17.00	19.08
Small Business	106,876	3.61	979.10	15.46	14.39	107,699	0.77	1,038.52	6.06	13.65
Medium Business	4,739	11.04	1,610.60	14.00	23.66	5,515	16.37	1,810.55	12.41	23.80
Large Business	331	12.97	2,599.34	9.33	38.19	357	7.85	2,898.24	11.50	38.11
OFF-ON Peak	3	50.00	47.78	18.86	0.70	3	0.00	49.32	3.23	0.65
Special Contract	6	0.00	290.07	8.64	4.26	6	0.00	319.92	10.29	4.21
Public Street Lighting	729	17.77	39.43	17.95	0.58	827	13.44	38.15	−3.25	0.50
Total	606,849	8.37	6,806.64	12.42	100.00	653,325	7.66	7,605.92	11.74	100.00
Loss	339.58 GWH (4.75%)					345.16 GWH (4.34%)				
Energy Purchased	7,146.21 GWH (% Increase 11.79)					7,951.09 GWH (% Increase 11.26)				

Remarks: Total Energy Sold + Loss = Energy purchased due to rounding errors.

Big Customers (For 69 kV, 115 kV Supply), 1979

PL Area	Customer	Energy Sold	Share to Total
Q 00	6	381 GWh	37.3%
D 10	8	247 "	24.2%
R 00	5	232 "	22.7%
Others	7	161 "	15.8%
Total	26	1,021 "	100.0%

The ratio of big customers in each PL Area (planning area) is shown in Fig. 5.

3. Distribution Demand (Demand excluding big customer)

(Existing situation)

The distribution demand excluding big customers supplied by 69 kV and 115 kV are scattered throughout the entire service area of the MEA. The MEA has detailed statistics of energy consumption by each planning area and by each category. Therefore, the load density and load characteristic of each planning area are available, even though the service area of every planning area is different.

(Results of analysis)

In order to grasp this scattered condition, the entire area was divided into meshes of 1 km x 1 km, and the peak demand recorded at the distribution substation was allocated proportionately to the capacities of the distribution transformers installed in the individual mesh. In these calculation, newly developped program for computer was used. Flow chart of the program is shown in Fig. 6. As a result, the maximum demand density per km^2 was approximately 20,000 kW and the minimum 0.1 kW. Overall status is as follows:

Fig. 5 Energy sold of each PL area - 1979

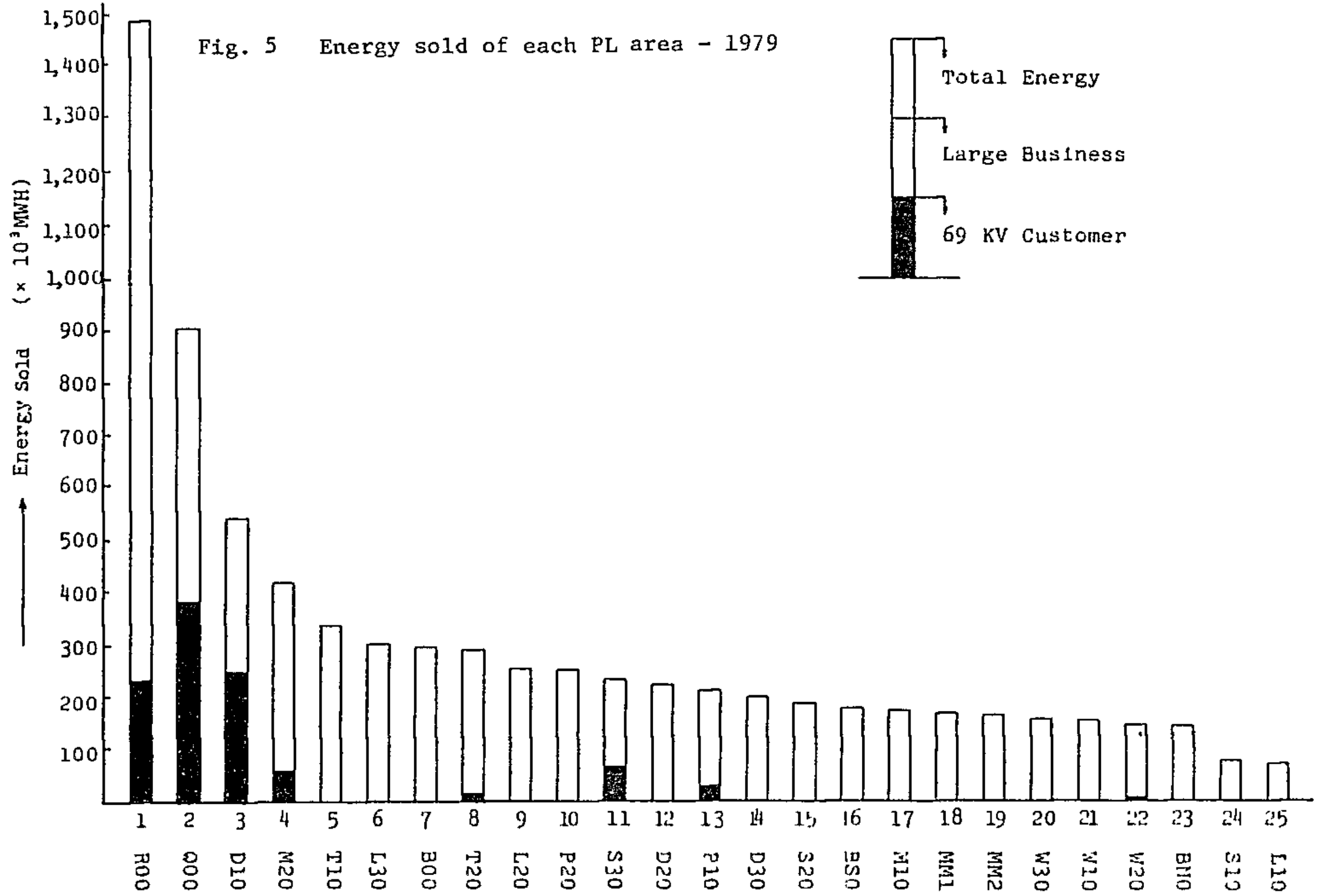


FIG. 6 CALCULATION OF LOAD DENSITY FLOW CHART No.1

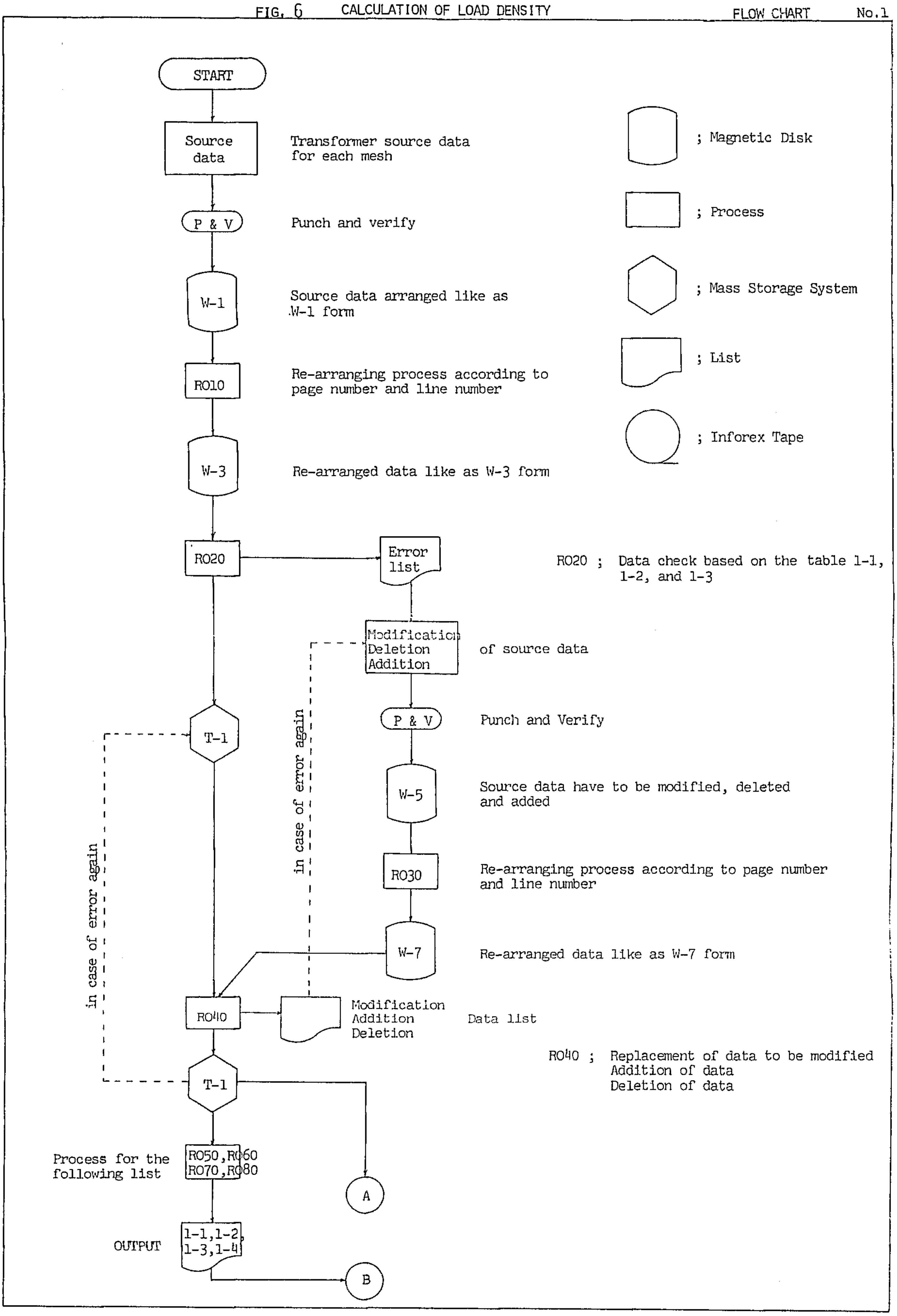


FIG. 6 CALCULATION OF LOAD DENSITY FLOW CHART No.2

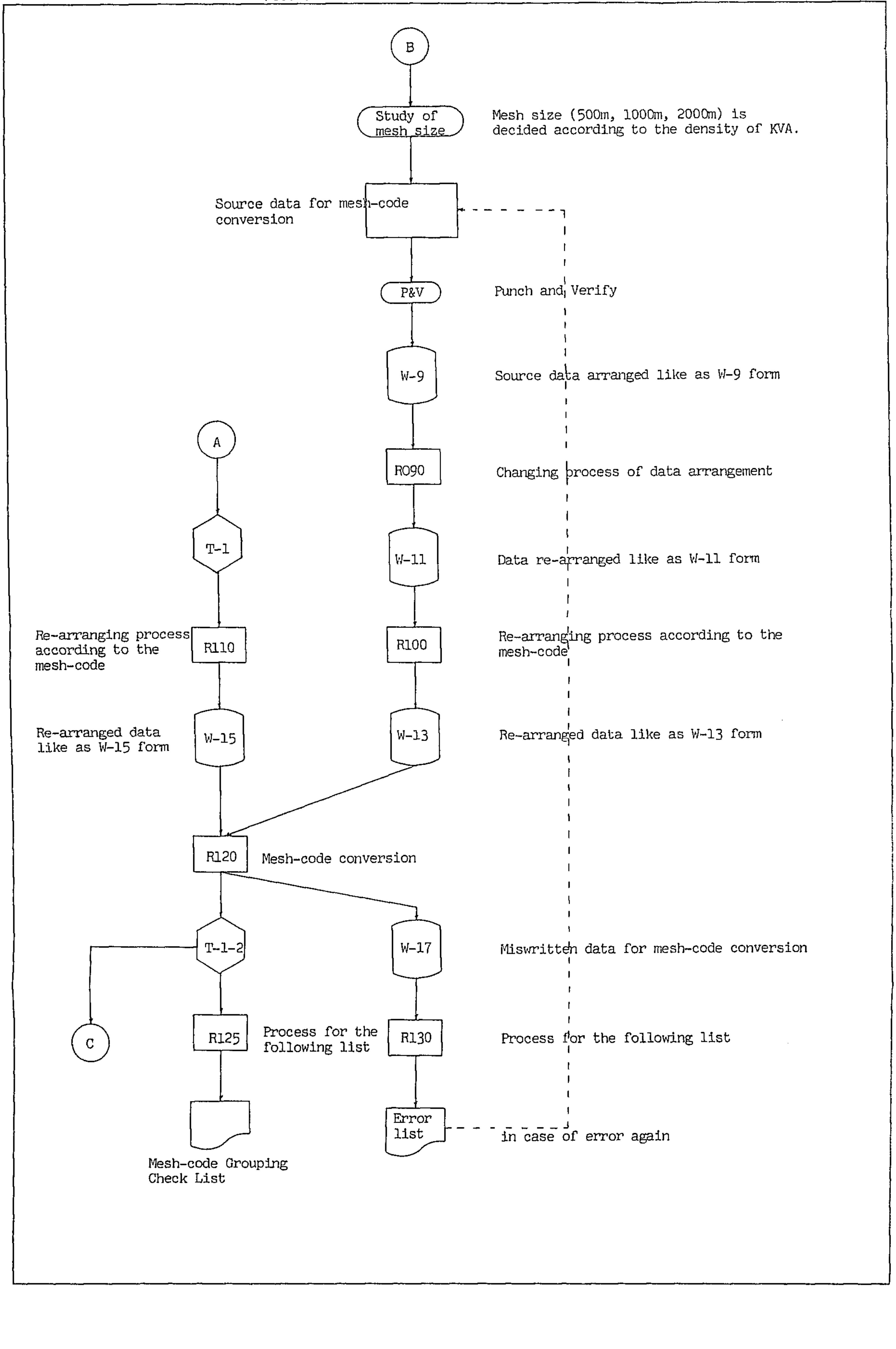


FIG. 6 CALCULATION OF LOAD DENSITY

FLOW CHART No.3

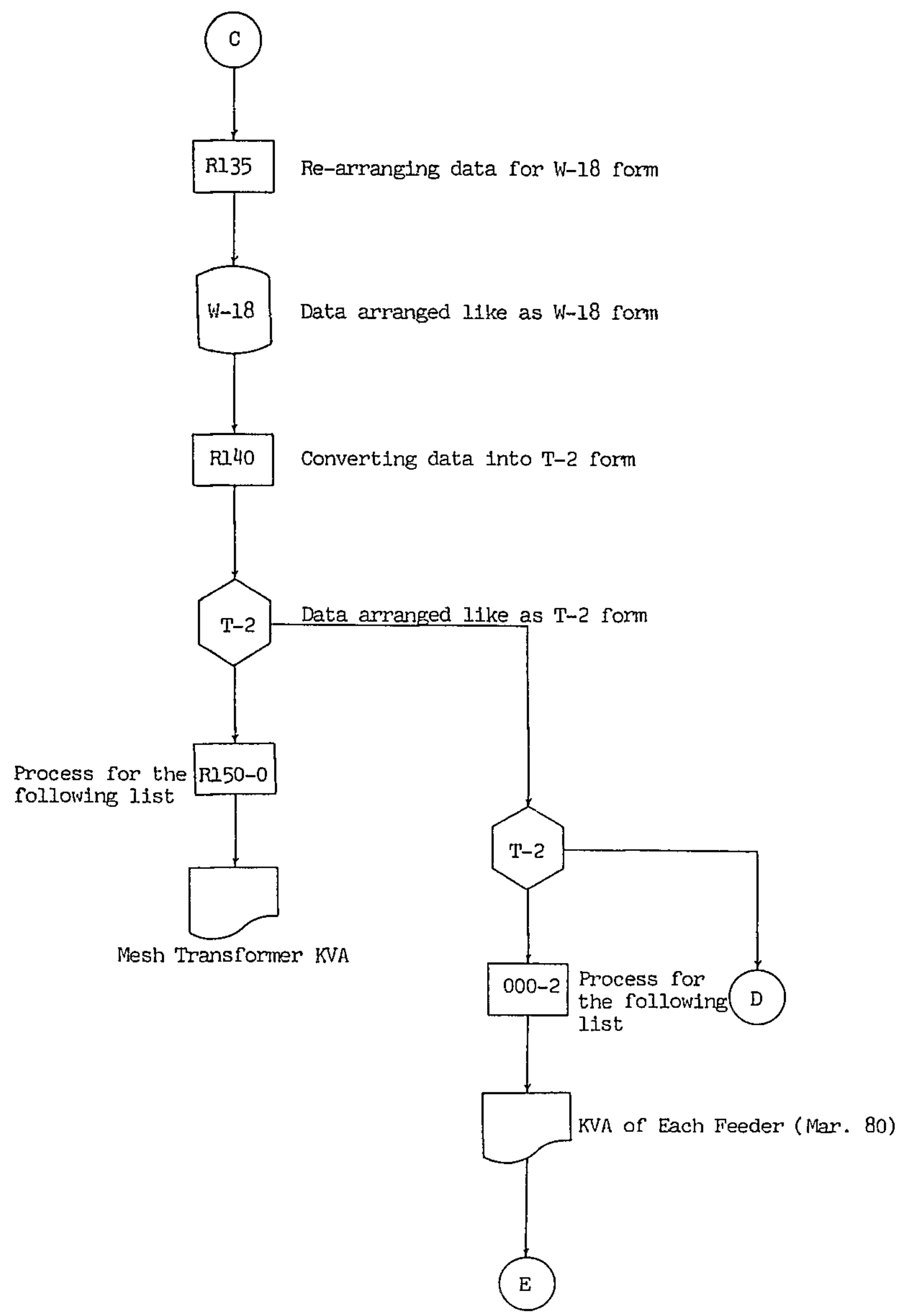


FIG. 6 CALCULATION OF LOAD DENSITY FLOW CHART No. 4

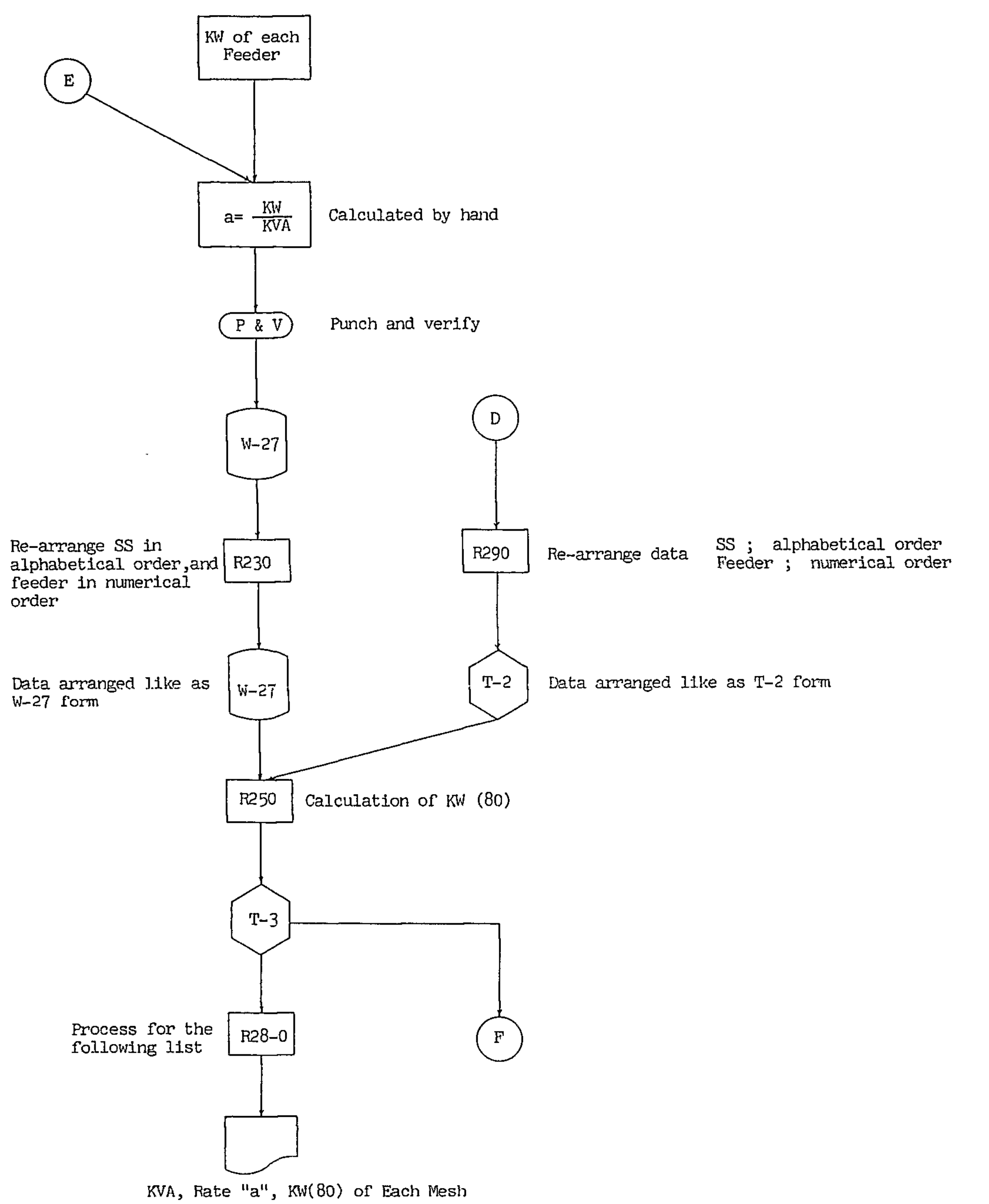
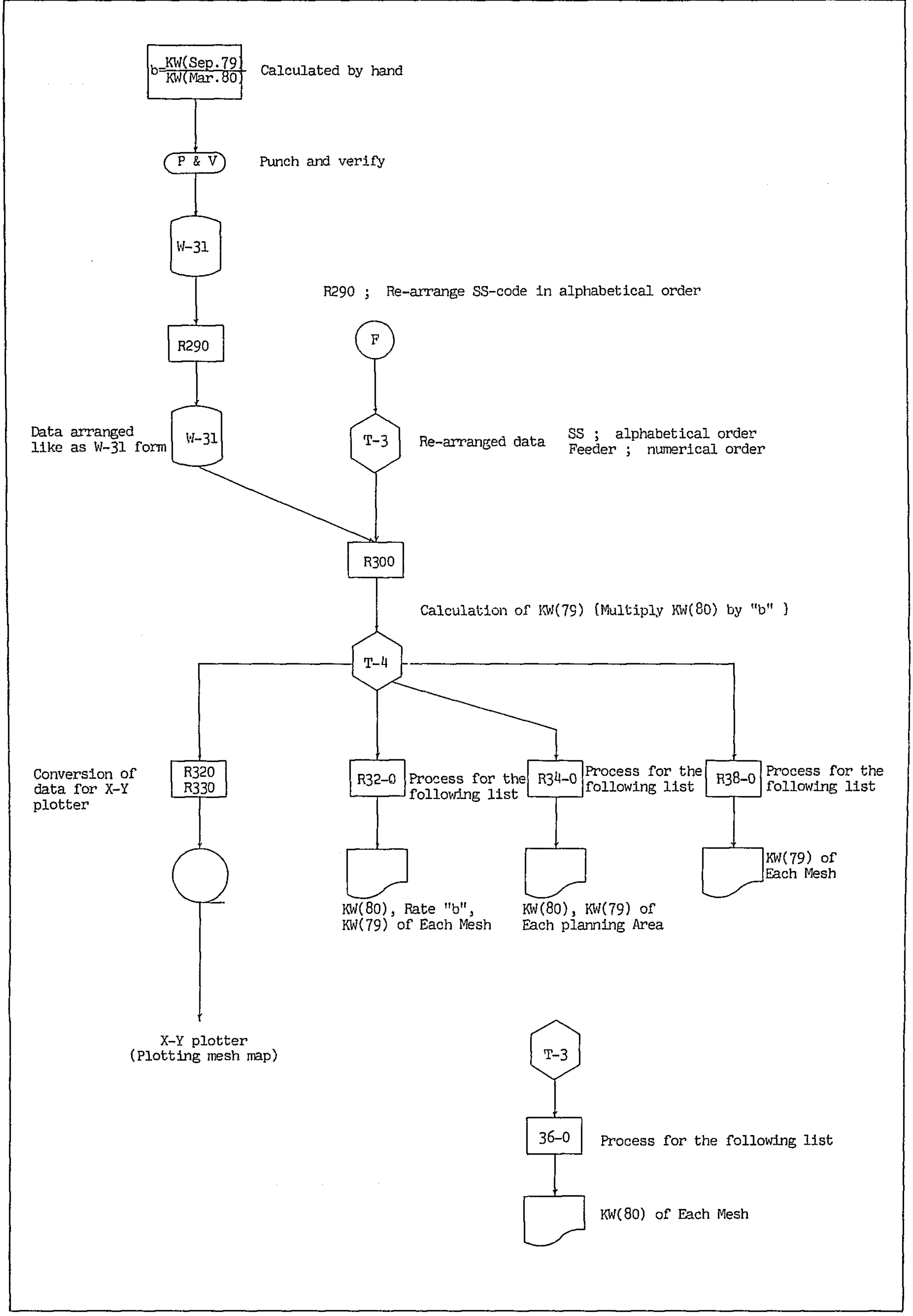


FIG. 6 CALCULATION OF LOAD DENSITY FLOW CHART No. 5



Load Density of 1 x 1 km Mesh, Sept. 1979

Load Density kW/km²	Number of Meshes	Share (%)
5,000 minimum	49	2.9
1,000 – 5,000	229	13.6
500 – 1,000	598	35.6
less than 500	803	47.8
Total	1,679	100.0

Low load-density meshes (less than 500 kW/km²) made up approximately one half (47.8%) of the entire area, with high load-density meshes (5,000 kW/km² and more) amounting to only 49 meshes, or 2.9%. Practically all of these high load-density meshes are concentrated in limited areas of the city.

Full figure of Load Density Map is attached in Appendix 16. We further subdivided the high load-density meshes into smaller meshes of 0.5 km x 0.5 km to make possible detailed analyses (Appendix 17). As for low load density meshes in the suburbs, those were combined into large meshes of 2 km x 2 km, thereby aiming for improved efficiency in subsequent analysis and planning operations. The profiles of load density along the XX and YY axes are shown in Fig. 7 and Fig. 8.

4. Load Curve

(Existing situation)

The transition in daily load curves in recent years is shown in Fig. 9, and that of load factors and Min-Max ratios are shown in Fig. 10.

(Results of analysis)

On looking at load curves, a sharp rise in mid-summer, February – May, on the annual load curve (trend of monthly maximum) is prominent. This is thought to clearly indicate the growth in use of air conditioners. In the past, it had been normal for the maximum load to be seen in September of the fiscal year – October through September, but it is thought there will be a change in the future with the peak appearing in May – June.

Regarding the daily load curve, there is a change going on from the evening peak type to daytime peak type. This is surmised to be due to air-conditioning load and factory motive power load coinciding at around 2 to 3 p.m. to constitute the daily peak. In Japan, also, a change occurred to a daytime peak type during the period of high economic growth after the World War II.

Consequently, the annual peak will appear during the daytime in mid-summer, and attention must be paid to the fact that the condition will be severe with respect to temperature rise for outdoor facilities and distribution transformers.

Fig. 7 Profile of Load Density

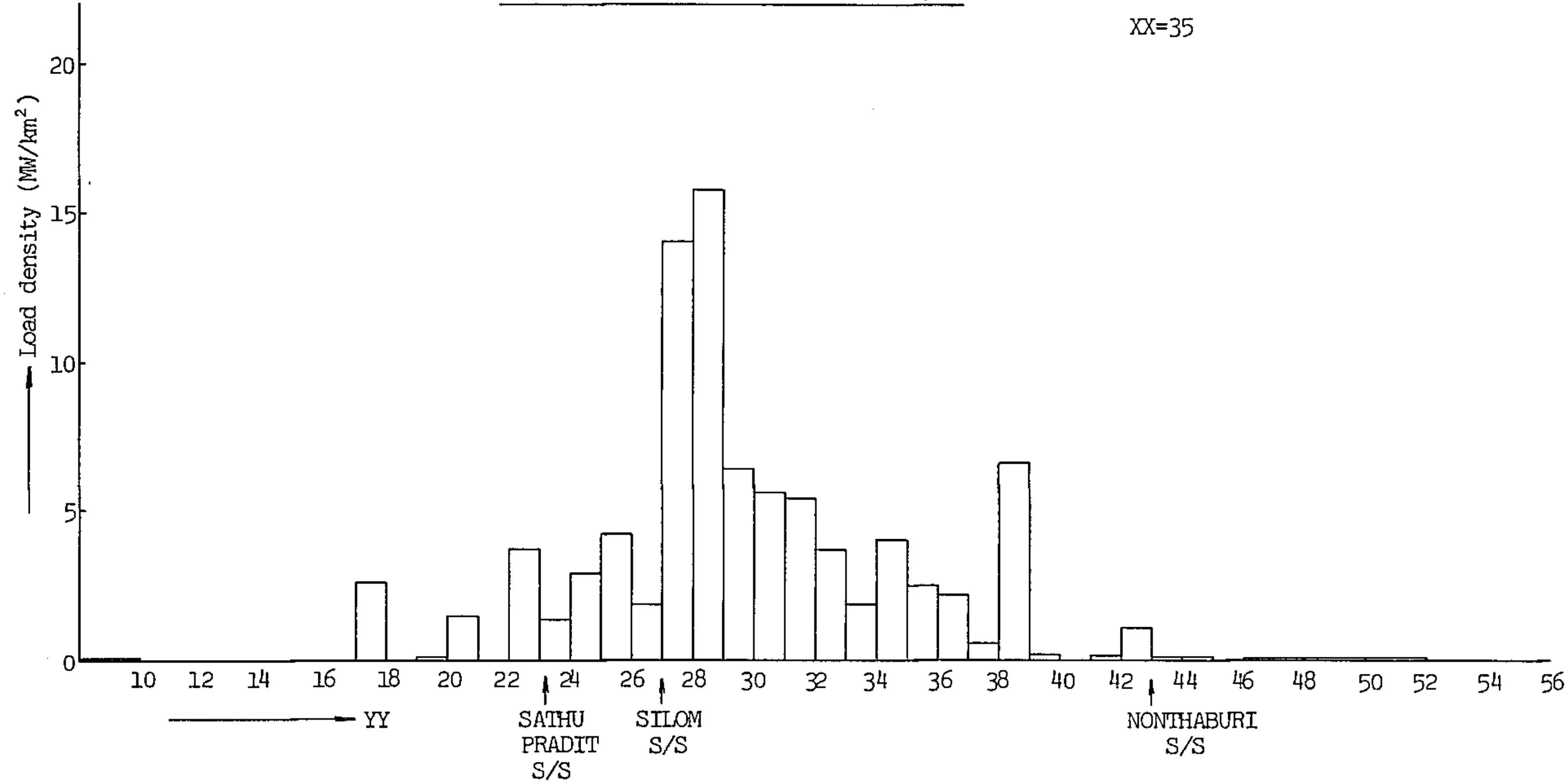


Fig. 8 Profile of Load Density

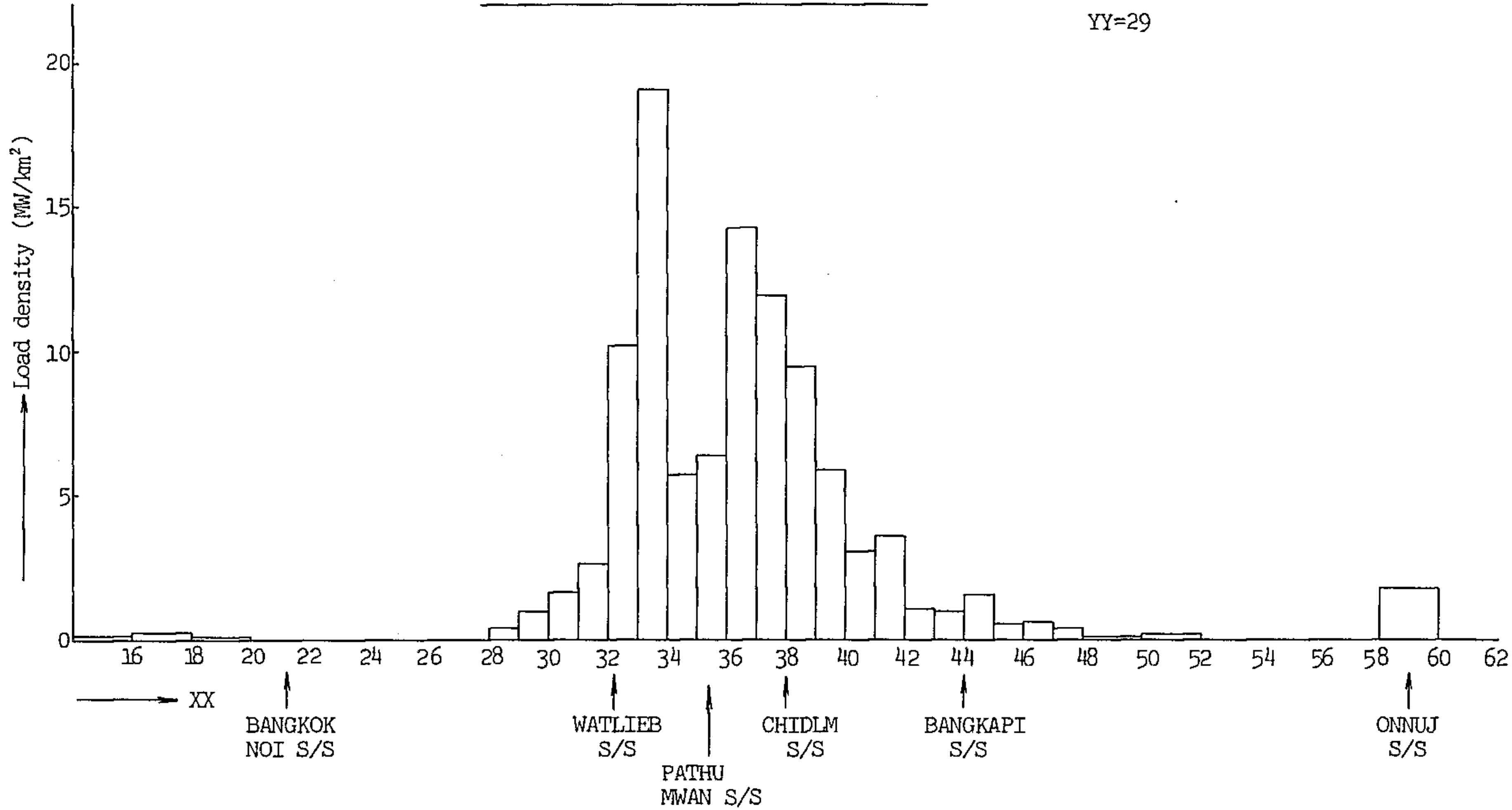


Fig. 9 Daily Load Curve in Peak Day of Each Year

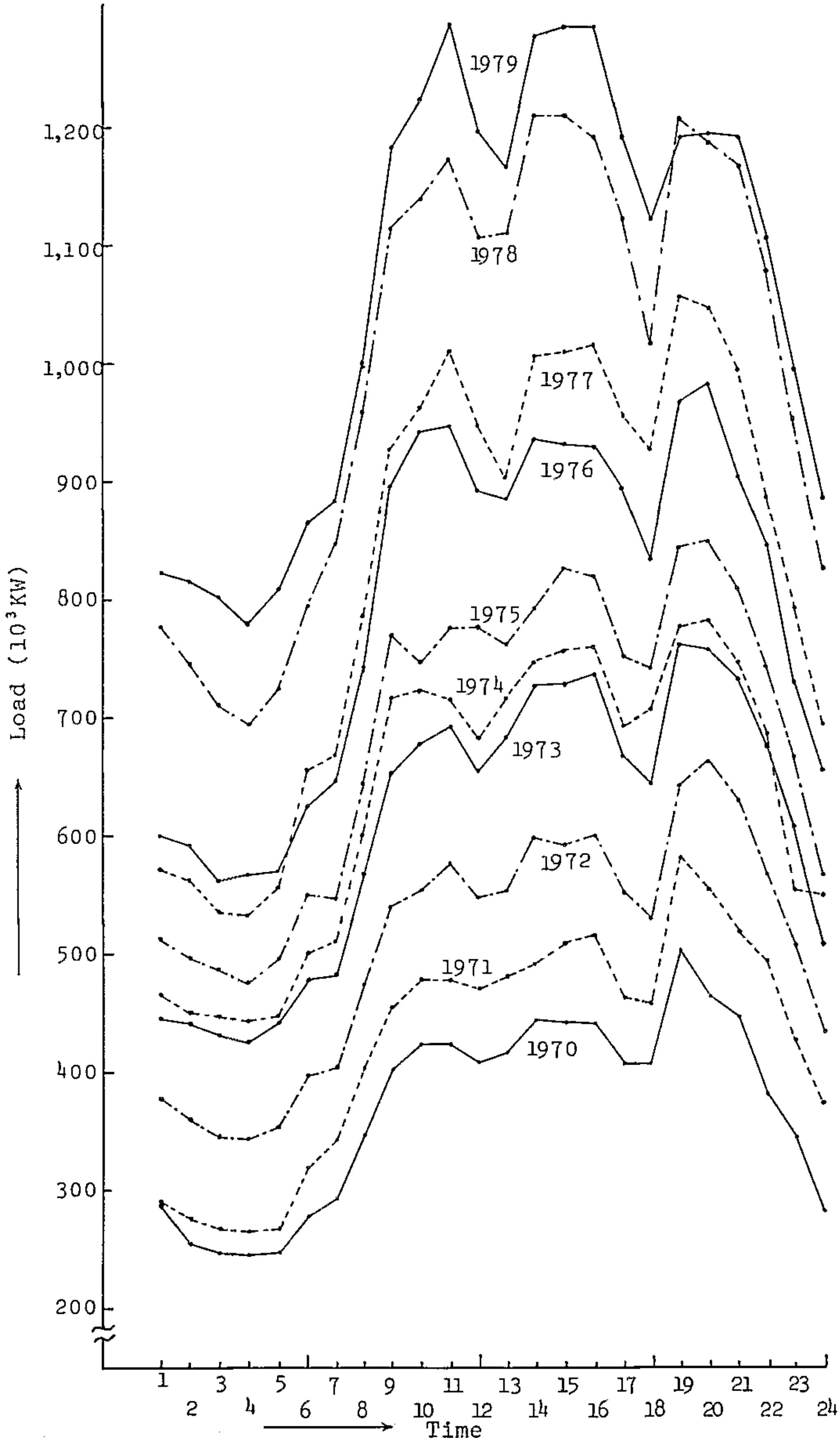
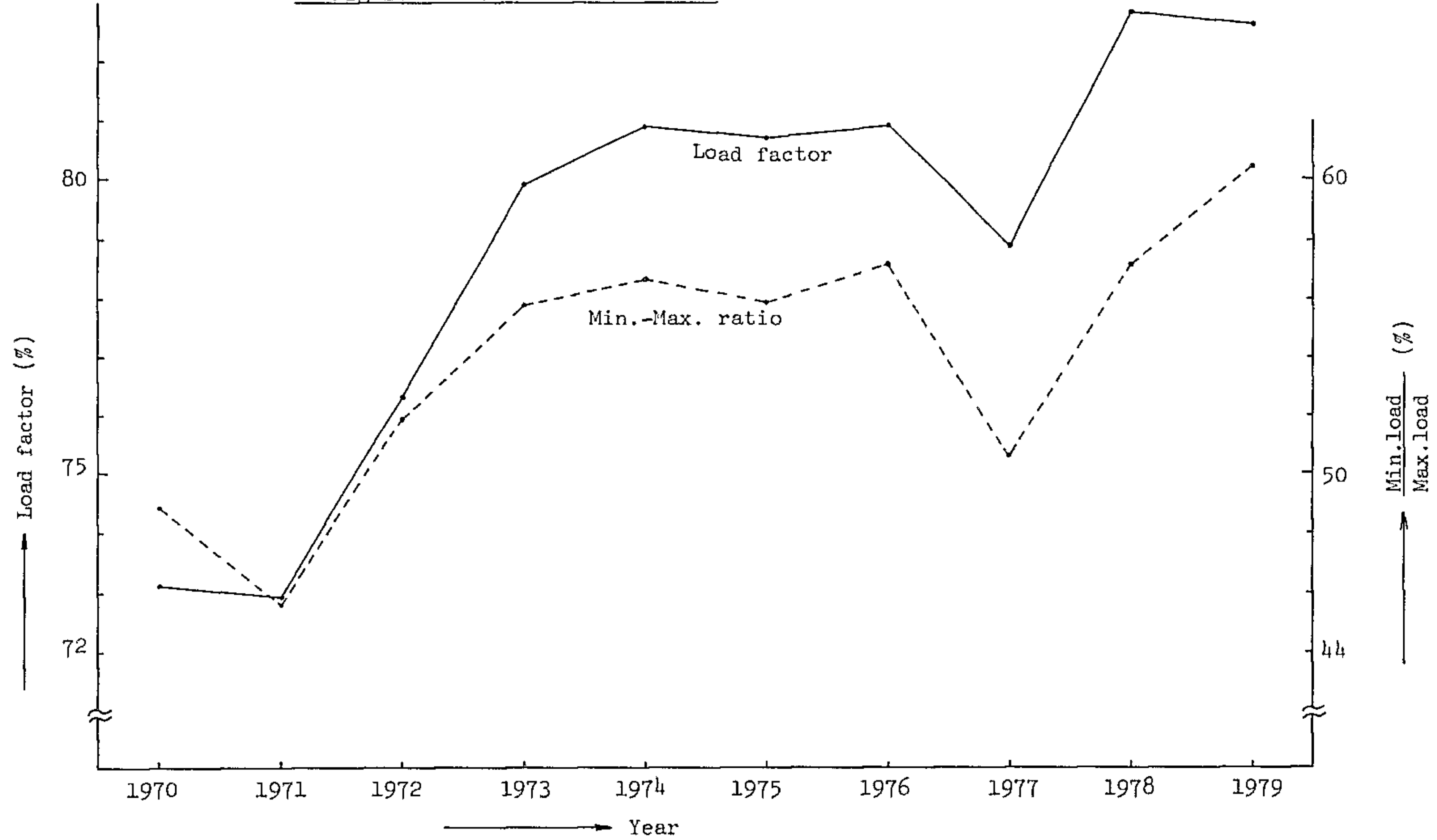


Fig.10 Load Characteristics



5. Supply Categories and Supply Voltages

(Existing situation)

(1) Supply categories

The electricity rate system of the MEA was revised in February 1980 and supply to customers is presently being done according to the categories below:

a. Residential
b. Small business
c. Large business
d. Small industrial
e. Large industrial
f. Large industrial OFF-ON peak
g. Stand-by

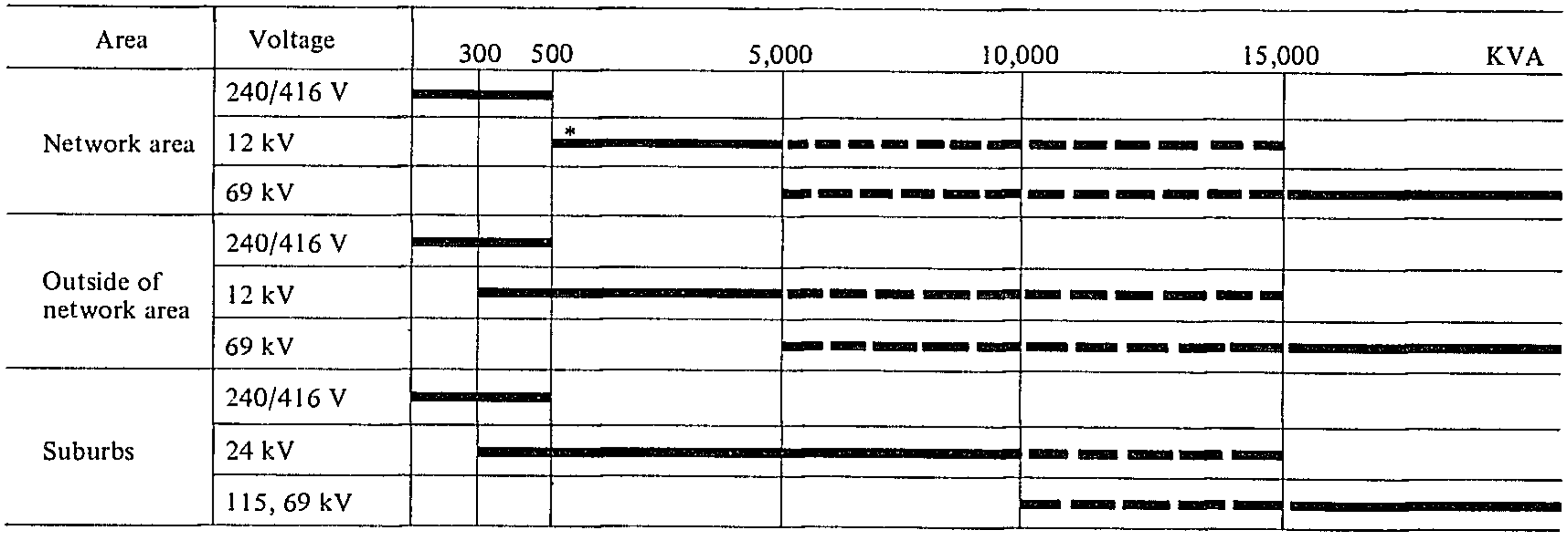
(2) Supply voltages

According to the electricity rate system of the MEA, customers are supplied in the following voltages:

Category	Range of Contract kW	Supply Voltage
Residential		240 V/416 V
Small business	less than 30 kW	240 V/416 V
Large business	more than 30 kW	240 V/416 V, 12 kV, 24 kV, 69 kV, 115 kV
Small industrial	30 kW ~ 499 kW	240 V/416 V, 12 kV, 24 kV
Large industiral	more than 500 kW	12 kV, 24 kV, 69 kV, 115 kV

Supply voltage for customers of large business, small industrial and large industrial categories are decided case by case, but usually it depends on a rule shown in Table 5.

Table 5 Contracted Demand and Supply Voltage



Note : The broken line portions can be 12, 24 kV or 69, 115 kV with either adopted depending on the location.
: *Meter is installed at the low voltage side.

(Results of analysis)
As shown in the above table, customers of five main categories can be supplied by 240V/416V – even if the contract kW is large. If a customer wants to contract 300 kW at 240V/416V – the MEA must prepare space for installation of stepdown transformer.

Especially in the network area, the MEA is supplying at 240V/416V to large business customers with contracts of 500 kW or about, and installation space of distribution transformer becomes a serious problem of the MEA. (SEE III-6) To solve such problem, it is advised that the MEA study revision of tariff system, especially concerning the limitation of supply at 240V/416V.

6. Power factor charge

(Existing situation)
A power factor charge is stipulated in the electricity rate system for only the customers in the categories below.

a. Large business
b. Small industrial
c. Large industrial
d. Large industrial OFF-ON peak

For lagging power factor customers, in any monthly billing period during which customer's maximum 15-minute kilovar demand is in excess of 63% of his maximum 15-minute kilowatt demand, a monthly power factor charge of Baht 7.00 for each kilovar in excess of said percentage (determined to the nearest whole kilovar) will be made.

(Results of analysis)
As shown in Appendix 2, MEA's power factor charge is only penalty charge, and there would be no incentive for customer to make efforts on his part to improve the power factor.

In the MEA, large numbers of condensers are installed on primary distribution lines or at substations. If power factor is improved at the low-voltage side, the effect will be propagated to the power supply source and the benefits of energy conservation through improvement in the loss rate and of full utilization of installed capacity will be substantial. Consequently, although it is necessary to install condensers for supplying reactive power to improve the power factor, considerations are needed policy-wise to encourage the customer to install static condensers of his own initiative.

In this sense, appropriateness of the power factor charge must be examined from the aspect of the electricity rate system.

III-3 Composition of power system

1. Outline of facility

(Existing condition)
As of September 1979, the MEA was receiving electric power from EGAT at 69 kV or 115 kV from 8 terminal stations, and using its own transmission system, the MEA distributes the power to 44 of its distribution substations and 26 customer owned substations. Such situation is shown in Fig. 11 and Fig. 12.

From those distribution substations, power is distributed by highvoltage distribution lines of 12kV or 24 kV, three-phase three-wire system, and after stepdown by distribution transformers, electricity is supplied to low-voltage customers. The low-voltage system consists of 240V/416V, three-phase four-wire system, and particularly, an area of approximately 8 km^2 inside Bangkok is supplied by a secondary network distribution system. The frequency is 50 Hz throughout the entire system.

Total amount of the facilities in the MEA are as shown in Table 6, and the standards of the principal facilities of the MEA are as shown in Table 7, there being good standarisation, and the standards are effectively realized in existing facilities.

A distribution substation has 2 banks of main transformers and 4 to 5 feeders per bank. The total capacity of main transformers and total capacity of feeders are in good co-ordination.

And by using bundled conductors for transmission lines near terminal stations, it is possible to supply two or more distribution substations.

(Results of analysis)

The MEA's standards are established in good co-ordination with the capacity of all facilities. But a fundamental problem is that, if these standrds are applied uniformly throughout the future, the quantity of facilities of the MEA will become enormous.

An analysis was made of the existing condition of each field of facility, and the results of analysis are described in the following paragraphs.

FIG.11 230KV OUTER RING AND TERMINAL SUBSTATION

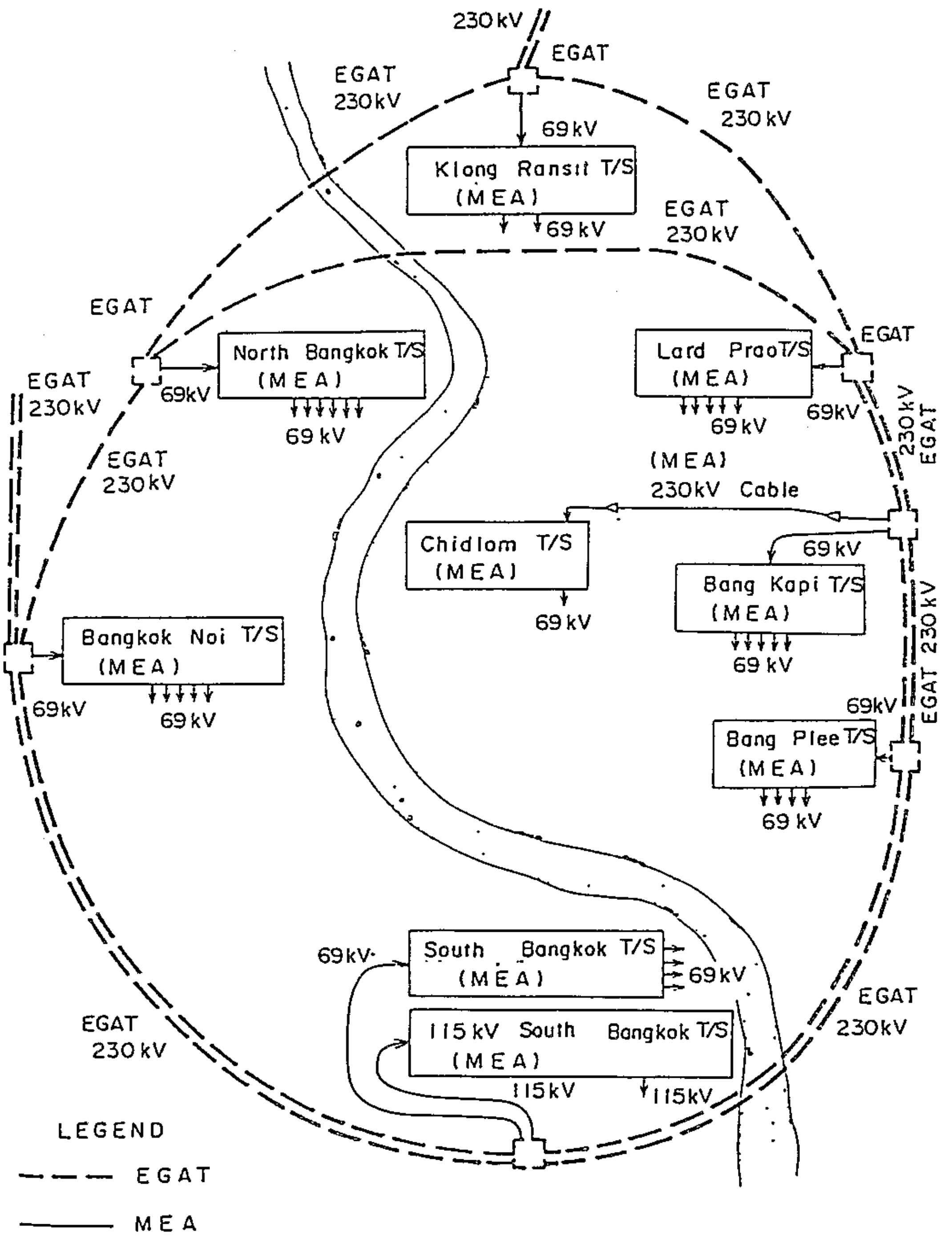


FIG.12 NORMAL PATTERN OF MEA'S POWER SYSTEM

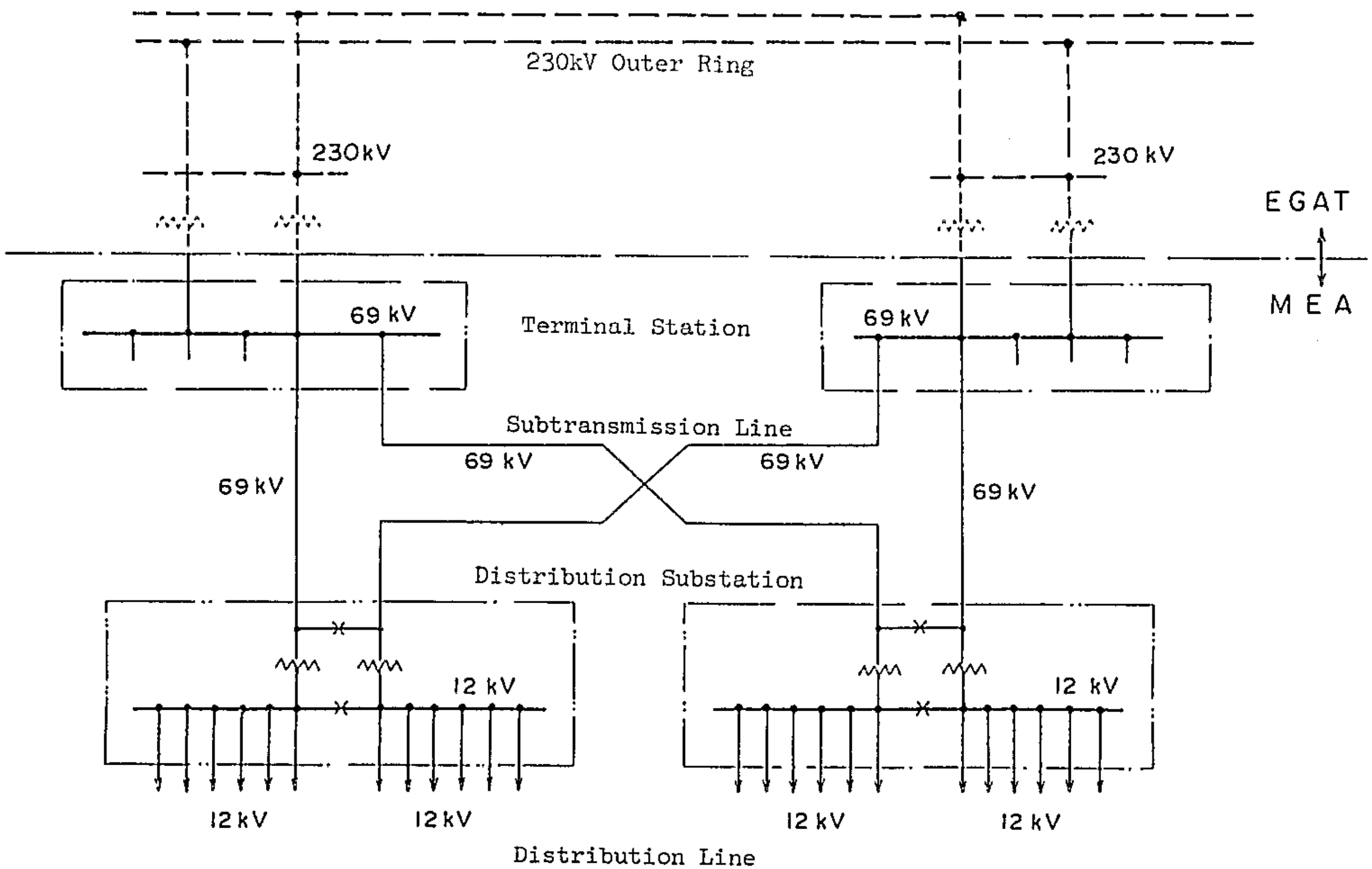


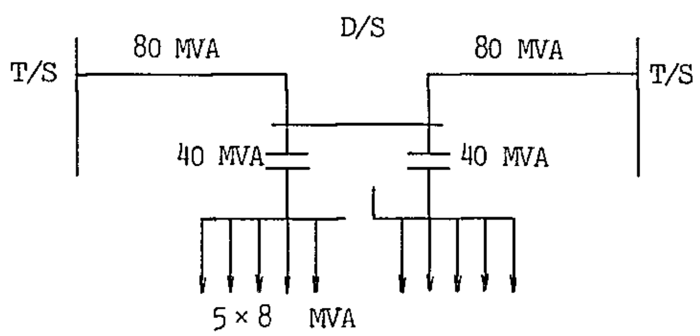
Table 6 Power System Facility of the MEA

Sep. 1979

Substation		
Distribution substation	44 Places	2,645 MVA
Customer's substation	26 〃	407 〃
Total	70 〃	3,052 〃
69/115 kV Transmission Line		
Overhead		
Bundle conductor		237 Circuit KM
Single conductor		207 〃
Underground cable		11 〃
Total		455 〃
12/24 kV Feeder	283 Feeders	4,158 Circuit KM
Distribution Transformer		
MEA owned	about 27,000 Sets	1,800 MVA
Customer owned		1,400 〃
Total		3,200 〃

Table 7 Facility Standard of MEA

Substation		
1 × Transformer	OA 30/FA 40 MVA	40 MVA
2 × "	"	80 MVA
69 KV Transmission Line		
Single Conductor	1 × AAC 795 MCM	80 MVA (800A)
Bundle "	2 × "	160 MVA (1600A)
12 KV Distribution Line		
Underground Cable	1 × Cu 325 mm^2	10 MVA (500A)
	4 × "	40 MVA
Underground Cable	1 × Cu 500 MCM	8 MVA (400A)
	5 × "	40 MVA
Overhead Trunk Line	AA 336.4 MCM	8 MVA (400A)



T/S : Terminal Substation

D/S : Distribution Substation

2. System composition

(Existing condition)

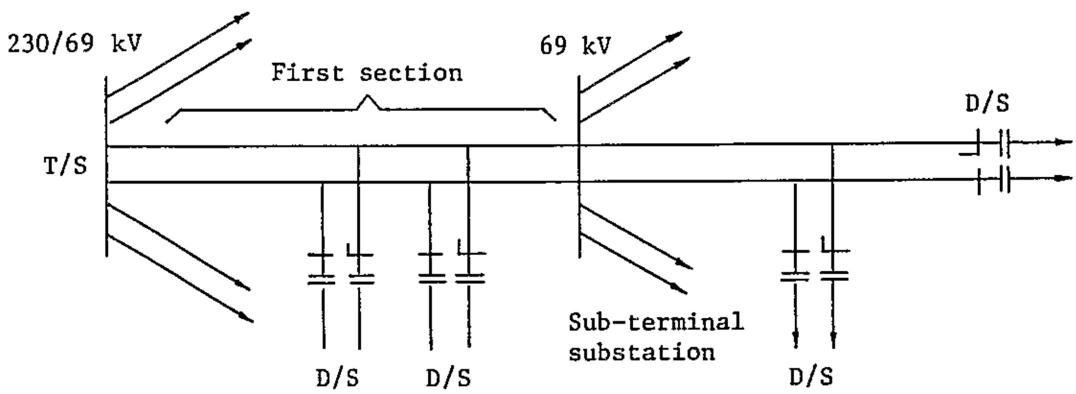
The 230 kV outer loop system of EGAT surrounds Bangkok, and the MEA is receiving power at 8 terminal stations along this outer loop, and from those terminal stations power is transmitted to the MEA owned distribution substations and costomer owned substations. Fig. 13 shows location of main facilities of the MEA.

Each of the MEA distribution substation has a system composition of interlinked loop type. Therefore it can be supplied from two terminal stations by different routes. (Fig. 14)

(Results of analysis)

(1) The existing system composition is comparatively simple, but with the increase in the number of distribution substations and customer owned substations, the system composition will become complex in the future. At that time the situation will become critical because of shortage of capacity of circuit breakers and difficulty to acquire right-of-way of transmission routes.

(2) Parallel two-circuit composition of transmission line is to be adopted at the section between 230/69 kV terminal substation and 69 kV subterminal substation (first section) taking power system reliability into consideration.



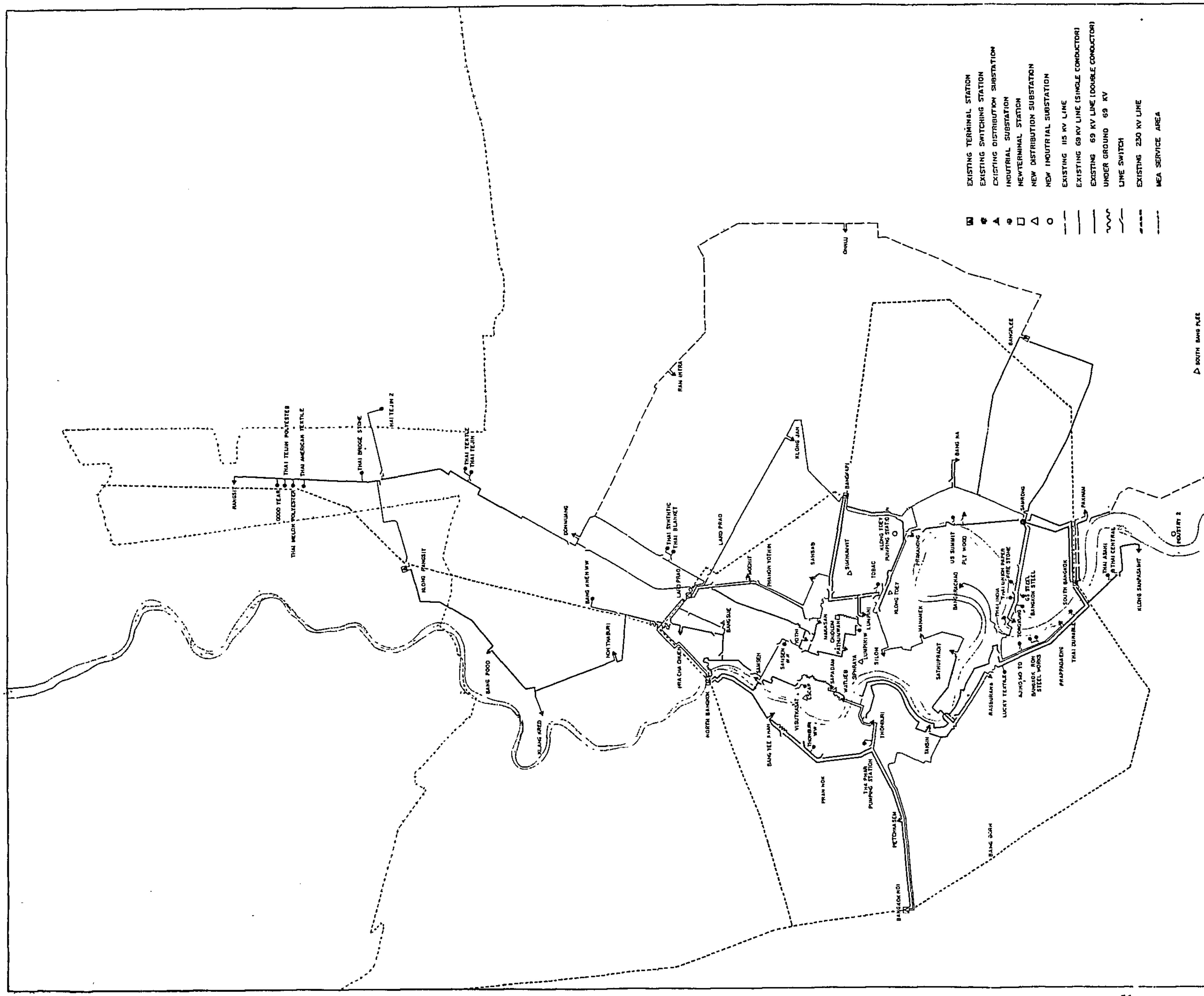
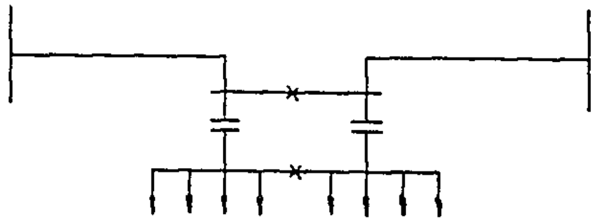


FIG. 13

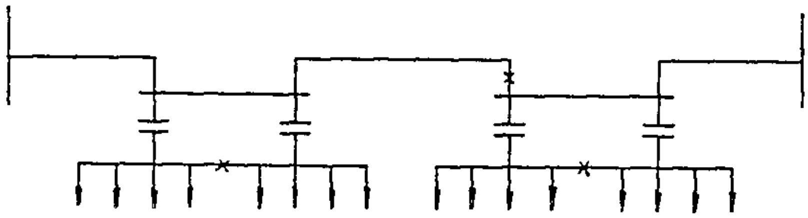
ROUTE DIAGRAM 69KV-115KV (1979)

Fig. 14 Existing System Pattern

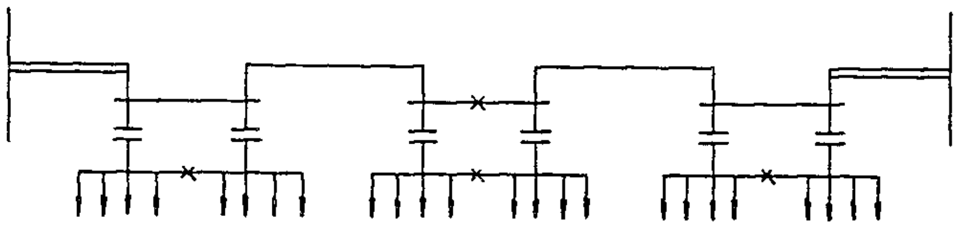
Pattern (A)



Pattern (B)



Pattern (C)



Note: T/S ..... Terminal station

D/S ..... Distribution substation

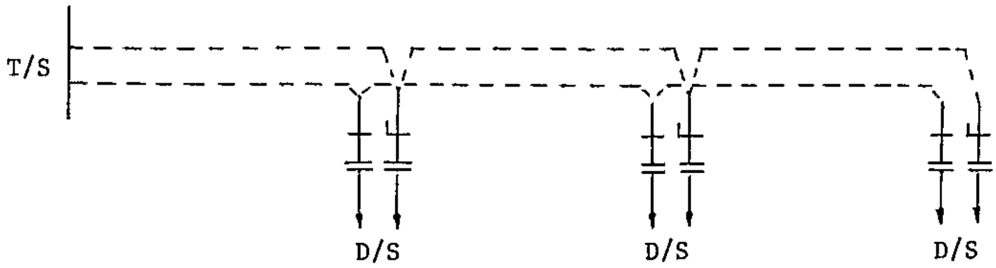
╪ ..... Transformer

x ..... Disconnecting switch

↓ ..... Distribution feeder

Double line shows bundled conductor of subtransmission line.

(3) Unit power receiving system shown below is to be employed for the underground cable system. (Broken line is underground cable)



3. System voltage

(Existing condition)

System voltage of existing power system is classified as follows:

230 kV (EGAT) — 115 kV · 24 kV / 69 kV · 12 kV — 3ϕ 4W 240V/416V

At present 115 kV and 24 kV are used in remote area, and 69 kV and 12 kV are used in city area. The ultimate distribution voltage of 3-phase, 4-wire 240V/416V is the standard in all areas, but at present four different systems are actually used, these are:

1ϕ 2W 240V
1ϕ 3W 240V/480V
3ϕ 3W 240V or 480V
3ϕ 4W 240V/416V

(Results of analysis)

(1) Transmission system voltage

In the existing 115 kV and 69 kV systems there are no problems in respect of power flow and voltage in each line and in each bus bar. However, if future loads are considered, then the system voltage must be studied. According to the MEA's load forecast, in the next 20 years the present load will grow by 4 times. In order to transmit power to supply this anticiapted load, new transmission lines will be required, and the selection of transmission voltage will be a critical point in reliable and stable supply of power.

In considering futrue transmission line schemes, it must be borne in mind that all lines into the central part Bangkok city will have to be underground lines. Underground lines which include considerable amount of civil works are costly. Therefore, where possible overhead lines should be planned, but inside Bangkok city where rapid development is taking place it appears to be virtually difficult to construct overhead lines, and the only alternative is underground cables

An important factor is to raise the investment efficiency of under ground lines, and in this respect it is beneficial to consider a large transmission capacity per line. That is to say, the higher the transmission voltage would be better. In the periphery of Bangkok city limits EGAT has a 230 kV transmission line system. In the light of the above consideration, it would be an effective approach to expand and reinforce 230 kV system into the city center.

When bulk power is transmitted into the city at high voltage, it will be appropriate to use 69 kV as the secondary line to supply power to distribution substations located in each district. Also, when 230 kV system into the city is expanded, the transmission distance of existing 69 kV lines will be reduced, creating a margin in the capacity of those lines. And through the coordinated operation with new 69 kV lines, it will be possible to form an effective distribution system.

At the present, the MEA's transmission voltages are 230 kV, 115 kV and 69 kV. When 230 kV lines are constructed in the city, it is considered that 69 kV is appropriate for secondary transmission voltage, and there is no need to step-up 69 kV to 115 kV in order to unify secondary system voltage.

The 115 kV lines used to serve very light load density areas in the suburbs, should be used at the present voltage because of the need to transmit power a long distance.

The foregoing is a summarized presentation of the results of analysis. The voltage to be adopted for transmission lines and substations to be built in the future should be determined in accordance with the conditions of each district based on load forecasts which would be an integral part of the exercises to be performed in preparing the master plan.

(2) Primary distribution system voltage

In the remote area, 24 kV is used as primary distribution system voltage. Length of distribution feeders becomes very long because the load density in such area is very small. The problem is not the current capacity of conductors but line voltage drop. Small size conductors on higher voltage are more economical than large size conductors on lower voltage. In view of such consideration, 24 kV is adequate system voltage of distribution line in the remote area. Fig. 15 shows the area supplied by 24 kV.

In the city area, 12 kV is used as primary distribution system voltage. Length of distribution feeders is short because of the high load density, and problems are supply capacity and reliability of the system.

Step up to 24 kV is indeed a measure to increase the supply capacity, but the investment becomes bigger than the 12 kV system.

In a study report in Japan concerning the economic evaluation of distribution system voltage, it is concluded that, the economic justification of adoption of 20 kV class system voltage is applicable under the condition that load density of service area is more than 100 MW per km^2.

The averaged value of load density of 37 km^2 in the center of Bangkok city is less than 8 MW at present. From this point of view, we assume that it is not economical to change the entire 12 kV system into 24 kV system. In the long future, some limited area may reach to a very high density, and to supply spot loads, 24 kV can be considered in the center area of Bangkok city.

Another problem is the existence of different system voltages. Distribution feeders on different voltage are impossible to be interlinked. Distribution feeders must be interlinked among the feeders on the same voltage. And the interlinking between 12 kV system and 24 kV system must be studied case by case including installation of interlinking transformer. Such cases are assumed to be very rare.

(3) Secondary distribution system voltage

The MEA standardized the secondary distribution system voltage at 3-phase, 4-wire 240V/416V. But actually there are four different kinds of system voltage still in use. The MEA is promoting to unify the voltage to 3-phase, 4-wire 240V/416V.

Early completion of the unification is desirable.

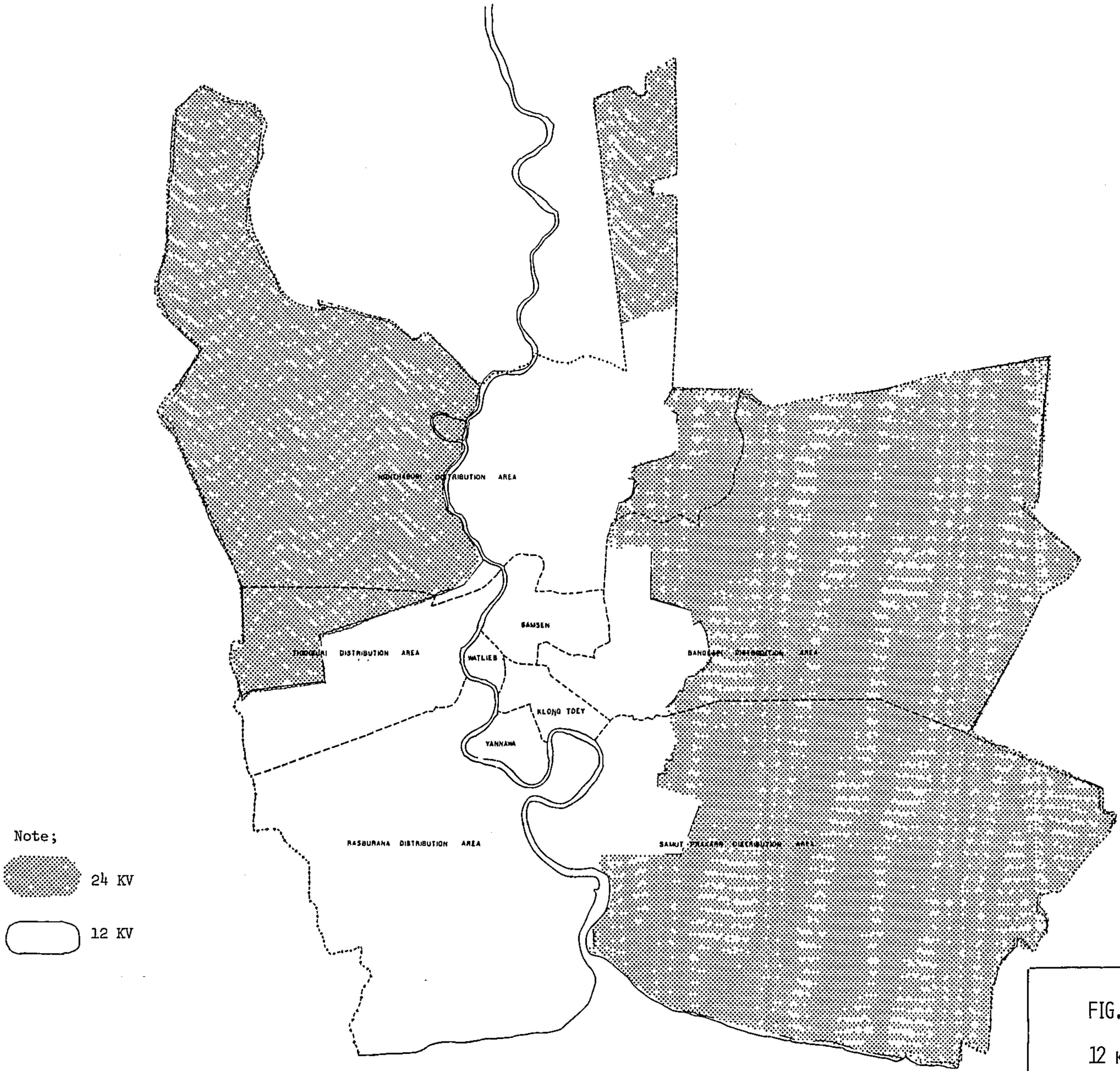


FIG. 15

12 KV-24 KV SERVICE AREA MAP

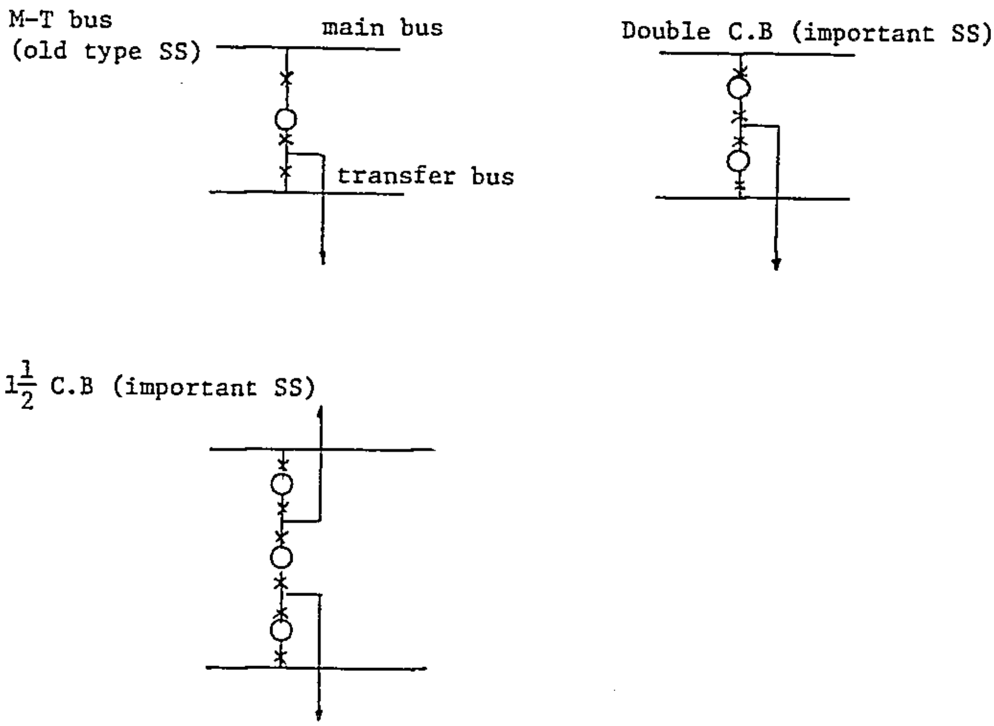
III-4 Substation facilities

1. Terminal stations

(Existing condition)

Existing bus systems of terminal stations are shown in Fig. 16, below.

Fig. 16 Existing bus composition for terminal station



The bus systems adopted for terminal stations are M-T bus (main & transfer bus) system, double CB system and 1½ CB system.

(Results of analysis)

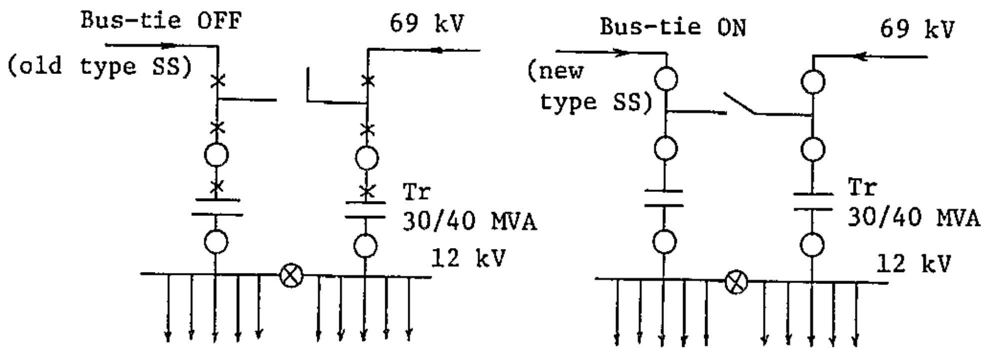
It is not necessary under present conditions for countermeasures to be taken immediately, but a study will be needed for adopting in future plans a bus system which will be economical and of high reliability as well.

2. Distribution substation

(Existing condition)

(1) Standard connection of distribution substation is shown in Fig. 17

Fig. 17 Existing bus composition for distribution substation



(2) Layout and connection of distribution substation are standardized in two types, outdoor type and indoor type. Typical sample of outdoor type is shown in Fig. 18 and Fig. 19. And of indoor type is shown in Fig. 20 and Fig. 21.

(Resutls of analysis)

(1) There is no problem in the existing bus system of distribution substation.
(2) Coordination of capacity of substation facilities are as follows:
   a. The interrupting capacities, except for Lumpini, have allowances of 2 to 3 times of the required interrupting capacity. The capacity ratio (ratio of required capacity to rating capacity) of Lumpini is 0.96 and slightly low, but it is thought this will not cause any trouble for practical purposes at present.
   b. Primary side current transformer of main transformer has a current capacity of 110% to 200% or more of main transformer's rated capacity and this is appropriate.
   c. Capacity of disconnecting switch on primary side of main transformer is 170% or higher than the main transformer rated capacity, but at 6 out of 12 substations, capacity of disconnecting switches for transmission lines become short of current capacity in case of single-circuit 2-bank supply, and some countermeasure will be required.
   d. Detailed data of above analysis is attached in Appendix 3.

(3) A survey of existing conditions of distribution substations was conducted in order to judge whether they can be extended or not. General information of surveyed substations are given in Appendix 4.

3. Geological features at substation site

According to field survey of distribution substations, there are locations where the effects of settlement of ground can be seen. Since the soil in Bangkok is soft clay down to about 25m from the ground surface at many places, adequate countermeasure will be necessary.

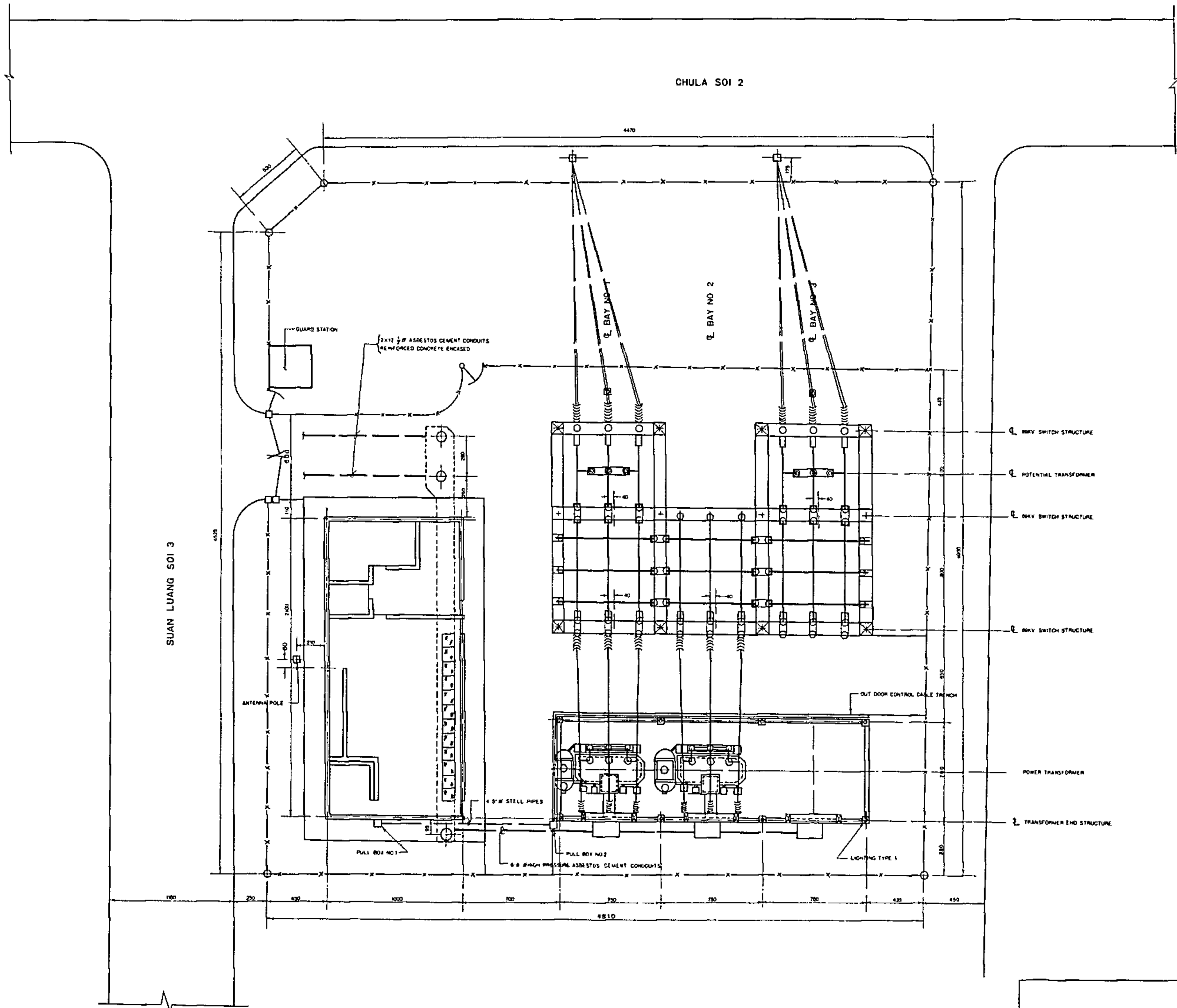


Fig. 18

LAYOUT OF OUTDOOR DISTRIBUTION SUBSTATION

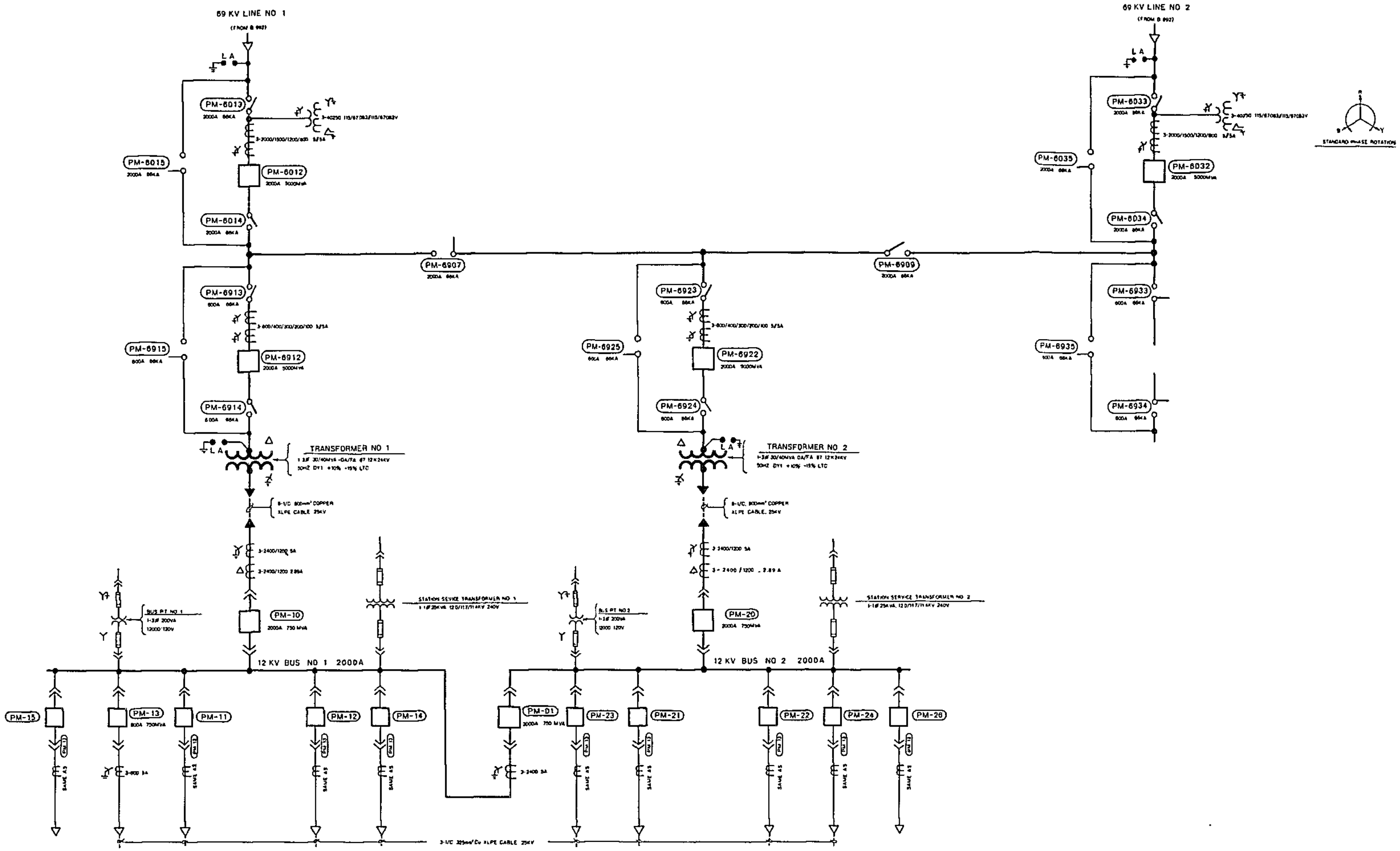


Fig. 19

CONNECTION OF OUTDOOR DISTRIBUTION SUBSTATION

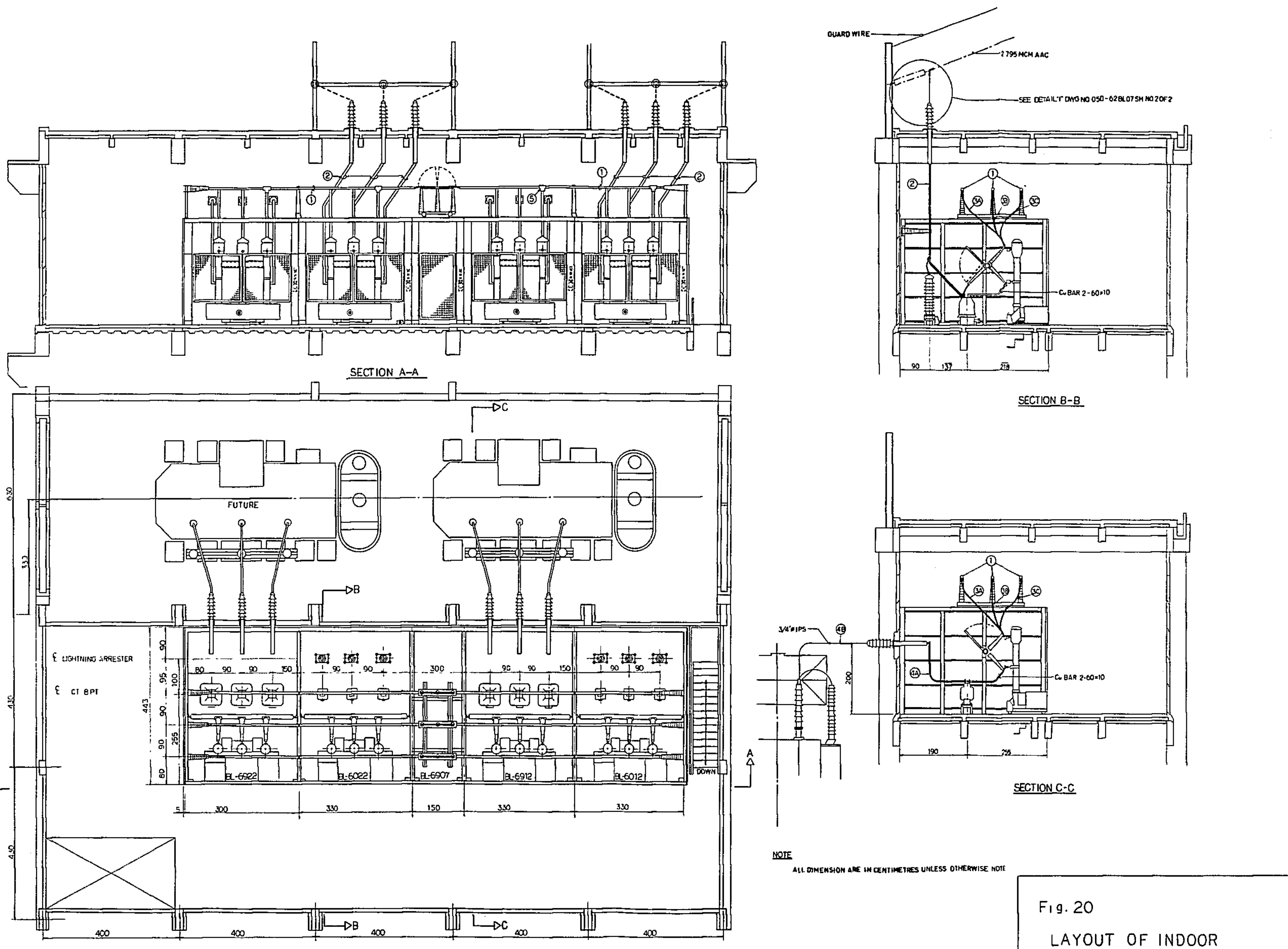
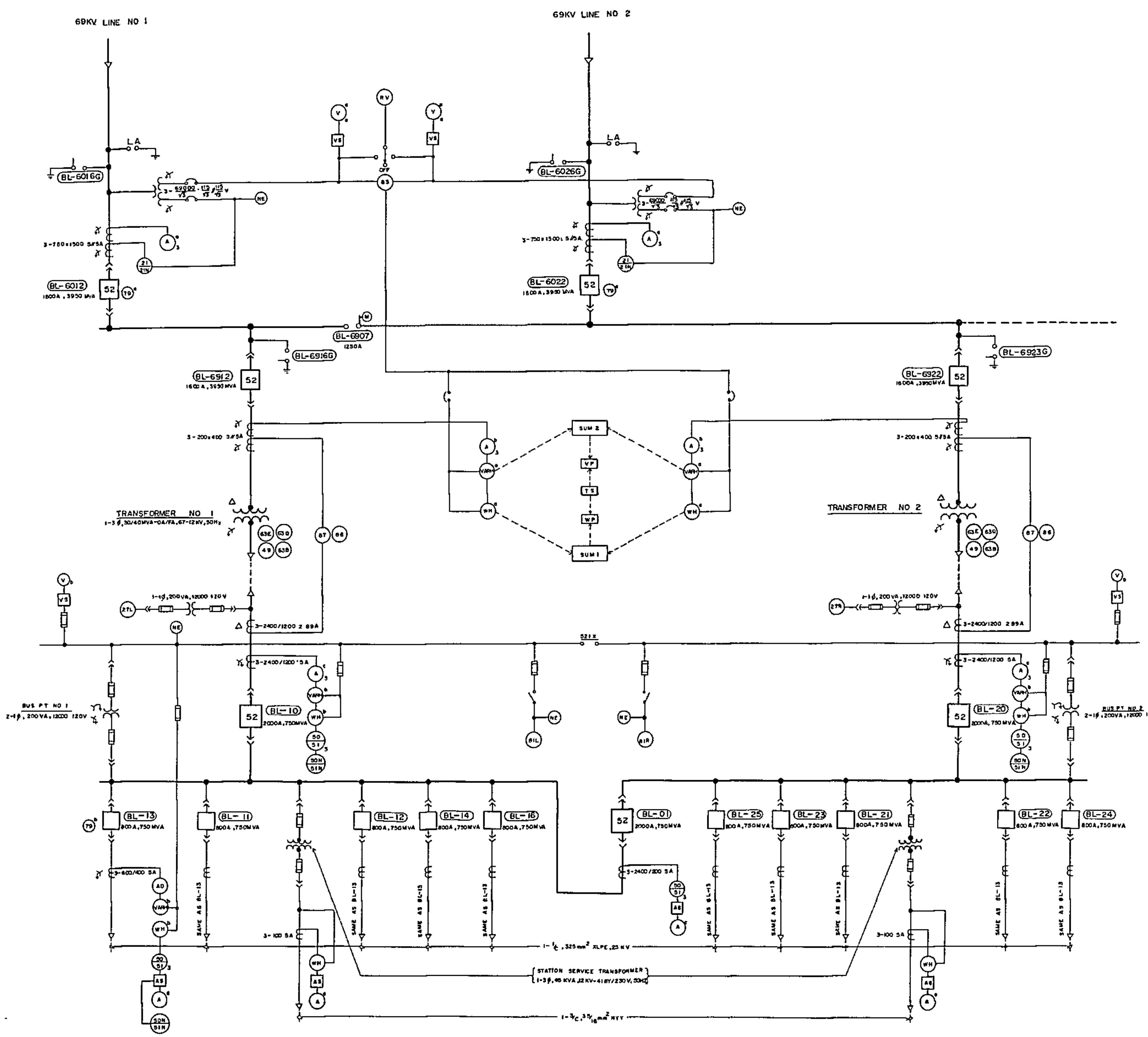


Fig. 20
LAYOUT OF INDOOR DISTRIBUTION SUBSTATION



SYMBOL	DESCRIPTION
21/21N	DISTANCE RELAY
49	THERMAL IMAGE RELAY
50/51	THREE PHASE OVERCURRENT RELAY
50N/51N	EARTH FAULT OVERCURRENT RELAY
52	CIRCUIT BREAKER
63B	BUCHHOLZ PROTECTIVE DEVICE, TAP CHANGER PROTECTIVE DEVICE
63E	EXPLOSION VENT WITH CONTACT
63Q	LIQUID LEVEL GAGE AND SWITCH
79 a	AUTO RECLOSE RELAY (SINGLE SHOT)
79 b	AUTO RECLOSE RELAY (GROUP SHOT)
81	UNDERFREQUENCY RELAY
83	VOLTAGE SELECTION RELAY
86	TRIP LOCK OUT RELAY (HAND RESET)
87	THREE POLE TRANSFORMER DIFFERENTIAL RELAY
A a	AMMETER 0-750/1500A
A b	AMMETER 0-200/400A
A c	AMMETER 0-1200/2400A
A d	AMMETER 0-300/600A
A e	AMMETER 0-100A
AS	AMMETER SELECTOR SWITCH
NE	NEON LAMP
RV	RECORDING VOLTMETER 0-80KV
SUM1	SUMMATOR FOR KILOWATT HOUR METER
SUM2	SUMMATOR FOR KILOVAR - HOUR METER
TS	TIME SWITCH
V b	VOLTMETER 0-15KV
VARH a	KILOVAR-HOUR METER
VARH b	KILOVAR-HOUR METER
VP	KILOVAR PRINTING DEMAND RECORDER
VS	VOLTMETER SELECTOR SWITCH
WH a	KILOWATT-HOUR METER
WH b	KILOWATT-HOUR METER
WH c	KILOWATT-HOUR METER
WP	KILOWATT PRINTING DEMAND RECORDER
V a	VOLTMETER 0-80KV
AD	MAXIMUM DEMAND AMMETER
27	UNDER VOLTAGE RELAY FOR BUS THROW OVER
(fuse symbol)	FUSE
(breaker symbol)	MINIATURE CIRCUIT BREAKER

Fig. 21

CONNECTION OF INDOOR DISTRIBUTION SUBSTATION

III-5 Power transmission facilities

1. Outline of facility

(Existing condition)

The features of the MEA transmission lines are as follows:

(1) 69 kV and 115 kV overhead transmission lines are installed normally using concrete poles as supports. They are installed also along main streets in the city area.

(2) On concrete poles for transmission lines, high- and low-voltage distribution lines and telephone lines are strung commonly.

(3) Size of conductor is normally AAC 795 MCM.

(4) Standards of pole assembly are shown in Fig. 22, Fig. 23 and Fig. 24.

(5) Air break switches are installed on the ple as shown in Fig. 25.

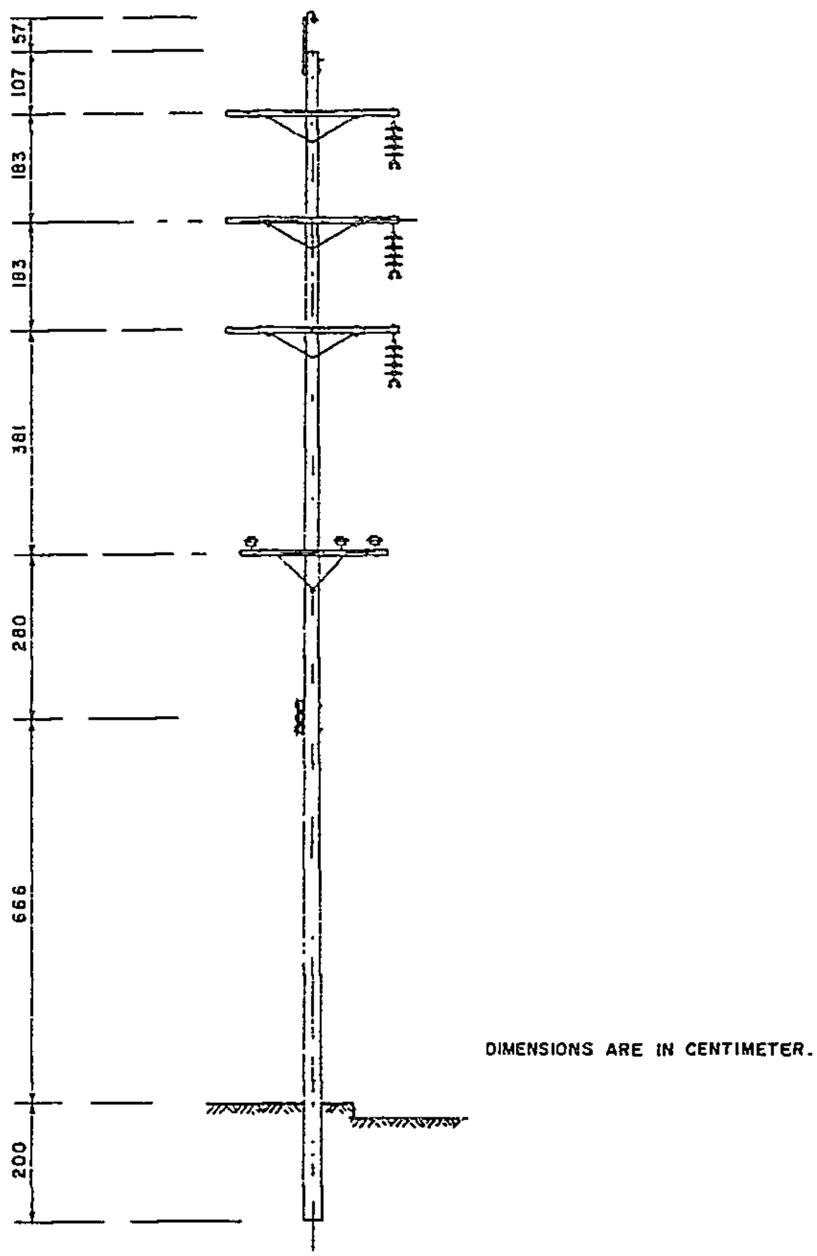


FIG. 22

69 KV. SINGLE CIRCUIT (DOUBLE CONDUCTOR)
TANGENT STRUCTURE
TYPE DC-DC - I

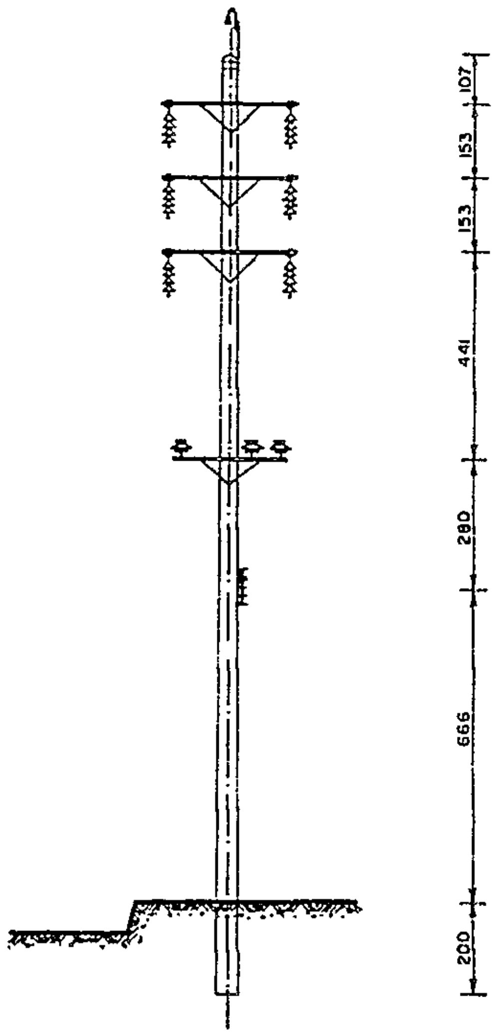
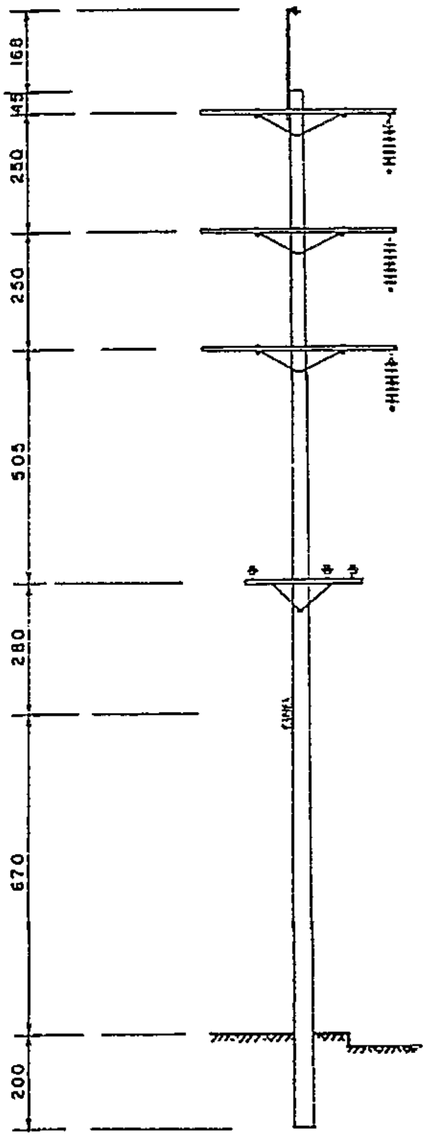


FIG. 23
69 KV. DOUBLE CIRCUIT
TANGENT STRUCTURE
TYPE DC-2B



DIMENSIONS ARE IN CENTIMETER

FIG. 24
115 KV. SINGLE CIRCUIT
TANGENT STRUCTURE
TYPE TS 115

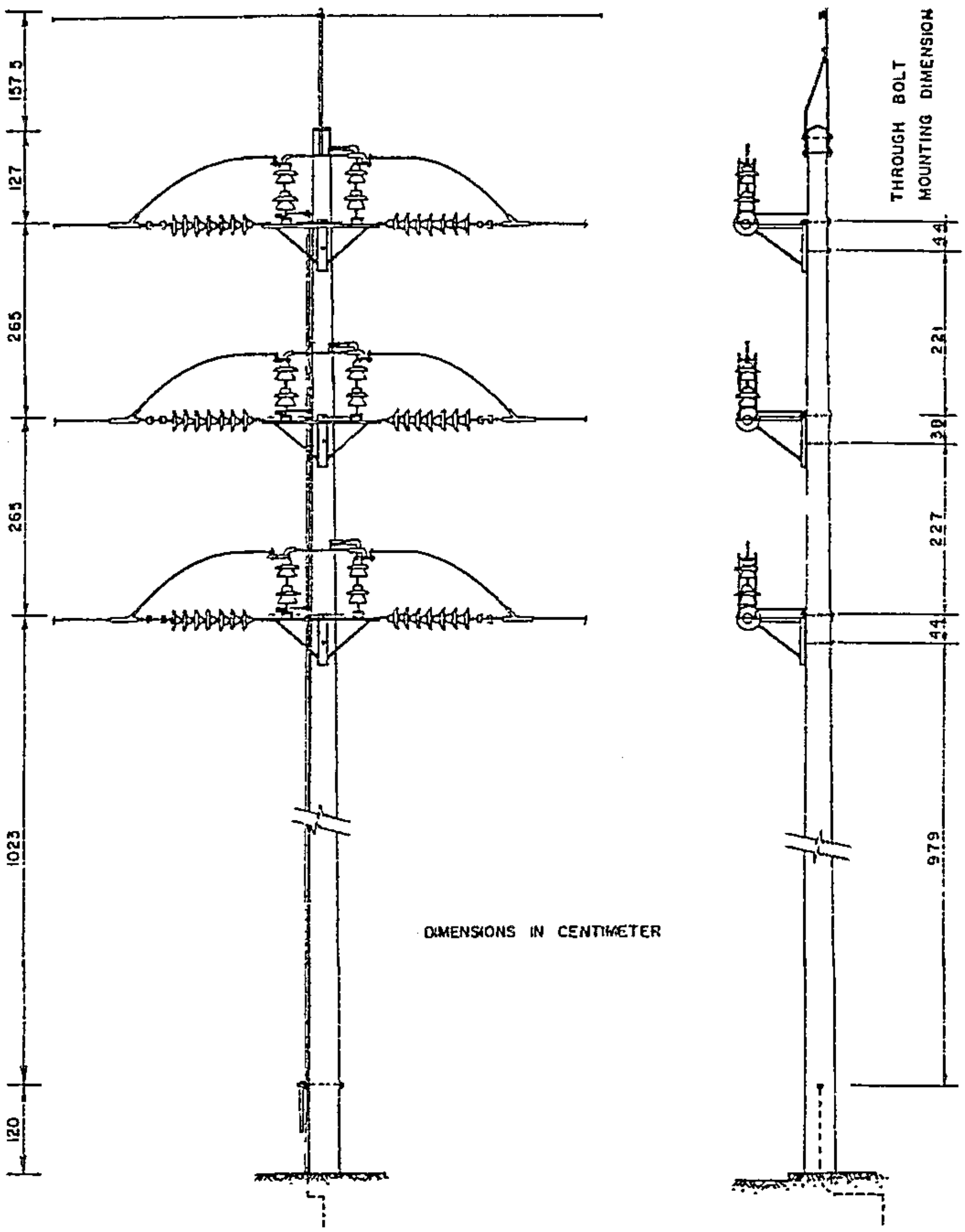


FIG. 25
SWITCHING STRUCTURE
FOR
69 KV. AIR BREAK SWITCH

(Results of analysis)

Analysis was made by each component of transmission lines. These are as follows:

(1) Concrete pole
(2) Electric conductor
(3) Overhead ground wire
(4) Crossarm and insulator
(5) Underground cable

Results of analysis are described in the following paragraphs 2 ~ 6.

2. Concrete pole

(1) Strength of concrete pole

To check the strength of pole, calculations were made of bending moment at ground level section under various condition. The maximum bending moment and strength of the pole are compared for each pattern of pole assembly, shown in Fig. 26. Detailed process of calculation is shown in Appendix 5 and 6, and results of calcuation are tabulated in Table 8.

This table shows that:

a. If one more circuit or one more wire is strung on existing poles, these must be replaced by higher strength poles.
b. If the wire is changed to heat resistant type, the existing poles can be used provided that the size of wire is nearly the same.

Fig. 26 Size and type of Pole

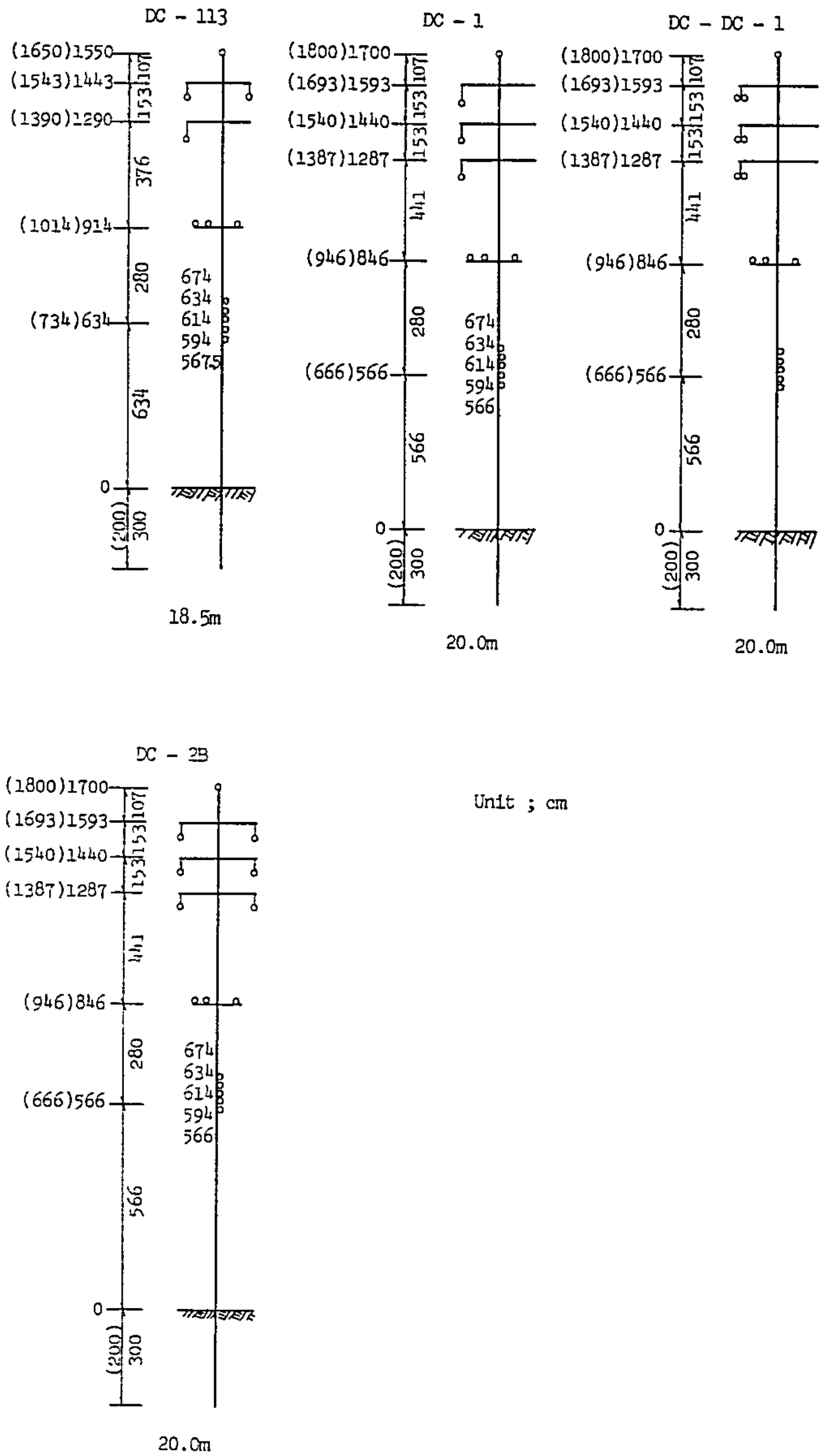


Table 8 Strength of Existing Concrete Poles

Type	Length (m)	Setting depth (m)	Present			If 1 cct is added		
			Strength (t-m)	Tolerance	Check	Required pole (t-m)	Strength	
							DC-DC-1	DC-2B
DC-1B	18.5	3.0	10.0	1.11	OK	14.0	OK	
DC-1B	20.0	3.0	14.0	1.36	OK	18.0	OK	OK
DC-1	20.0	3.0	14.0	1.50	OK	14.0 18.0	OK OK	NO OK
DC-1	22.0	3.0	14.0	1.17	OK	18.0	OK	OK
DC-DC-1	20.0	3.0	14.0	1.04	OK	14.0 18.0	OK OK	NO OK
DC-DC-1	22.0	3.0	14.0	0.82	NO	18.0	OK	OK
DC-2B	20.0	3.0	14.0	0.92	NO	18.0		OK
DC-2B	22.0	3.0	14.0	0.73	NO	18.0		OK
DC-1B	18.5	2.0	10.0	0.98	NO	14.0	OK	
DC-1	20.0	2.0	14.0	1.32	OK	18.0	OK	OK
DC-DC-1	20.0	2.0	14.0	0.93	NO	18.0	OK	OK
DC-2B	20.0	2.0	14.0	0.82	NO	18.0		OK

Note : (1) Tolerance = $\frac{\text{Strength of pole}}{\text{Actual bending moment}}$

(2) Bending strength of pole is considered at ground level section.
18.5 m pole .... 10.0 t-m
20 m, 22 m pole .... 14.0 t-m

(2) Addition of primary distribution line on common-use pole

Allowable size of primary distribution line conductor which can be installed on common-use pole was checked and the results are as follows:

Calculation was made for the case of 69 kV wires installed on DC-DC-1 because this case is the most severe condition to add another primary distribution line.

a. Bending moment of pole at ground level

Bending moment of pole at ground level was shown in paragraph III-5-2(1).

For the case of DC-DC-1, 20 m pole, it was calculated as follows:

5/16" GW	474.98 (kg-m)
2 x 795 AAL	2,837.93
	2,565.36
	2,279.79
3 x 336.4 HT DL	755.647. . . . . A
SL Wire	116.332
Neutral LT	189.137
3 x 336.4 LT	698.992
Communication Cable	480.76
Total	10,411.859 (kg-m) . . . . B
Allowable bending moment by conductors is	10,926.7 (kg-m) C

Therefore, the permissible value of bending moment by primary distribution lines is:

$$X = C - (B - A)$$
$$= 10,926.7 - (10,411.859 - 755.647)$$
$$= 1,270.488 \text{ (kg-m)}$$

b. Calculation of maximum allowable size of conductor

Bending moment = (Wind pressure) x (height of conductor)

Therefore,

$P_c \cdot D \cdot S \times h = 1,270.488$

Where:

P_c = Wind pressure of conductor 44 (kg/m^2)

D = Summation of outer diameter of conductors (m)

S = Length of one span 40 (m)

h = Height of conductor from ground level (m)

From this equation:

$$D = 0.08533 \text{ (m)}$$
$$= \underline{85.33} \text{ (mm)}$$

As a result, the limit to size of conductor is:

3 wires . . . . less than $\frac{85.33}{3} = 28.4$ (mm)

6 wires . . . . less than $\frac{85.33}{6} = 14.2$ (mm)

3. Electric Conductor

(1) As far as the span is about 80 m, existing hard aluminum stranded wire of size MCM 795 is suitable and has no problem in mechanical strength or current capacity.

But further studies should be made of fault record caused by torsion of spacer wiring of multiple conductors.

(2) Common wiring

a. Clearance between subtransmission line and distribution line is being kept strictly at more than 2.0 m.
Distance of all spans is less than 100 m, and grounding is suitable done.
Furthermore, arresters are being equipped at required places. Thus, common wiring with distribution lines has no basic problem.

b. Telecommunication cable should be electro-magnetically shielded cable in common wiring with high voltage power line.
If it is not shielded, line protector equipped at both end terminals will be damaged, and it may cause harm to human being.

4. Overhead Ground Wire

(1) Lightning stroke

It is assumed that many cases of breaking of ground wire by lightning stroke occurred at the connecting point between main wire and pull-down wire of each tower when the contact resistance is very high. Because of the fact that connecting of wires cannot be avoided, it becomes very important to keep every connecting point in low contact resistance.

Therefore, selection of connecting terminal which has low contact resistance is important. At the tensile end, compressed terminal is recommendable.

(2) Corrosion

Corrosion of ground wire is usually caused by chemical reaction due to existence of accumulated rain water at connecting point. Another cause of corrosion is peeling off of galvanized zinc on the surface of wire. In installation work of ground wire, some kinds of tool or clamp often leave small damage to galvanized zinc of wire.

To avoid rapid corrosion of wires, it is better to apply a coat of zinc-paint immediately after completion of installation work.

In the follow-up maintenance, conventional corrosion-proof paint, which is mixed with rust-proof paint and grey colored oil paint, must be applied in double overwrapped coat once in one or two years.

In our experience, even though we perform maintenance in the abovementioned manner, 20 – 30 years seem to be the maximum life of ground wire.

If the wire passes through an area polluted by salt, dust or gas, it is better to use corrosion-proof wire such as almo-weld wire.

(3) Vibration

Some kind of light-weight wire, for example galvanized steel wire, almo-weld wire, ACSR, etc., sometimes receive minute vibration caused by breeze generated by heavy traffic of automobiles.

To equip dampers is a normal countermeasure against vibration.

5. Crossarm and Insulator

(1) Crossarm

Wooden crossarms are used on 69 kV line poles. Metal parts of suspension-type insulator are not grounded.

When power leakage occurs by reason of deterioration or damage of insulator, this may ignite wooden crossarm. Burning of wooden crossarm will cause drop down of wires. This is one of the serious situation of fault and damage. To avoid such situation, pin of insulator should be grounded.

Furthermore, when a ground fault occurs in one phase, mis-tripping of protective device may happen.

In such sense, corroded wooden crossarm should be replaced by metal crossarm which is grounded by grounding wire.

(2) Insulator

Ball-socket type 10 inch insulator has no problem in mechanical strength and in insulation function. But, equipping of arcing-horn is to be considered as a countermeasure against damage by lightning because frequency of lightning is very high in the Bangkok area.

6. Underground Cable

Because of natural conditions including heavy flood in the Bangkok area, underground transmission cable has not gained wide use.

Even though underground facilities are costly, the MEA must invest in underground facilities more and more in order to meet increasing demand for electricity.

The MEA already has several experiences of construction of underground cable. Therefore, establishing of construction standards of underground cables must be prepared in the MEA taking into consideration the special conditions of the Bangkok area.

One thing which must be considered is the allowable current of underground cable.

The allowable current of underground cables will decrease because radiation of heat becomes poor when many circuits are laid in the same duct, and careful attention will be required concerning this matter at the time of planning. For example compared with the allowable current in case of single-circuit the value will decrease to 74% from 77% when three circuits are laid in the same duct.

III-6 Distribution Facilities

1. Standards for Distribution Facility

(Existing condition)

Power distribution of the MEA is performed by dividing the service area into 3 patterns.

(1) Old city district of Bangkok .... Secondary network system

In this zone, 12 kV distribution lines are all underground and low-voltage lines are normal network of overhead lines.

(2) New city district of Bangkok and surroundings .... 12 kV overhead line system

Power is taken from distribution substations by 12 kV underground cables and connected to overhead lines.

(3) Bangkok suburbs .... 24 kV overhead line system

This zone is low load density area and power is supplied by long-distance distribution lines.

The MEA has established its construction standard of the existing distribution system which may be summarized as follows:

- The outgoing line from substations is mainly underground cable:
  Underground cable is made of copper, insulated with paper or polyethylene. The conductor is of two different sizes as follows:

12 kV	325 mm^2	500 A (600 A)	10 MVA
	500 MCM	400 A (500 A)	8 MVA
24 kV	325 mm^2		
	500 MCM		

Note: Figures in ( ) apply only to emergency case.

Structure standards of manhole and duct bank for underground cable are shown in Fig. 27, Fig. 28 and Fig. 29.

- No. of outgoing feeders:

12 kV ┬ 6 Feeders/1 bank (One feeder is normally a spare.)
      └ 12 " /2 "

24 kV ┬ 4 " /1 "
      └ 8 " /2 "

- Square-type RC pole are used as supporting structure for overhead line in two kinds.

RC pole ┬ 14 M (Span 40 m)
        └ 12 M (Span 40 m)

Typical dimension of equipment position is shown in Fig. 30.

- Conductor for overhead line is of AA (all aluminum), classified into 4 kinds.

AA	336.4 MCM	(Main trunk line)	400 A (530 A) .... 8 MVA
	4/0	(Branch line)	340 A (410 A)
	2/0	(")	250 A (300 A)
	#2	(")	160 A (190 A)

- Switches and their capacity on overhead line

12 kV	LBS (Triple-pole controlled)	800 A
	D.S. (Single-pole switch)	800 A
	PFS (for branch with fuse)	400 A
	" (")	200 A
24 kV	D.S.	600 A
	PFS	300 A

Equipping standard of disconnecting switch is shown in Fig. 31.

- Capacity of distribution transformer

1ϕ .... 5, 10, 15, 25, 37.5, 50, 75, 100, 167, 333 kVA
3ϕ .... 45, 75, 112.5, 150, 300, 500, 750, 1,000, 1,500, 2,000 kVA

Equipping standards of distribution transformer are shown in Fig. 32 and Fig. 33.

o Watt-hour meter

1ϕ 2 W	240 V	5 A ~ 100 A
3ϕ 4 W	240 V/416 V	15 A ~ 400 A
3ϕ 4 W	240 V/416 V	15 A ~ 800 A (for network area only)

o Pole mounted capacitor

200 KVAR x 3 or 1.8 MVAR (Switched)

Equipping standards are shown in Fig. 34 and Fig. 35.

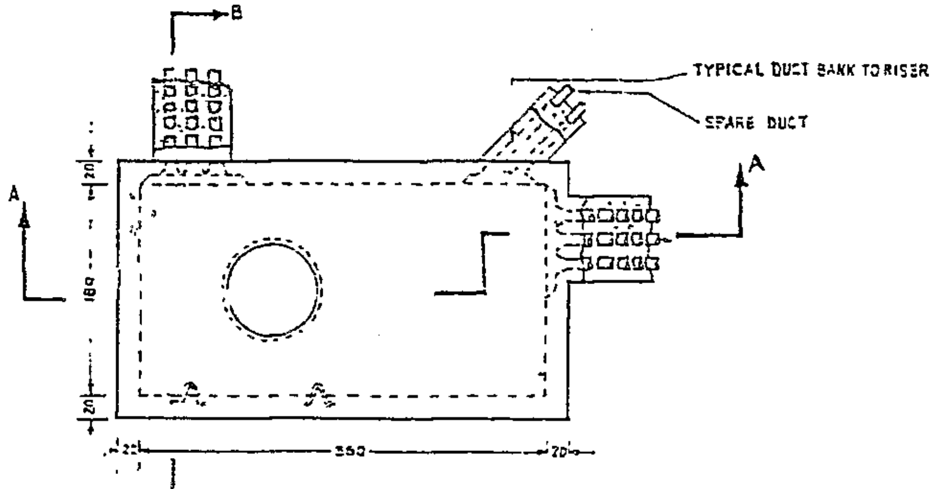
(Results of analysis)

(1) The rule for standardization of distribution facility is followed strictly and faithfully and is well coordinated with the standard for substation facility. However, since uniform application of the established standard is not 'economical' in all instances, review must be made on an individual basis for the optimum formation of a system with due consideration given to utilization factor and the local condition.

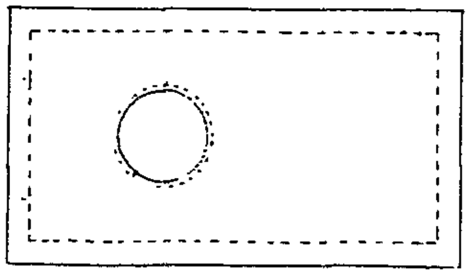
(2) The distribution line is equipped with many disconnecting switches of single-pole type. The type takes much time to open or reclose the lines during faults, and has a problem concerning safety too. Consequently, it will be necessary to consider the adoption of switches which are safe and easy to operate. Use of 12 kV air break switches (triple-pole) and vacuum switches is recommended and adoption of the automatic operation system should be considered.

(3) Customer-owned transformer capacity is not as yet fully standardized. Those existing transformers in use are diversified into various types and made in various countries abroad. Under such condition, voltage control, load control and also mounting on pole will become complex. It is therefore advisable that at the time old units are taken out of service, new transformers should be unified under the equipment standard.

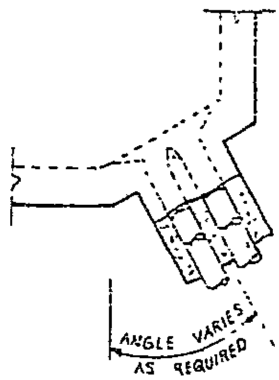
(4) Existing concrete poles for distribution lines do not have much allowance strength-wise and will not be able to handle future extension. (See Appendix 7)

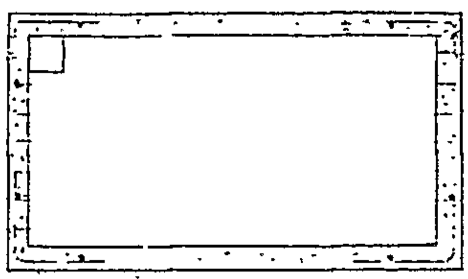


PLANE



ROOF

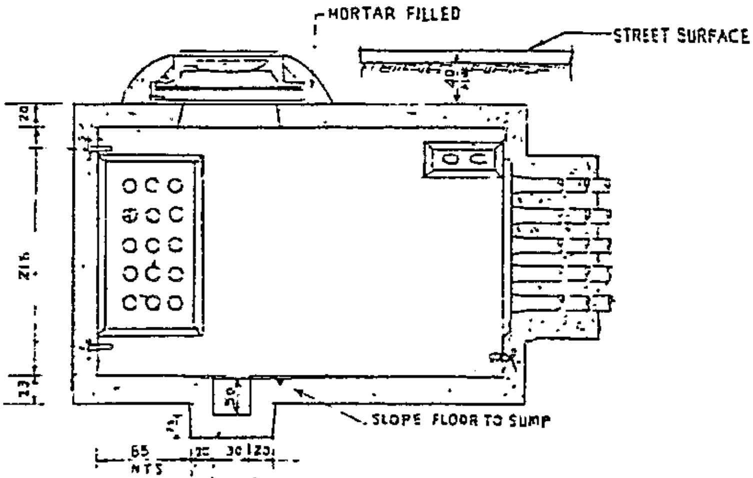




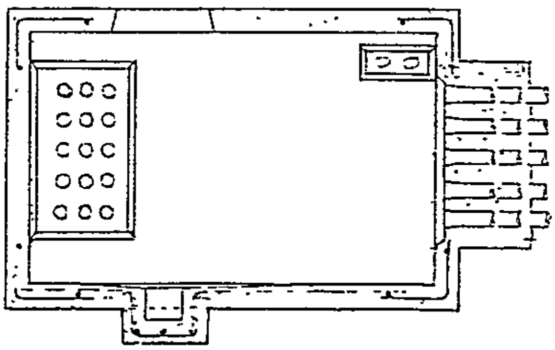
FLOOR

FIG. 27

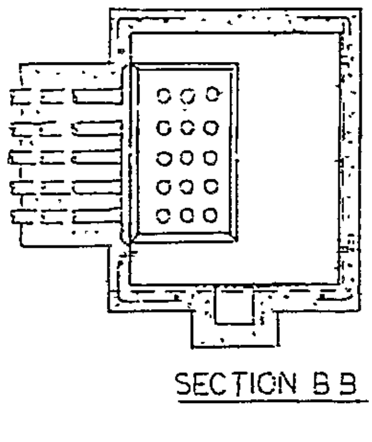
MANHOLE TYPE A-1



SECTION A-A 1:50



SECTION 'A-A'



SECTION B B

FIG. 28

MANHOLE TYPE A-1

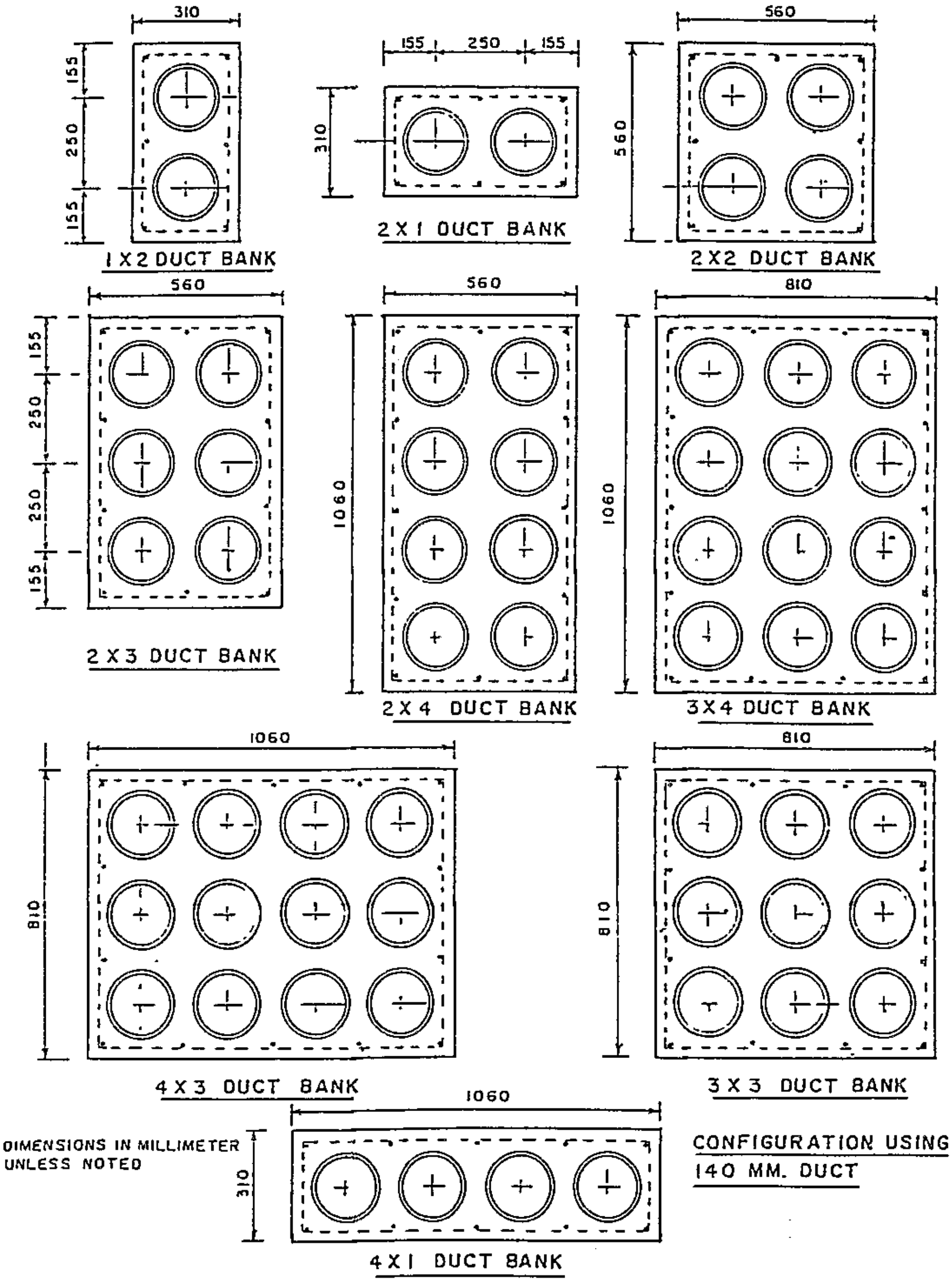
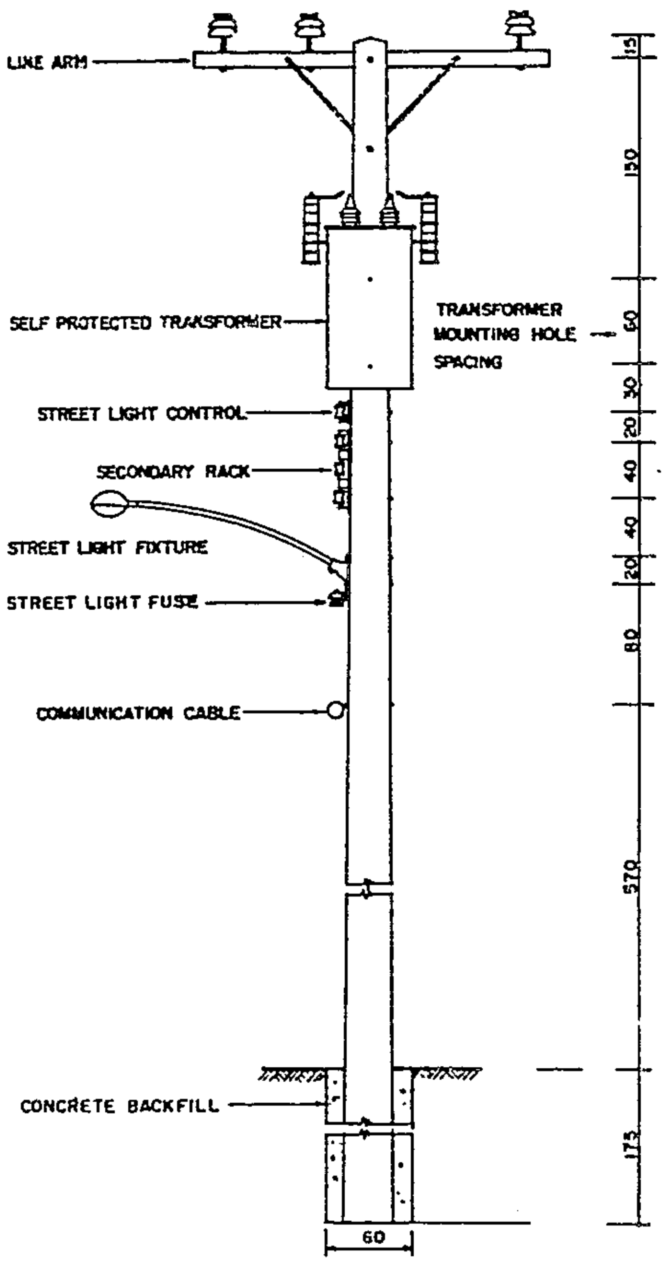


FIG. 29

REINFORCED DUCT BANK SECTIONS USING ASBESTOS CEMENT DUCTS



NOTES.

DIMENSIONS ARE IN CENTIMETER.

FIG. 30
12 M. CONCRETE POLE
FRAMING DETAILS
(EQUIPMENT POSITION)

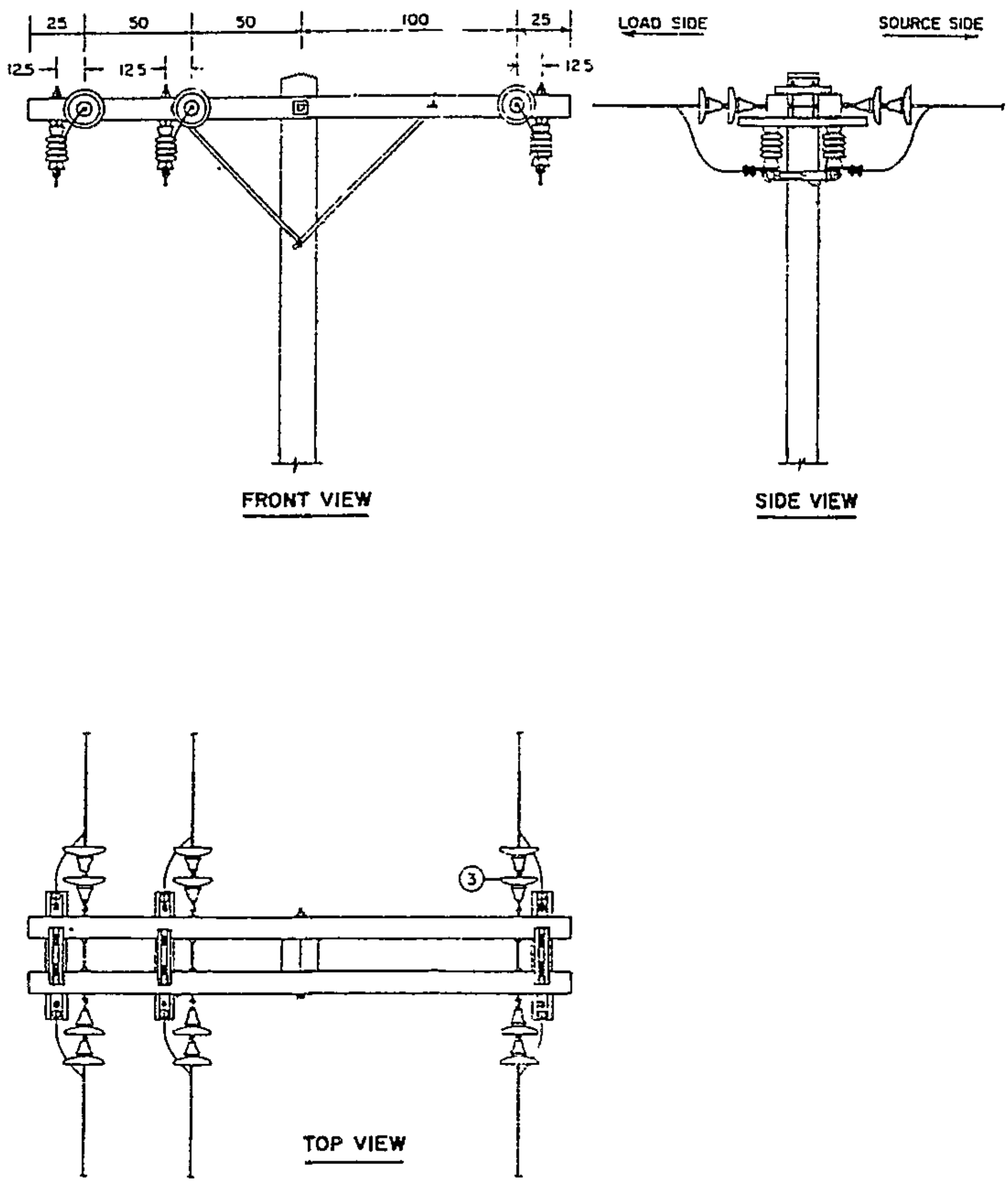
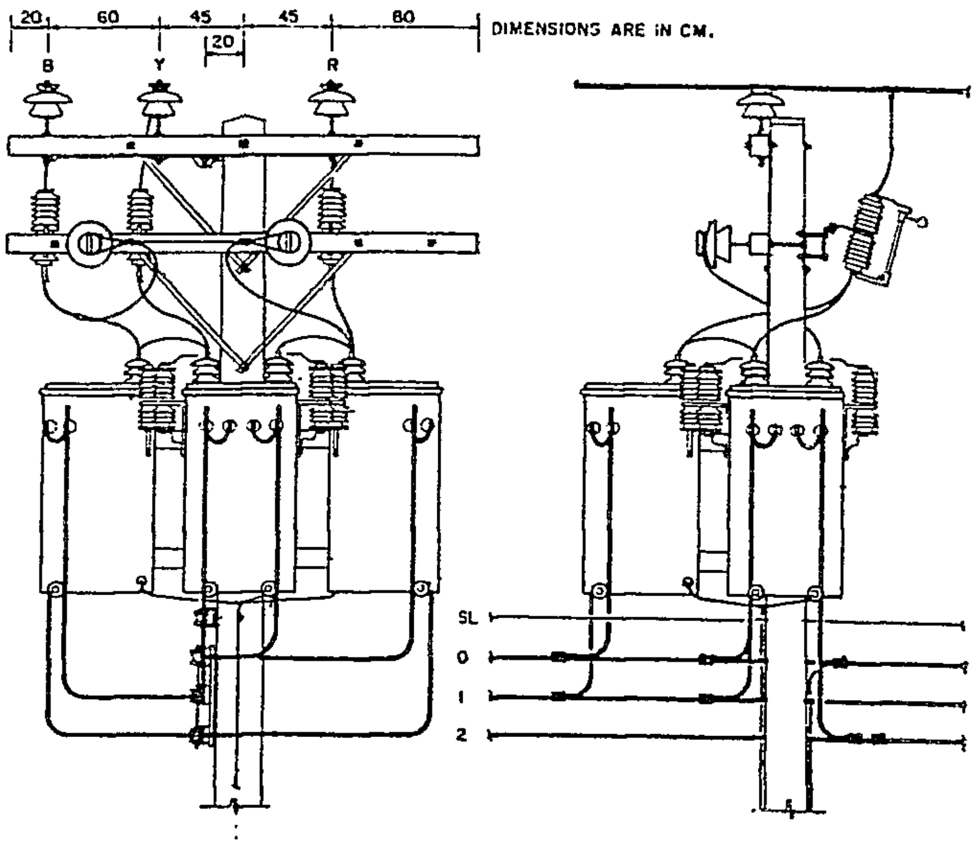


FIG. 31

DISCONNECTING SWITCH



NOTE

SPACED AERIAL CABLE XLPE NO. 2 AWG. (CODE NO 229-030) OR
SPACED AERIAL CABLE XLPE 336.4 MCM.(CODE NO. 229-060)

FIG. 32

3-Ø TRANSFORMER STATION

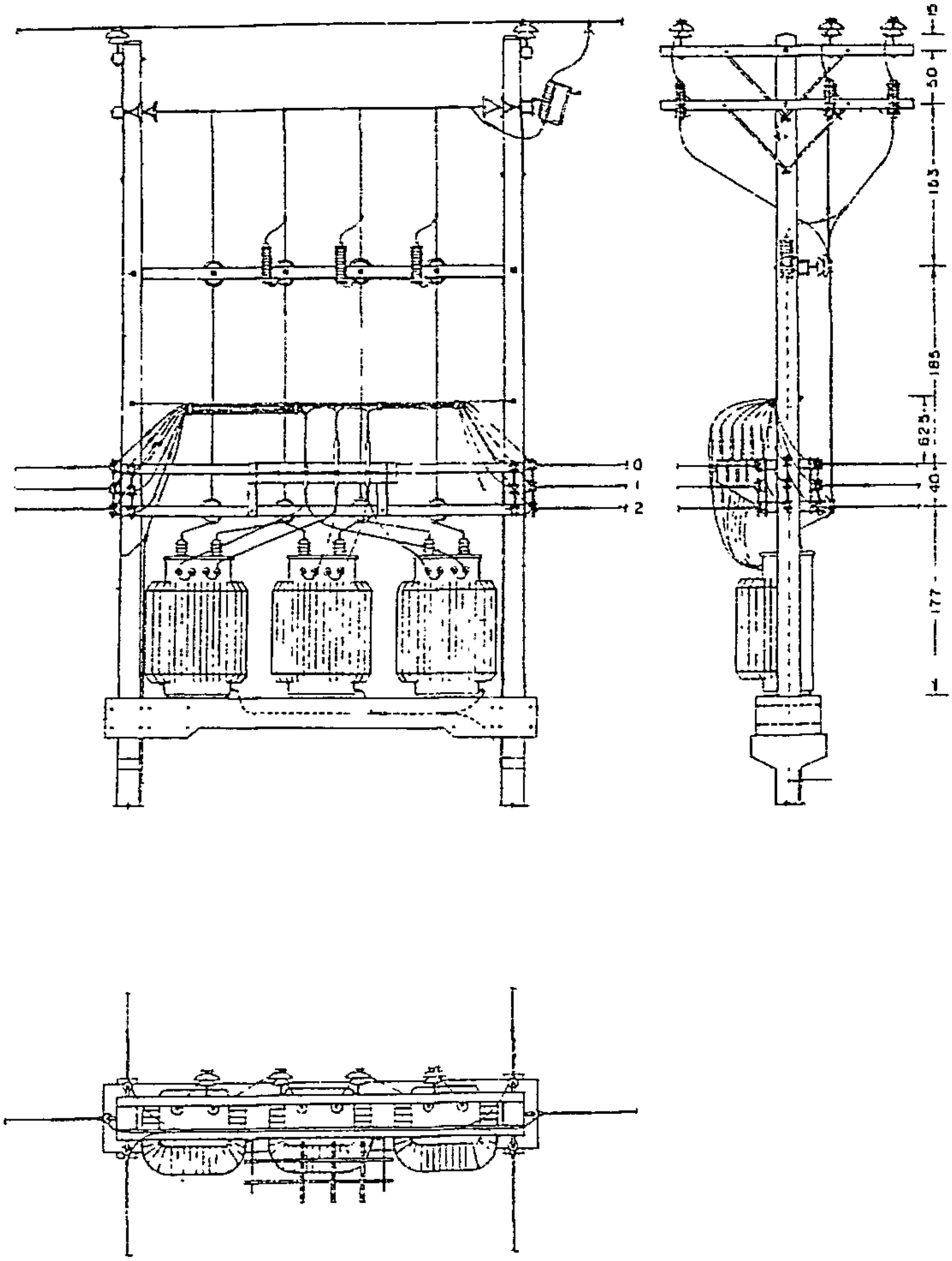
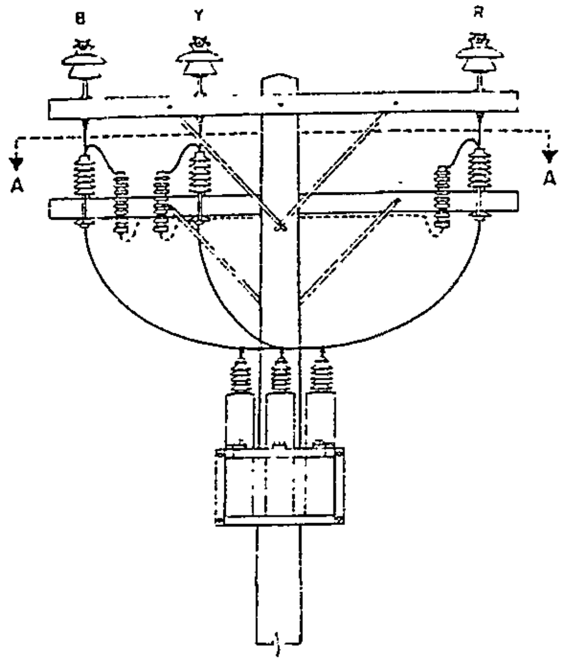
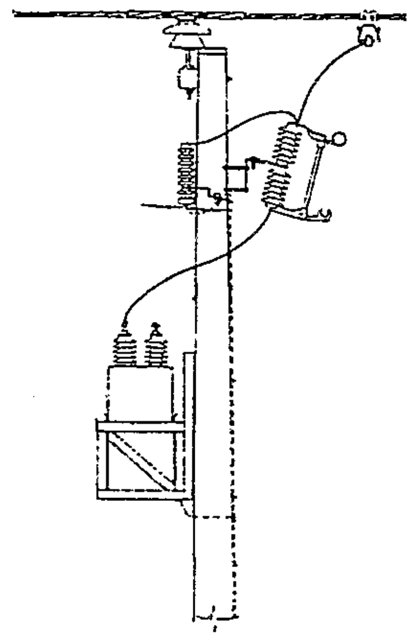
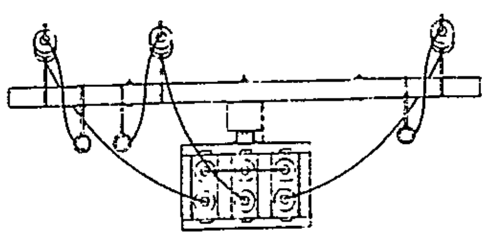


FIG. 33

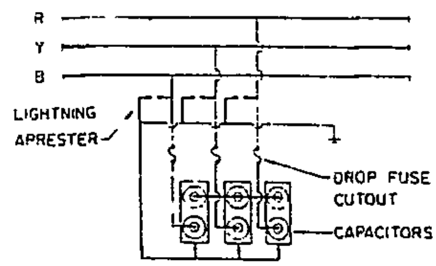
3 x 167 KVA. AND 3 x 333 KVA.
TRANSFORMER STATION







SECTION A-A



CONNECTION DIAGRAM
(Y - CONNECTION)

FIG. 34
POWER CAPACITOR
3×200 KVAR

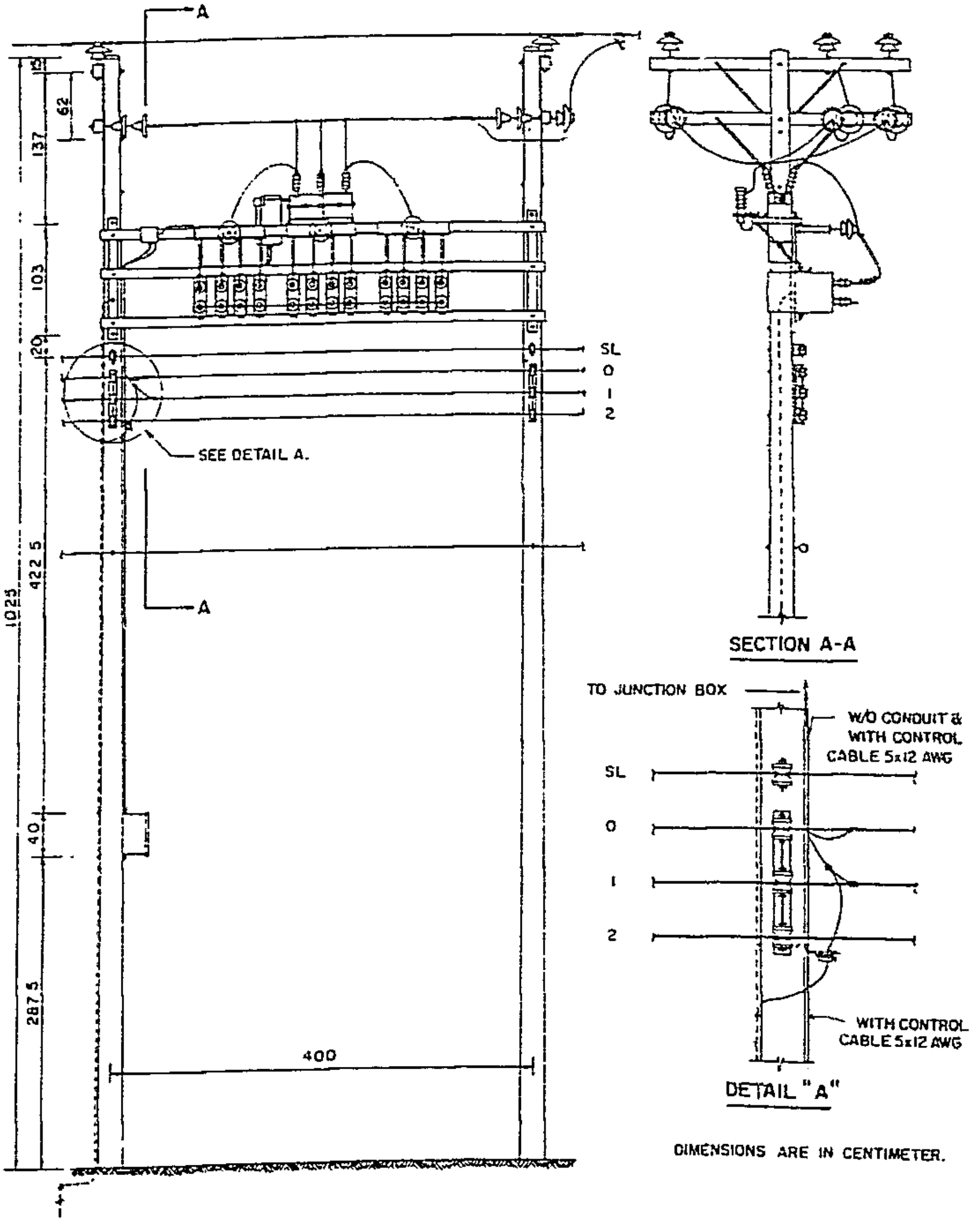


FIG. 35

POLE-MOUNTED SWITCHING CAPACITOR

1.8 MVAR

2. Secondary Network System

(Existing condition)

(1) Existing facilities

The service area supplied by secondary network system covers an area of about 8 km^2 located at the center of Bangkok, including many splendid temples, palaces and the MEA's head office.

The whole area is divided into three (3) blocks with normal network formation consisting of 12 kV distribution lines of all underground cables and low voltage lines of overhead conductors. Fig. 36, Fig. 37 and Fig. 38 show the existing facilities in this area.

The following three substations supply energy to distribution feeders in this area.

WATLIEB S/S	(40 MVA x 2)	Total 240 MVA
N. SAPANDAM S/S	(")	
S. SAPANDAM S/S	(")	

Voltage of secondary network is 240 V/416 V, and size of conductor is as follows:

3 x 336.4 MCM AW .... phase conductor
1 x 4/0 AW .... neutral conductor

440 units of distribution transformers are installed in this network as follows:

300 kVA x 10 unit		Total capacity is 233 MVA. All transformers are equipped with network protector.
500 " x 406 "		
750 " x 8 "		
1,000 " x 7 "		
1,200 " x 3 "		
1,500 " x 2 "		
1,800 " x 2 "		
2,000 " x 2 "		

Equipping standard of 500 kVA transformer is shown in Fig. 39.

Service reliability in this area is extremely high because power supply is available from the low voltage side even at simultaneous outage of two (2) feeders.

Actual load of each feeder in this area is shown in Table 9.

(2) Problems in present network system

The existing network system is, no doubt, the distribution system of highest reliability. But the problem is that the area does not have sufficient space and there is the environmental issue to permit additional installation of transformers though a brisk power demand of high density is anticipated. Furthermore, network protector which is needed to be attached to distribution transformer has become expensive and this will be a burden to the MEA in its maintenance cost.

Fig. 36 NETWORK AREA

WATLIB D/S (8 Feeders)

Trans. KVA \ Feeder	W-11	W-12	W-13	W-14	W-21	W-22	W-23	W-24	Total
300			1						1
500	18	12	18	23	18	17	14	17	135
750			1				1		2
1000		2		1	1				4
1500							1		1
Total Number of Trans.	18	14	18	24	19	17	16	17	143
Total Capacity (MVA)	9.0	8.0	9.05	12.5	10.0	8.5	9.25	8.5	74.8

SOUTH SAPANDAM D/S (8 Feeders)

Trans KVA \ Feeder	SD-11	SD-12	SD-13	SD-14		SD-21	SD-22	SD-23	SD-24	Total
300	1									1
500	26	24	22	13		22	23	22	22	174
1000								1		1
Total Number of Trans	27	24	22	13		22	23	23	22	178
Total Capacity (MVA)	13.3	12.0	11.0	6.5		11.0	11.5	12.0	11.0	88.3

NORTH SAPANDAM D/S (9 Feeders)

Trans KVA \ Feeder		SD-32	SD-33	SD-41	SD-42	SD-44	SD-34	SD-43	SD-46	Total
300	1	1	2		3	1				8
500	18	11	15	20	15	17			1	97
750		1		1		1	1		2	6
1000							2			2
1200			2	1						3
1500							1			1
1800							1		1	2
2000								1	1	2
Total Number of Trans	19	13	19	22	18	19	5	1	5	121
Total Capacity (MVA)	9.30	6.55	10.50	11.95	8.40	9.55	6.05	2.00	5.80	70.10

(Note) Feeder SD-34, SD-43, SD-46 are Suppling for SPOT LOAD.

GRAND TOTAL

KVA	300	500	750	1000	1200	1500	1800	2000	Total
Number of Trans	10	406	8	7	3	2	2	2	440
Capacity	233.20 MVA								

FIG. 37

LOW-VOLTAGE DISTRIBUTION LINE

IN SECONDARY NETWORK AREA

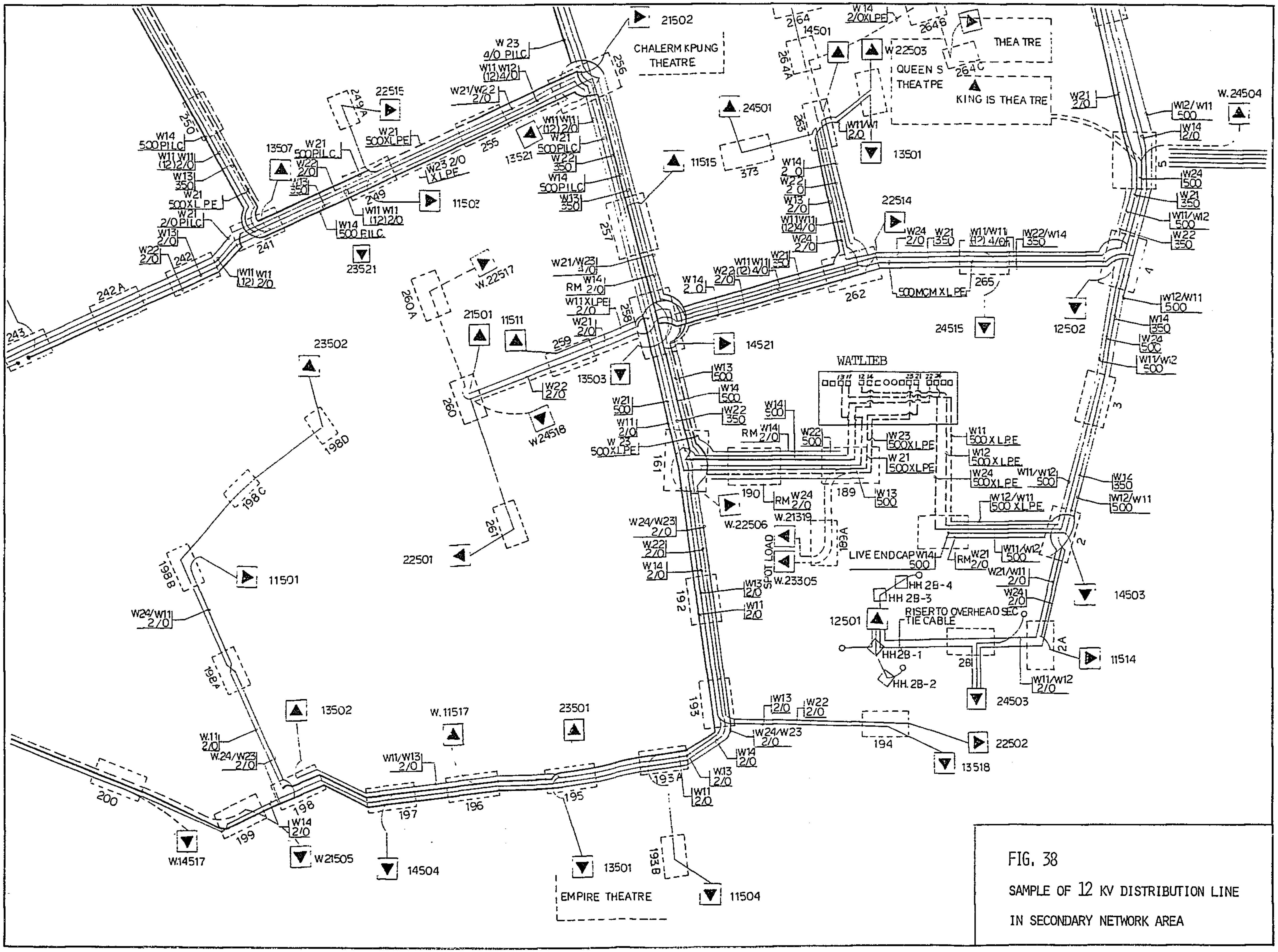


FIG. 38

SAMPLE OF 12 KV DISTRIBUTION LINE IN SECONDARY NETWORK AREA

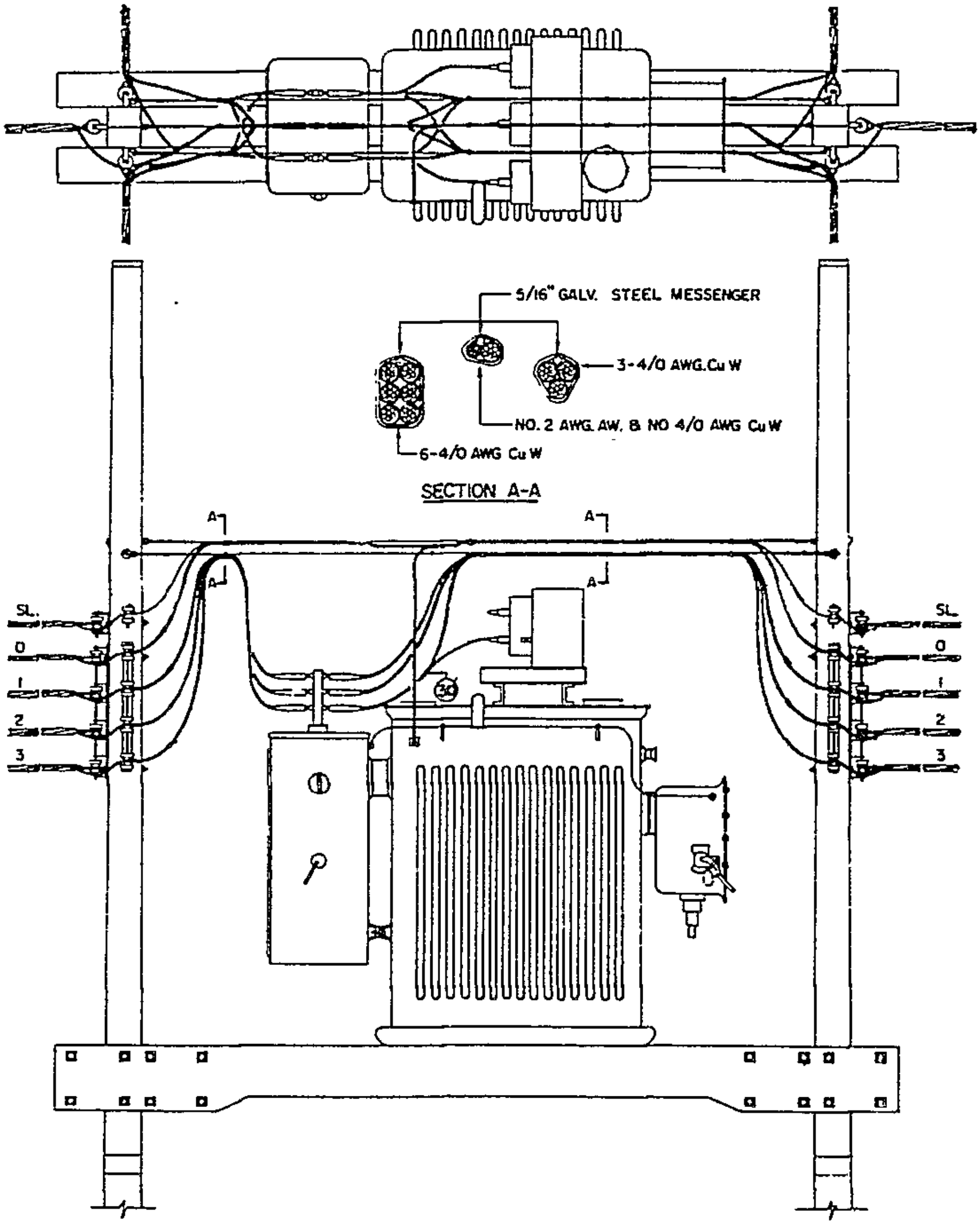


FIG. 39

NETWORK TRANSFORMER STATION

Table 9 Load of Network Area

Feeder	Capacity of Dist. TR. (A)	Max. Load in Sep. 1979			Utility Factor (B/A x 100)	Remarks
		MW	P.F.	MVA (B)		
	MVA	MW	%	MVA	%	
W-11	9.0	4.617	95.2	4.85	53.9	
W-12	8.0	3.769	〃	3.959	49.5	
W-13	9.05	3.015	〃	3.167	35.0	
W-14	12.5	5.348	〃	5.618	44.9	
W-21	10.0	5.277	〃	5.543	55.4	
W-22	8.5	4.146	〃	4.355	51.2	
W-23	9.25	4.052	〃	4.256	46.0	
W-24	8.5	4.146	〃	4.355	51.2	
Sub. Total	74.8	34.37		36.103	48.3	
SD-11	13.3	5.868	82.5	7.113	53.5	
SD-12	12.0	5.135	〃	7.224	51.9	
SD-13	11.0	4.890	〃	5.927	53.9	
SD-14	6.5	2.771	〃	3.359	51.7	
SD-21	11.0	5.915	〃	7.17	65.2	
SD-22	11.5	4.557	〃	5.524	48.0	
SD-23	12.0	5.662	〃	6.863	57.2	
SD-24	11.0	5.577	〃	6.76	61.5	
Sub. Total	88.3	40.375		48.94	55.4	
SD-31	9.3	4.31	87.7	4.914	52.8	
SD-32	6.55	2.7	〃	3.099	47.0	
SD-33	10.50	4.31	〃	4.914	46.8	
SD-41	11.95	5.354	〃	6.105	51.1	
SD-42	8.40	3.511	〃	4.003	47.7	
SD-44	9.55	4.915	〃	5.604	58.7	
SD-34	6.05	1.98	〃	2.258	37.3	Spot Load
SD-43	2.0	0.018	〃	0.021	1.1	Spot Load
SD-46	5.8	2.282	〃	2.602	44.9	Spot Load
Sub. Total	70.1	29.38		33.52	47.8	
G. Total	233.2	104.125		118.563	50.8	

(Results of analysis)

(1) Construction of additional substation

North Sapandam and South Sapandam substations are situated in the same site.
A new substation must be constructed as soon as possible near the load center of growing density of power demand.

(2) Curbing of load from pole transformer

At present, all customers with contract up to 500 kVA are served by 240/416 volts. To suppress the increase of distribution transformer units, this upper limit of load must be curbed down to a lower level, for instance 200 or 300 kVA. And it should be a requirement that any large customer with contract in excess of this limit provides his own transformer installed inside or on the roof of the newly constructed building. Or otherwise, the MEA will have to install the transformer inside of such building, using any available vacant space on a rental basis. this is matter which is related to the electricity rate system and the MEA's policy. However, it is desirable to take a drastic step in the revision of the MEA's customer service regulations.

(3) Study of dismantling of network system

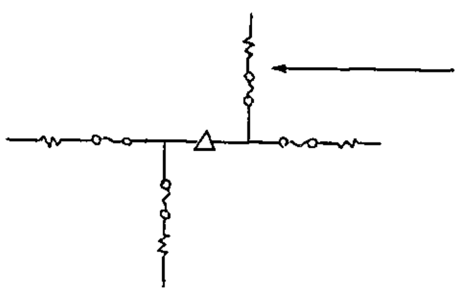
The network system requires relatively high cost for its upkeep. This is not for the purpose of strengthening of power supply capacity, but it is for the improvement of service reliability. Therefore, review should be made of applicability of the loop system, the spare line system and the automatic remote control system of switches which may cost far less.

In this purview, methods of dismantling of existing network are studied. Detail of the result of the study is shown in Appendix 8. Further, composition of distribution system after dismantling of existing network is also studied and the results are shown in Appendix 9.

3. Load management on distribution transformer

(Existing condition)

In the network area, transformer current is measured monthly by reading of ammeter with maximum indicator attched in the network protector. And line current at required spot is measured at random.



Plug-type ammeter is used for measurement.

Measuring hours a.m.: 10 and 11
p.m.: 1 and 2
p.m.: 6, 7 and 8

In non-network area, no regular measurement is made periodically on transformer current.

Normally, when an application for power supply is received, the MEA staff measures the actual load of the transformer from which supply is to be made.
And the existing transformer is replaced if the transformer has no marginal tolerance of capacity. When an elecric air conditioner has been purchased at a private residence, the electrical work contractor notifies the MEA of the new installation of such applicance, but no other information are passed on to the MEA.

(Results of analysis)

(1) Purposes of transformer load management are as follows:
   a. To prevent fire damage of transformer due to overloading
   b. To improve utilization factor by taking out light load units
   c. To reduce distribution power loss
   d. To check voltage drop within service area

(2) As a normal practice, load current in the line must be measured periodically beacuse overloading of transformer by natural load increase occurs frequently. If the MEA does not get any information of such overloading, those transformer might burn out.

(3) Because of the many transformers in service within the MEA's territory, the method of measurement as stated in the preceding paragraph becomes extremely difficult. It is therefore recommended that consideration be given to the earliest introduction of application of the computer system as the method to calculate load on each transformer by input of the recorded data on monthly kWh consumption for each customer.

4. Power supply to big customers

(Existing condition)

There does exist some problems as follows in the Silom Road area.

(1) There are large customers of over 300 kW amounting roughly to 20, and among them contracts of over 5,000 kW are as follows:

Dusit Thani Hotel (Served by 12 kV aerial line)
Hyatt Rama Hotel (Served by 12 kV aerial line)
Bangkok Bank Ltd. (30-storied building under construction)

The Bangkok Bank building will be served by 12 kV, 2-circuits of underground cable connected to Silom Substation.

This district is known as the commercial and amusement center with office buildings, theatres, large restaurants and stores, and higher density of demand is anticipated in the future.

(2) The low-voltage distribution line serving this area is of the following standard:

240V 1-phase, 2-wire system
240V 3-phase, 3-wire system

(3) Trouble due to droppings from wild birds

Many birds (Nok Nang-An) flock together on the distribution lines every evening on Silom Road during their immigrating season. Droppings from them not only stain all the existing equipment such as transformer, disconnecting switch, arrester, condenser and conductor, but also give rise to the cause of grounding fault during rainfall.

(Results of analysis)

(1) Spot load supply

There are four types of distribution systems to supply spot loads as shown in Fig. 40. Each of the system has its own characteristics as described below.

a. π loop system
This system adopts one circuit of distribution line and is designed to give high reliability. The trend is that this system will expand worldwide in the future. Heavy wire and large capacity breakers are required. Though the line composition is simple, it is rather costly. And at the time of line fault some time is required to operate switches.

b. Spare line system
For this system, 2 circuits of distribution lines are required.
Light wires can be used for both circuits from the substation and switches need the capacity to supply each spot load only. Therefore, though this system is a dual installation of distribution lines, the cost is small. At time of fault some time is required to operate switches.

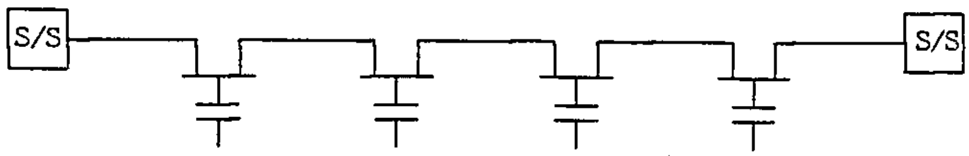
c. Spot network system
This system requires 3 circuits of distribution lines and netwok protector on the secondary side. This system is costly, but there will be no service interruption at time of fault in distribution line, except in the case of simultaneous fault in 3 circuits.
Therefore, the adoption of this system should be restricted to supply customers that require the highest supply reliability.

d. Remote control system
In this system one circuit of distribution line is used with switches installed to sectionalize the line. The switches are controlled and operated remotely in order to shorten their operation time at time of line fault. This system which is used for overhead lines requires large capacity switches and signal transmission line, but compared to underground cable the cost is less.

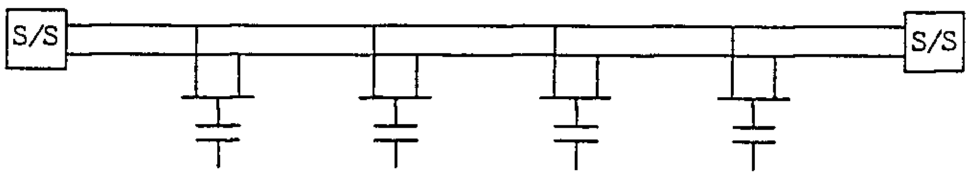
Each of the above described systems has their own features. As a result of analysis it is the conclusion that if overhead lines are used (b) spare line system or (d) remote control system is preferable. And for underground distribution line, the preferable system is either (a) π loop system or (b) spare line system or (c) spot netowrk system.

Fig. 40 Power Supply Countermeasure for Spot Load

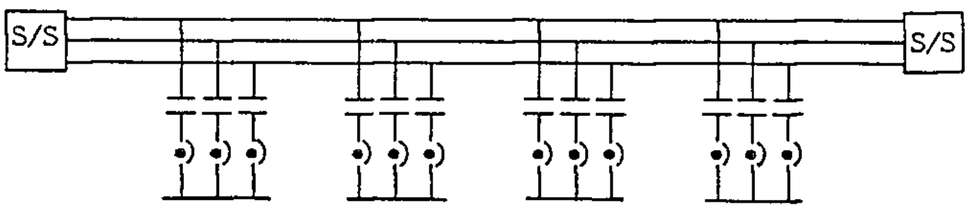
Power supply system for spot load are as follows:



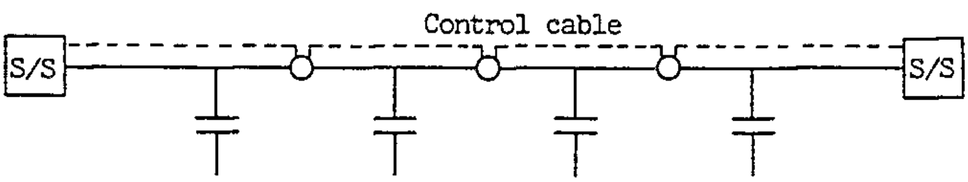
π - loop system



Spare line system



Spot network system



Remote control system

Note: ╪ Transformer

◗ Network protector

o Line switch

(2) Change-over in low-voltage supply system

There is no problem at all with regard to 1-phase 240V, but, changeover from 3-phase 240V load to 3-phase 416V load is not so easy. To solve this problem:

a. To make survey of existing number of equipment designed at 3-phase, 240V, 3-wire system and concurrently to see if they are dually rated at 240/416V.

b. To encourage future purchase of such equipment dually rated at 240/416V by official notice of the MEA.

c. To apply the stepped-up rating of 416V only to the service area where a new transformer has been installed, on a step-by-step basis.

d. To make technical review of the possibility to substitute the 240V equipment in hand with the 416/240V step-down autotransformer.

(3) Protection against droppings from birds

After conversion of the distribution line in the Silom Road area to the underground system, those birds will probably move to lines running in the neighboring road area, where they would do similar harm. As a protection against this, insulation cover must be provided for any exposed live parts (of conductor and equipment) near the supporting structure.

Those birds should be captured or chased away by seeking professional advice of zoologist.

(4) Underground distribution lines

In congested areas, such as in the Silom Road area, the existing lines should be changed to underground cables.

5. Calibration of watt-hour meters

(Existing condition)

The MEA has the calibration system for watt-hour meter. But with regard to the watt-hour meter (including attached transformer) now being used for metering of power and energy sold to each customer, they have seldom been tested or re-calibrated. It is believed that there are few meters still in service that give false reading because of error.

(Results of analysis)

Since the watt-hour meter is an instrument essential to business transaction with the customer, it must always be maintained fairly and properly in utmost accuracy. In many countries, the meter is checked at the time of installing and subsequently at regular intervals of time as aftercare. This calibration system is usually established by law to check if any error of the meter is within the tolerable limit in order to ensure fair practice of transaction with the customer.

In Japan, it is stipulated that all instrument of ordinary type should undergo calibration test every 7 years after installation at customer's premise to detect if the error is within tolerable limit.

Generally speaking, the watt-hour meter tends to fall into a minus error, during its service period, resulting from gradual lagging in its rotation due mainly to abrasion, dust and rust at its bearing. Such lagging tendency is remarkable, needless to mention, at the condition of small rotating torque or at light load rotation.

On the other hand, the watt-hour meter is affected severely by demagnetization of the brake magnet. Therefore, contrary to the error mentioned above, it sometimes turns into a plus error with lapse of service years.

Although those new products developed recently seldom follow any similar pattern of examples as afore cited, a watt-hour meter is normally fated to fall into such errors as afore stated. Especially, the meter of old type may be affected much more severely.

It is therefore, recommended that the following procedures may be proposed:

(1) In the case of the MEA, survey should be conducted by sampling, first of all to clarify the actual status of error on the watt-hour meter.

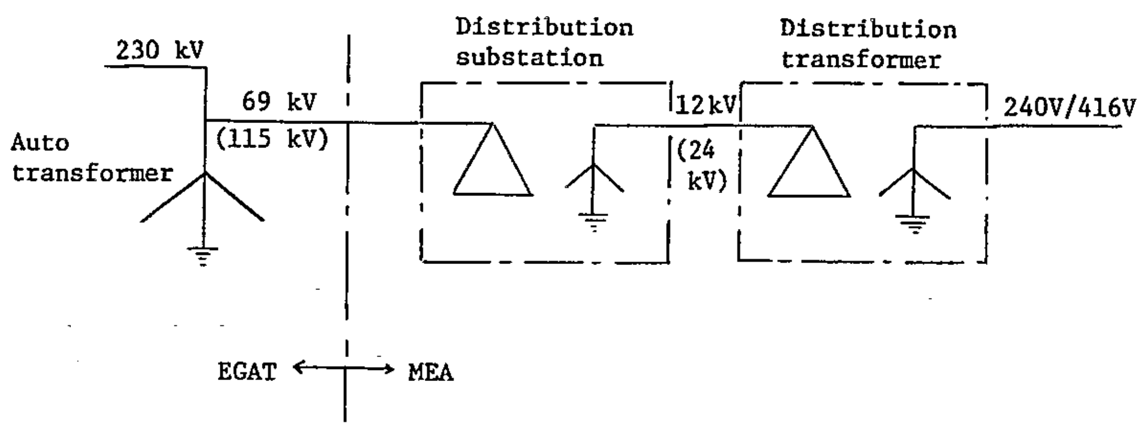
(2) As MEA already has a regulation to test and re-calibrate the watt-hour meter regularly, MEA must follow that regulation very seriously.

III-7 Protective Relay

(Existing condition)

1. System Grounding Scheme

The 230 kV system of the EGAT and the 69 kV (115 kV) and 12 kV (24 kV) system of the MEA are all directly grounded systems. Basic scheme is described as below.



2. Protective Relay Systems for Transmission Lines and Distribution Lines

(1) Kinds of existing protective relays are as follows:

	Ordinary substation	Important substation
Short-circuit Protection	Overcurrent, directional overcurrent	Differential zone, distance
Grounding protection	– ditto –	– ditto –

(2) Co-ordination of time setting is performed in the following pattern.

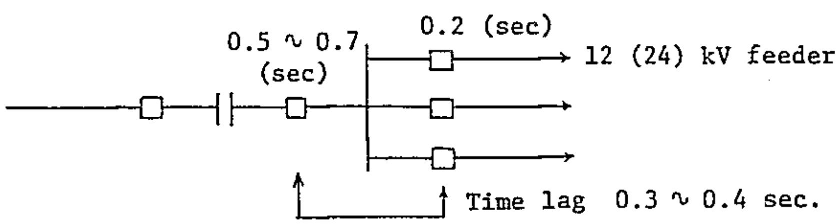
a. Between transmission lines

The time setting of relay, T_1 and T_2 are set as follows:

$T_1 > T_2$ .... Normal
$T_1 = T_2$ .... Winding ratio of current transformer of A s/s is bigger than B s/s.

These are determined taking into consideration system composition, including line length and winding ratio of current transformer, etc.

b. Transformers secondary side and distribution feeder



(3) Reclosing is scheduled as follows:

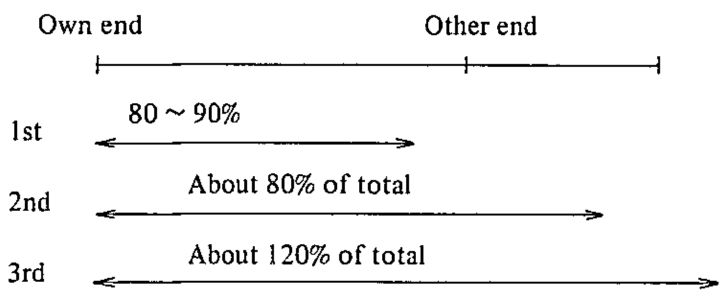
a. 69 (115) kV Once 2 sec. later
b. 12 (24) kV Twice 3 sec. later and 1 min. later

(4) Underfrequency relays for load shedding are equipped at some substations.

Tripping conditions are as follows:

			Percent of load shedding to demand	
a.	1st step	49.0 Hz	~ 20%	Total about 50%
b.	2nd step	48.5 Hz	~ 15%	
c.	3rd step	48.0 Hz	~ 15%	

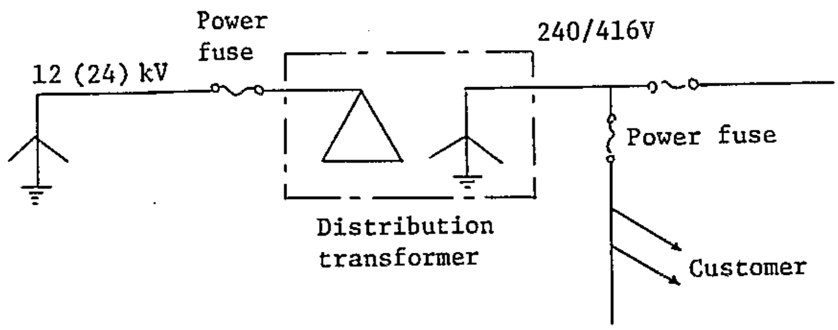
(5) Protection range of distance relay is set as follows:



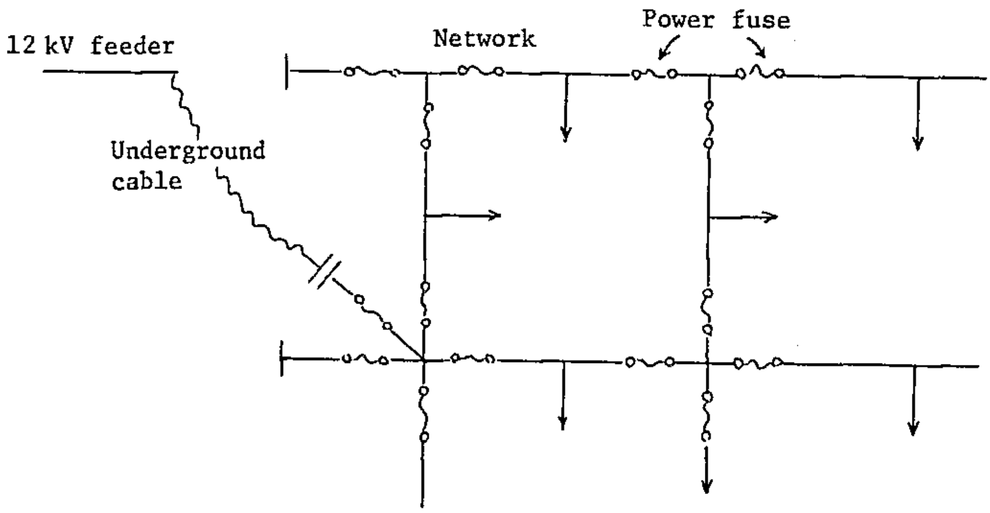
(6) Protection for low voltage line is done by power fuse

Standard scheme is as follows:

a. Outside of network area



b. Network area



(Results of analysis)

Study was made mainly concerning the existing setting condition of subtransmission line protective relays. Outline of results of study is as follows:

1. Short circuit protection

   * Distance setting for Zone I must be shortened for some impedance relays. Details are described in Appendix 10.
   * When two or more distribution substations are connected to one transmission line, it is recommended that a restudy be made of the coordination of setting time among protective relays.

2. Line to ground fault protection

   At several substations, setting time of protective relay must be shortened. Details are described in Appendix 10.

III-8 Reliability

(Existing condition)

The MEA is giving great attention to supply reliability, and actual fault records are neatly arranged in monthly reports tabulating several forms of statistics.

One of those is fault statistics of 1979 which is given in Table 10 showing the average value per month from January to December of 1979. Causes of fault of distribution line are shown in Table 11 and Table 12, which shows that nearly half of faults are recorded as "unknown".

(Results of analysis)

1. Indices of Reliability

Three fundamental elements of power supply reliability are

- adequate frequency
- adequate supply voltage
- continuity of power supply

Frequency must be controlled mainly in the EGAT system. Voltage control is studied in another paragraph. Thus, in this paragraph an analysis is given of continuity of power supply, that is, service interruption.

As index of reliability, the MEA adopts the energy loss by fault in unit of MW-min.

Such method is one form of adequate index to manage service reliability, as far as MW during fault can be expressed in a suitable way.

Recently the following indices have become popular;

- Annual averaged number of interruption per customer
- Annual averaged interruption time per customer

To apply such indices, basic data of facility and customer must be arranged in such a manner so that the connection between distribution facilities and each customer are clearly identified. It is advised that the MEA study the possibility of the application of such indices.

Table 10 Fault Statistics in 1979 (per month)

		Frequency of Fault				Frequency per 100 km or 100 Unit	Out of Operation (min.)	Interruption of Service (min.)	Loss by Fault (MW-min.)
		Reclosing Success	Re-reclosing Success	Reclosing Unsuccess	Total				
Transmission Line		4.58	–	4.92	9.50	2.07	438.0	298.5	4,394.4
Substation	69 kV 115 kV	0.17	–	1.75	1.92	1.48	188.6	43.5	392.1
	12 kV 24 kV	0.33	–	0.75	1.08	0.41	3.5	15.3	92.9
	Total	0.5	–	2.50	3.0	1.89	192.1	58.8	485.0
Distribution Line	Underground	–	–	–	0.29	0.96	24.1	240.3	256.5
	Overhead	–	–	–	386.7	8.73	1,611.4	21,124.7	18,750.0
	Total				386.99	9.69	1,635.5	21,365.0	19,012.5
								Total	23,846.9

Table 11 Cause of Fault of Distribution Line

1979

Cause of fault	Number of fault	Percentage (%)	Remarks
Wind and rain	949	20.2	
Inferior equipment	284	6.0	
Man	273	5.8	
Crane truck	219	4.7	
Birds and beasts	213	4.5	
Trees	204	4.4	
Overhead wire	191	4.1	
Kite	139	3.0	
Arrester	94	2.0	
Transformer	78	1.7	
Others	58	1.3	Car-hit, boat-hit
Unknown	1,979	42.3	
Total	4,681	100	

Table 12 Number of Fault for Each Month

1979

	Number of fault				Remarks
	Unknown	Wind and rain	Others	Total	
January	111	18	87	216	
February	123	82	112	317	
March	198	1	238	437	
April	222	144	191	557	
May	188	166	241	595	
June	162	222	141	525	Rainy season
July	192	45	174	411	
August	151	171	147	469	
September	229	95	157	481	
October	157	5	95	257	
November	118	0	85	203	
December	128	0	85	213	

2. Level of Reliability

Existing level of reliability in the MEA is comparatively low. For instance, frequency of occurrence of fault per 100 km of transmission line is 2.07 in the MEA while it is 0.14 in Japan. In case of distribution line, it is 9.69 in the MEA and 0.27 in Japan.

This difference is assumed to come from not only weather and environmental conditions, but also from the original characteristics of facility, maintenance, operation and quick recovering system.

3. Improvement of Reliability

To improve reliability, studies of measures must be made of the following:

- to prevent frequent occurrence of fault
- to minimize interrupted area
- to recover quickly as possible

(1) To prevent frequent occurrence of fault, suitable quality and quantity of facilities must be installed. But, natural conditions and load characteristic are different in each area. It is advised that studies be initiated to establish reliability standards by each area.

Adequate performance of maintenance work is also important for sake of decreasing the occurrence of fault.

(2) To minimize the interrupted area, the fundamental requirement is to equip sectional switches on distribution line and to interlink each feeder to other. The MEA has installed several number of distribution switches as shown in Fig. 41, but those are all knife-type switches which cannot operate for 3 phases simultaneously. It is advised that existing line switches of single pole type be changed to multi-pole type switches.

(3) To recover quickly, the following points must be re-examined of the existing condition.

- Detection method of fault section
- Fast finding of fault spot
- Quick removal of fault by mobile maintenance crew
- Radio communication between base station and mobile station

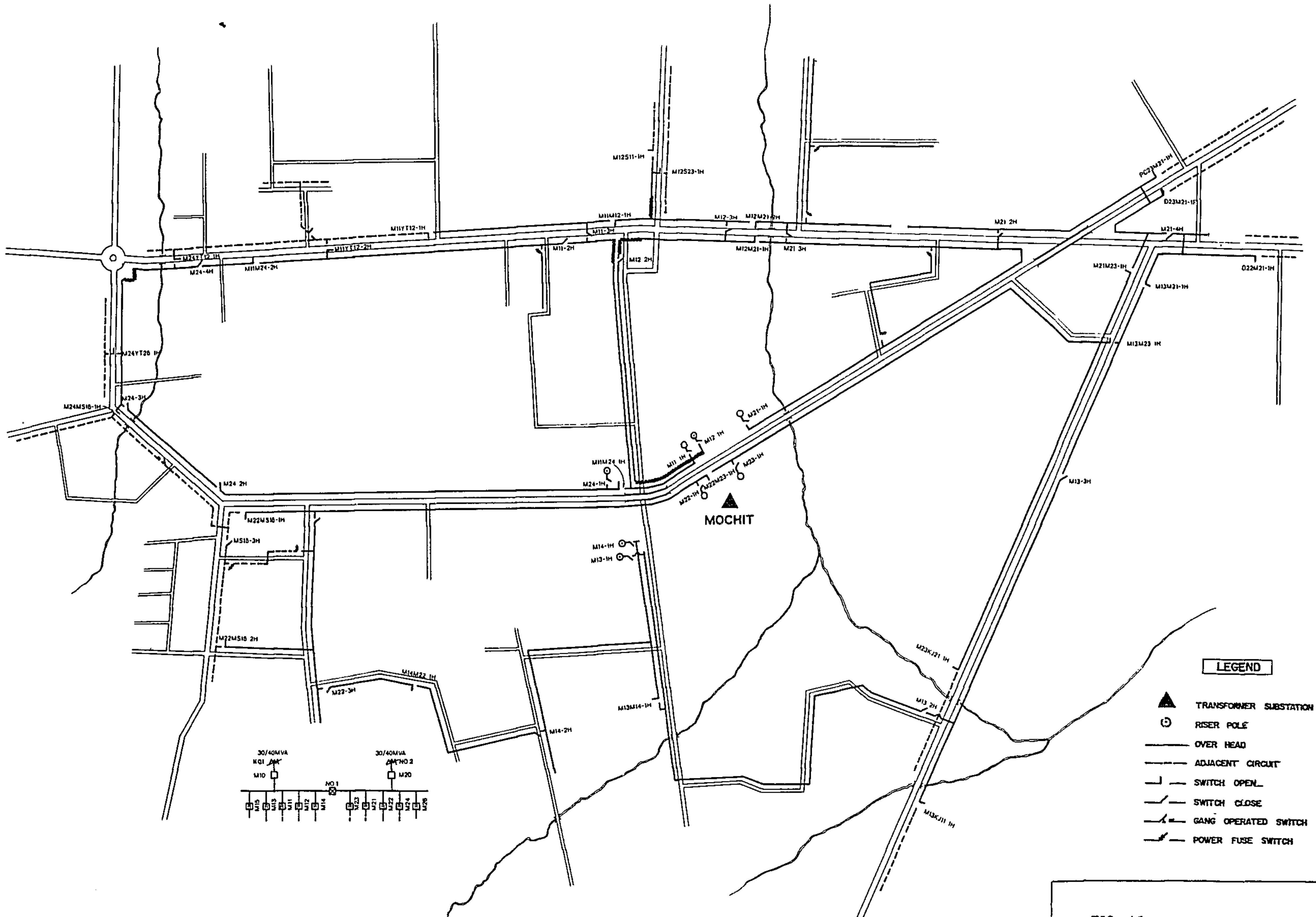


FIG. 41

A SAMPLE FOR INSTALLATION OF DISTRIBUTION LINE SWITCH