CHAPTER 6.

PRELIMINARY DESIGN

CHAPTER 6. PRELIMINARY DESIGN

6.1 Major Structures

1) General

In the layout of Nam Yuam hydroelectric development project, a spillway has been installed at the left bank taking account of the topographical and geological conditions at the dam site. Also for the intake, a location providing smooth water-intake, has been chosen taking the low water level and high water level of the reservoir into consideration.

As for the headrace in the waterway, a route has been selected taking full account of the rock covering of the tunnel. The steel penstock is connected to an exposed pipe at a location of about 100m downstream the dam axis via a surge tank and further connected to a semi-outdoor type powerhouse.

2) Diversion facilities

As the design flood for diversion facilities at Nam Yuam site, 1,300m^3/sec with 20-year probability has been taken into account.

Since the design flood is great compared with the river width, it has been judged that tunnel diversion system is suitable. It has been decided to excavate 2 diversion tunnels at the left bank whereby the tunnel length can be reduced, taking the layout of each structure and topography into consideration.

The upstream cofferdam has been decided to be a fill type and it is economical usually to locate the dam at the upstream end as a part of the main dam body. It has thus been judged to be proper that the crest elevation be determined taking the following into account; economical possible banking in 6-month non-flood period in a year at Nam Yuam site, workability of core section of main dam body and required inner sectional area of diversion tunnel.

Based on the above judgment, as the diversion facilities, 2 diversion tunnels each having diameter of 9m have been determined to be installed with the cofferdam of crest elevation of 95m. Moreover, it has been considered that one diversion tunnel will be converted to a bottom outlet tunnel enabling to discharge downstream and, thus, to lower the reservoir in an emergency.

3) Dam

The dam planned to be built at Nam Yuam site is a rock-fill dam with a center core and the scale is as follows; dam height: 116m, crest length: 350m and total embankment volume: 4,650,000m^3.

The geological conditions at the dam site are as follows; both banks are composed of non-calcareous shale and calcareous sandstone. These rocks are weakly weathered in general and although they are solid and hard, some cracks are found.

The dam axis has been determined taking account of the geological and topographical condition acquired so far.

The typical section adopted for the dam is a standard center core type and it has been decided with a rough stability calculation by using estimated design values based on the results of material test performed heretofore. Namely, the gradient of face of slope at upstream side has been set to 1:2.0 and that at downstream side, 1:1.8, respectively. For the foundation treatment, a grout curtain system has been adopted taking the geological conditions into consideration.

In the future, however, it is necessary to make detailed examination about the dam axis, typical section and scale of foundation treatment by carefully performing geological survey of the dam site and embankment material survey.

4) Spillway

The spillway has been located at the left bank taking the geology and topography at Nam Yuam site into account.

The specifications of the spillway forebay have been set as follows; crest elevation: 158m and total crest length (including pier length): 60m. With these dimensions, a flood routing has been made based on the estimated flood inflow with the peak discharge of 6,200m^3/sec of PMF.

As a result, the spillway capacity has been decided to set to 4,770m^3/sec by cutting 1,500m^3/sec approximately by providing surchage of 0.9m at normal high water level of 170m. The spillway has been equipped with 4 radial gates each being 12m in width.

The dissipator for this spillway is adopted a ski jump type and the direction of center of spillway and the location of end sill have been selected so as not to affect other structures. When designing in detail, there would be a need to decide more appropriate layout and dimensions by performing a hydraulic model test and further making examination in various aspects.

5) Intake, headrace tunnel and penstock

The intake is located just upstream the dam at the right bank and the elevation of the forebay has been selected to assure smooth water-intake even at low water level of the reservoir.

The headrace tunnel diameter has been set to 7.8m and the route has been determined to take the sufficient rock covering of natural ground.

The surge tank has been placed at downstream of the dam axis along the route of penstock, where is also and appropriate in topography.

The penstock has been decided to be an exposed pipe and connected to the powerhouse. Its plane and longitudinal route has been selected taking the topographical conditions into consideration as well as conditions not to cause negative pressure by surging in the steel pipe line.

It would be necessary hereafter to select optimum waterway route and surge tank location with careful geological survey and, at the same time, to examine these dimensions closely.

6) Powerhouse

The powerhouse is of semi-outdoor type and its location and direction have been selected to provide smooth flow-down of running water from a draft.

The turbine center and draft dimension have been decided to ensure sufficient safety of the turbine and draft against cavitation. Also, the dimensions of the powerhouse have been fixed taking account of the rough dimensions of turbine, generator and attachments and allocation of the rooms.

Moreover, when designing in detail, it is necessary to examine carefully the layout of the powerhouse with consideration given to the detailed dimensions and loads of the turbine and generator equipment.

7) Switchyard

The switchyard has been planned to install at a site having elevation of 90m, which is to be prepared on the yard between the dam foot and powerhouse. This elevation has been determined taking account of the highest water level of 85m in downstream in case of flood.

8) Description

(i) Diversion tunnel

Design flood	1,300m^3/sec
	(20 year return period)
Type	Pressure tunnel horse-shoe type
Number of tunnels	2
Inner diameter	9.00m
Length	No. 1 730m
	No. 2 840m

(ii) Cofferdam (Upstream cofferdam)

Type	Rockfill dam with center core
Crest elevation	95.00m
Crest width	10.00m
Crest length	290.00m

(iii) Dam

Type	Rock fill dam with center core
Crest elevation	176.00m
Crest length	350.00m
Crest width	10.00m
Dam volume	4,650,000m^3
Normal high water level	170.00m
Max. water level	170.90m

(iv) Spillway

Design flood	6,200m^3/sec (P.M.F)
Design discharge	4,770m^3/sec
Crest elevation	158.00m
Crest length	60.00m (including pier width)
Dissipator	Ski jump type

(v) Power intake

Number of intakes	1
Max. inflow	215m^3/sec
Sill elevation	130.00m

(vi) Power tunnel and penstock

Number of tunnels and penstocks	1 → 2
Max. discharge	215m^3/sec
Inner diameter	7.80m (power tunnel)
	7.80 - 5.50 - 4.40m (penstock)
Total length	538.00m

(vii) Surge tank

Type	Differential surge tank

(viii) Powerhouse

Type	Semi-outdoor Type
Turbine type	Vertical Shaft Francis
Elevation of turbine center	69.00m

6.2 Electrical Equipment

1) Main equipment of power station

This power station is planned with the normal effective head of 87.3m, maximum available discharge of 215m^3/sec and power plant output of 162MW.

To meet this scale of development, the number of units is to be two where each unit consists of a 82.8MW vertical-shaft Francis turbine, a 90MVA synchronous generator and a 90MVA main transformer.

The unit system where a generator is correspondingly connected with a main transformer is to be adopted for main circuit. The main generators are to be connected by metal enclosed bus with the outdoor-type main transformers installed adjacent to the powerhouse, while the main transformers are to be connected by overhead lines with the 230kV buses of the switchyard.

2) Switchyard equipment

The outdoor-type switchyard is planned for a conventional type of norminal voltage of 230kV just beneath the dam, and the necessary equipment are to be installed.

The 230kV buses are composed of a double-bus system, and two-circuit, 230kV, transmission line is to connect from the left bank side.

To meet the demands at the place in the vicinity of this power station, one-circuit transmission line for norminal voltage of 69kV and several distribution lines for norminal voltage of 22kV are to be prepared for the outgoing facilities.

The outlined specifications of the main equipment at Nam Yuam power station aggregating the above are as listed below, while the single-line diagram, plan and cross-sectional drawings of the power station and switchyard are indicated in Figs. 10-1, 10-2, and 10-3.

3) Specifications of main equipment for Nam Yuam Power Station

(i) Power plant output: 162,000kW

(ii) Turbine

Type:	Vertical-shaft Francis turbine
Number of units:	2
Normal effective head:	87.3m
Max. discharge:	107.5m^3/sec
Output:	82.800kW
Revolving speed:	188rpm

(iii) Generator

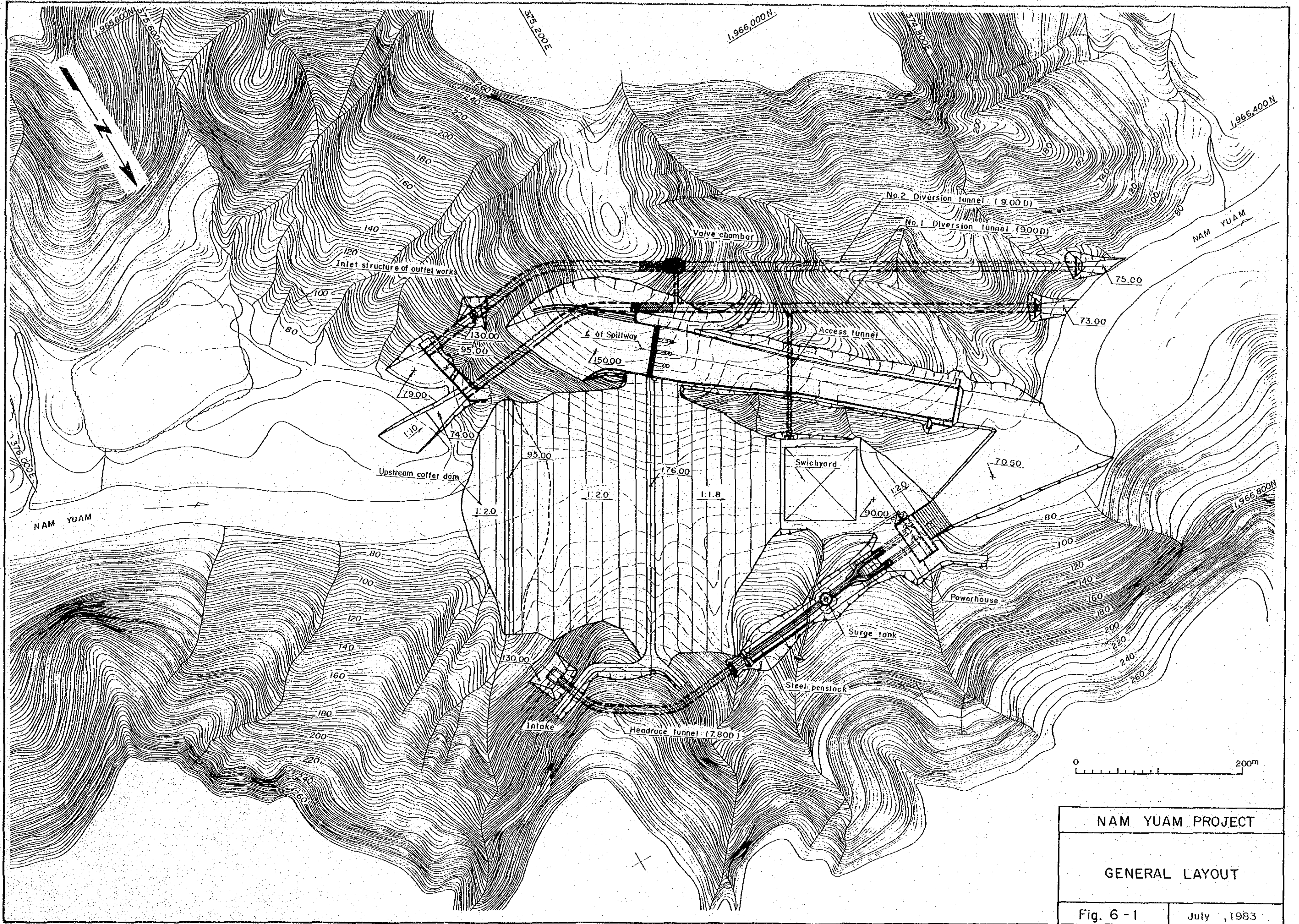
Type:	Three-phase, AC, synchronous generator
Number of units:	2
Capacity:	90,000kVA (power factor: 0.9 lagging)
Frequency:	50Hz

(iv) Main transformer

Type:	Three-phase, outdoor, oil-immersed
Number of units:	2
Capacity:	90,000kVA
Voltage:	230/13.8kV

(v) Switchyard equipment

Type:	Outdoor conventional type
Bus connection:	Double-bus system
Number of circuits connected:	2 (230kV)
	1 (69kV)

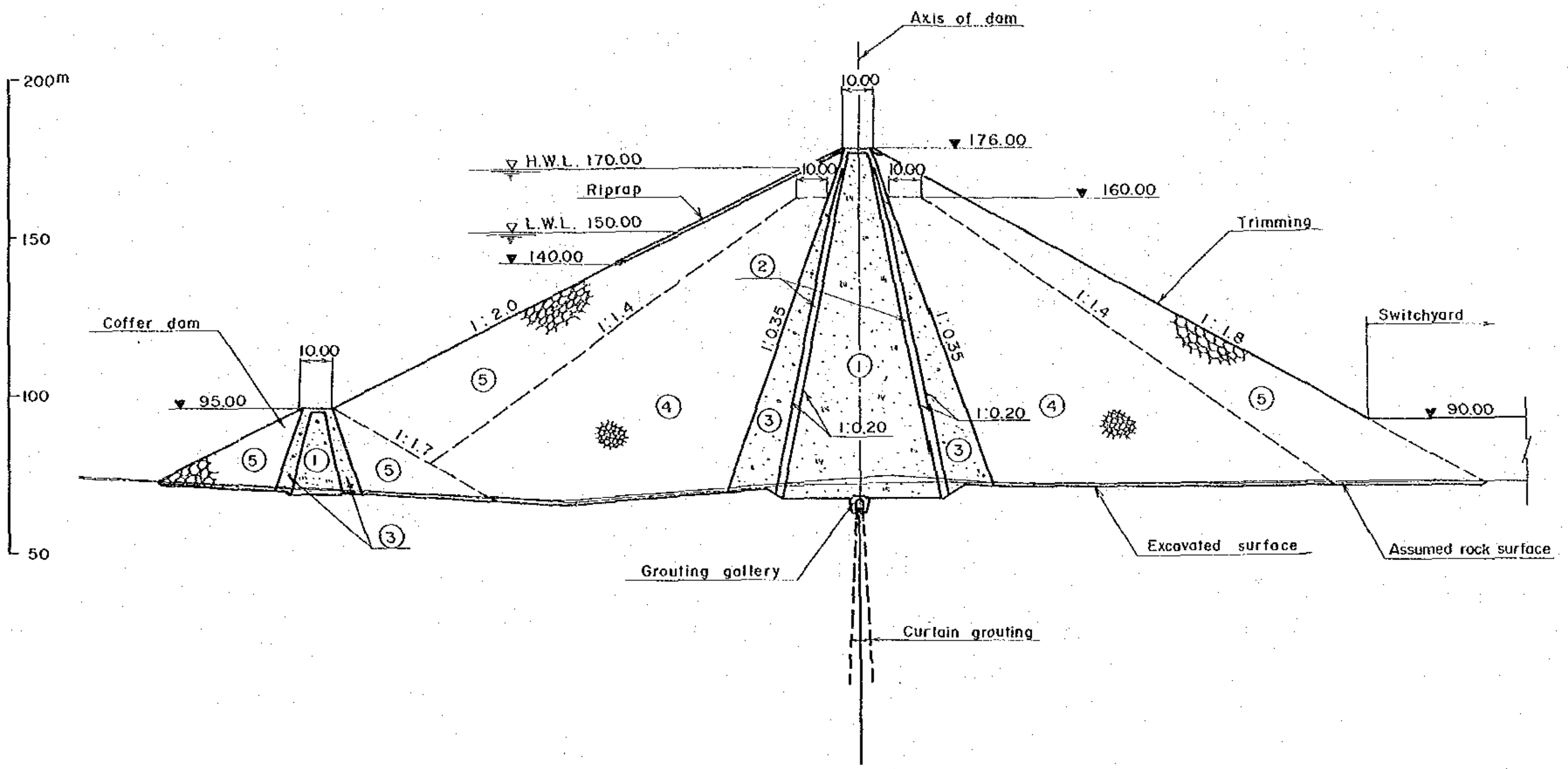


NAM YUAM PROJECT

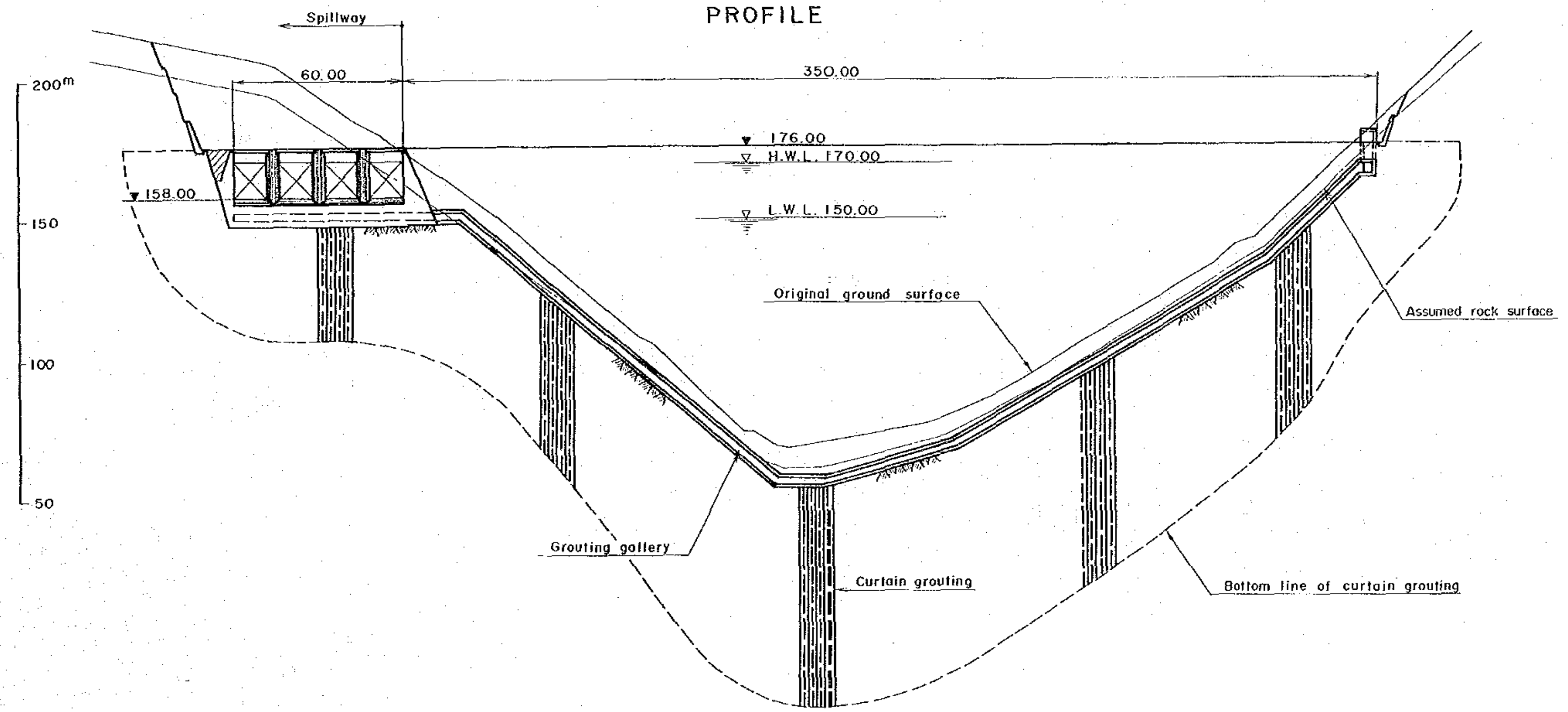
GENERAL LAYOUT

Fig. 6 - 1 | July, 1983

TYPICAL SECTION OF DAM

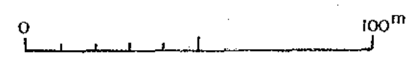


PROFILE



LEGEND

①	Impervious core
②	Filller fill
③	Transition fill
④	Smaller size rock fill
⑤	Larger size rock fill

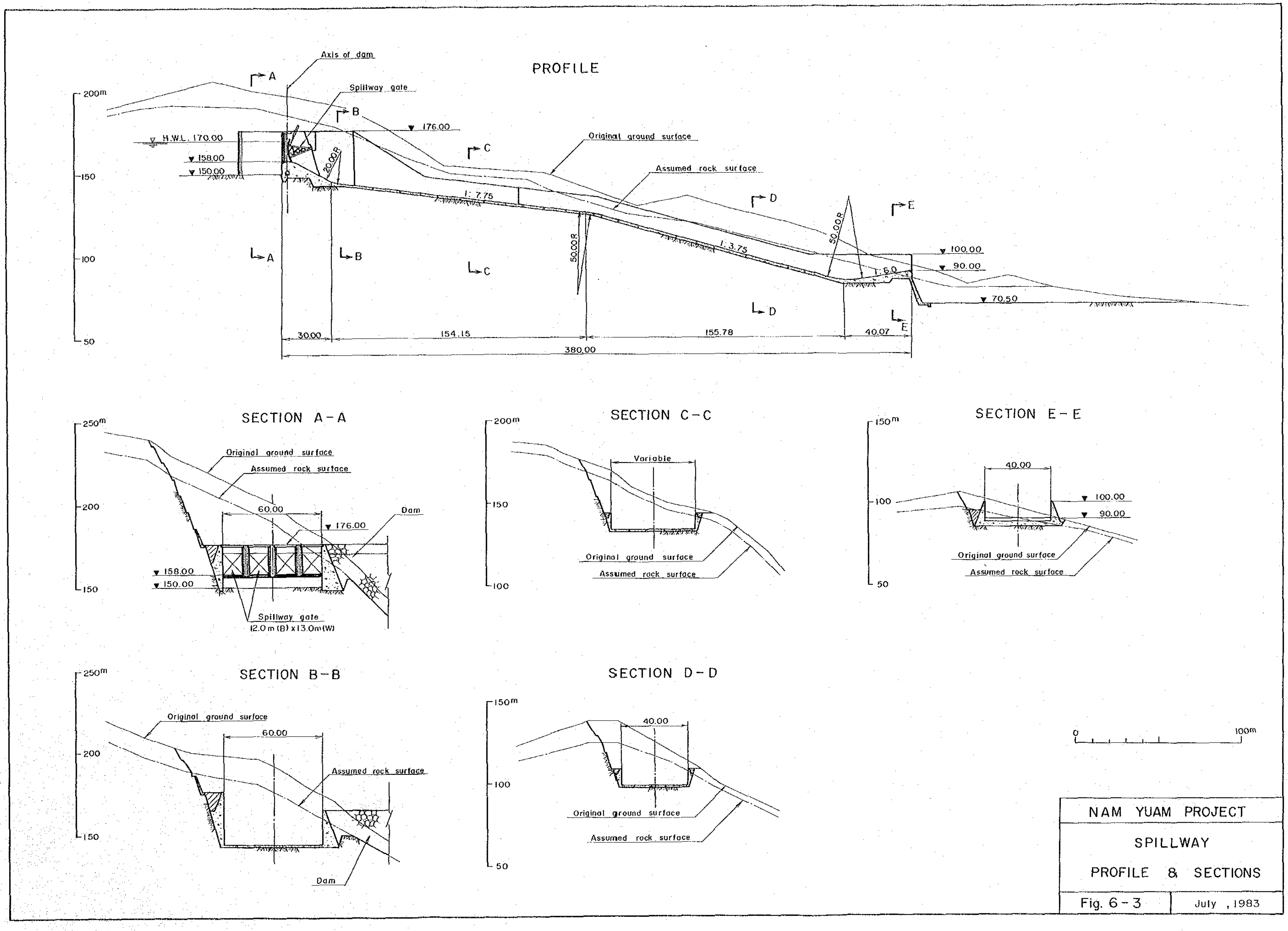


NAM YUAM PROJECT

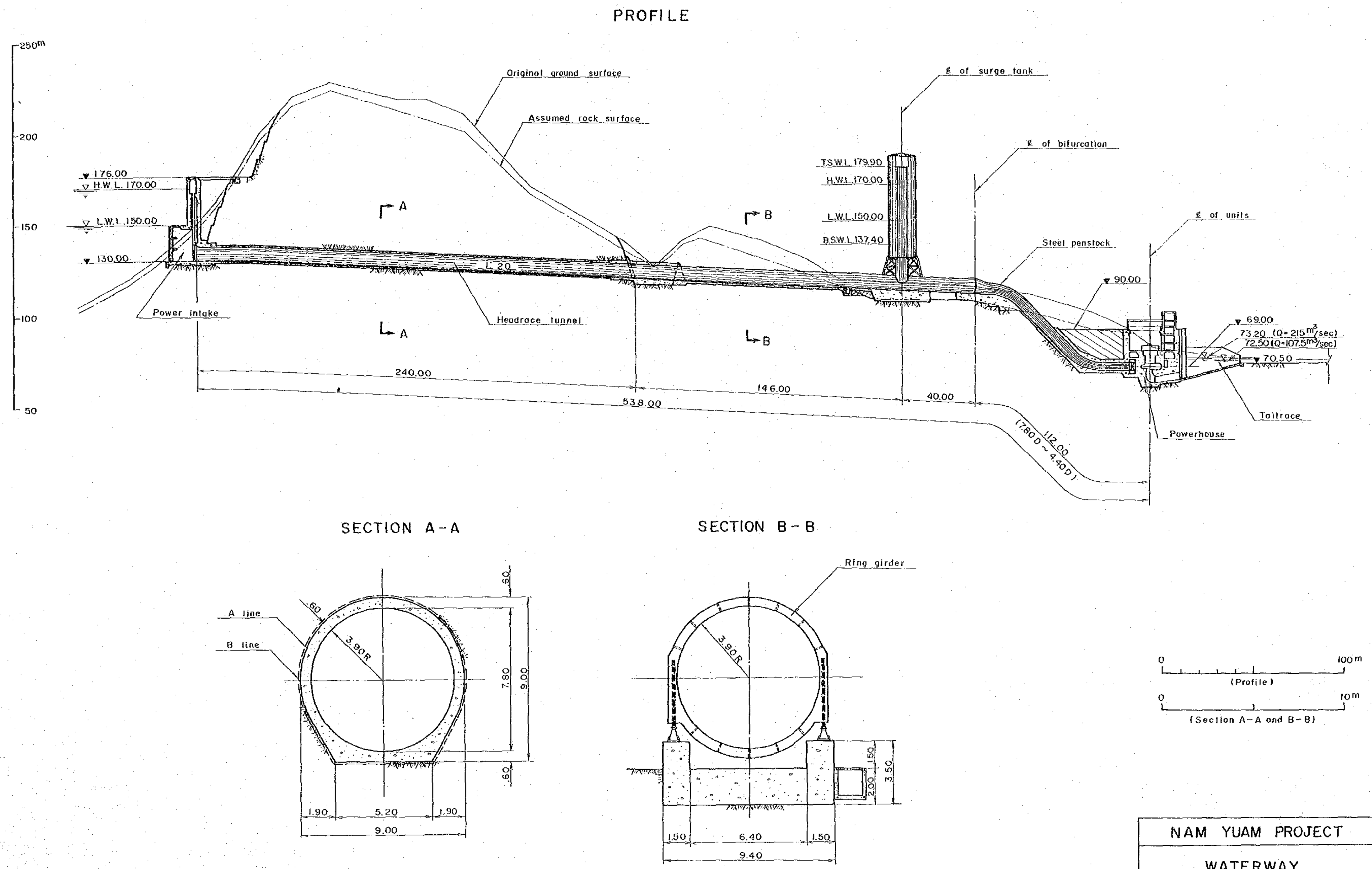
DAM

TYPICAL SECTION & PROFILE

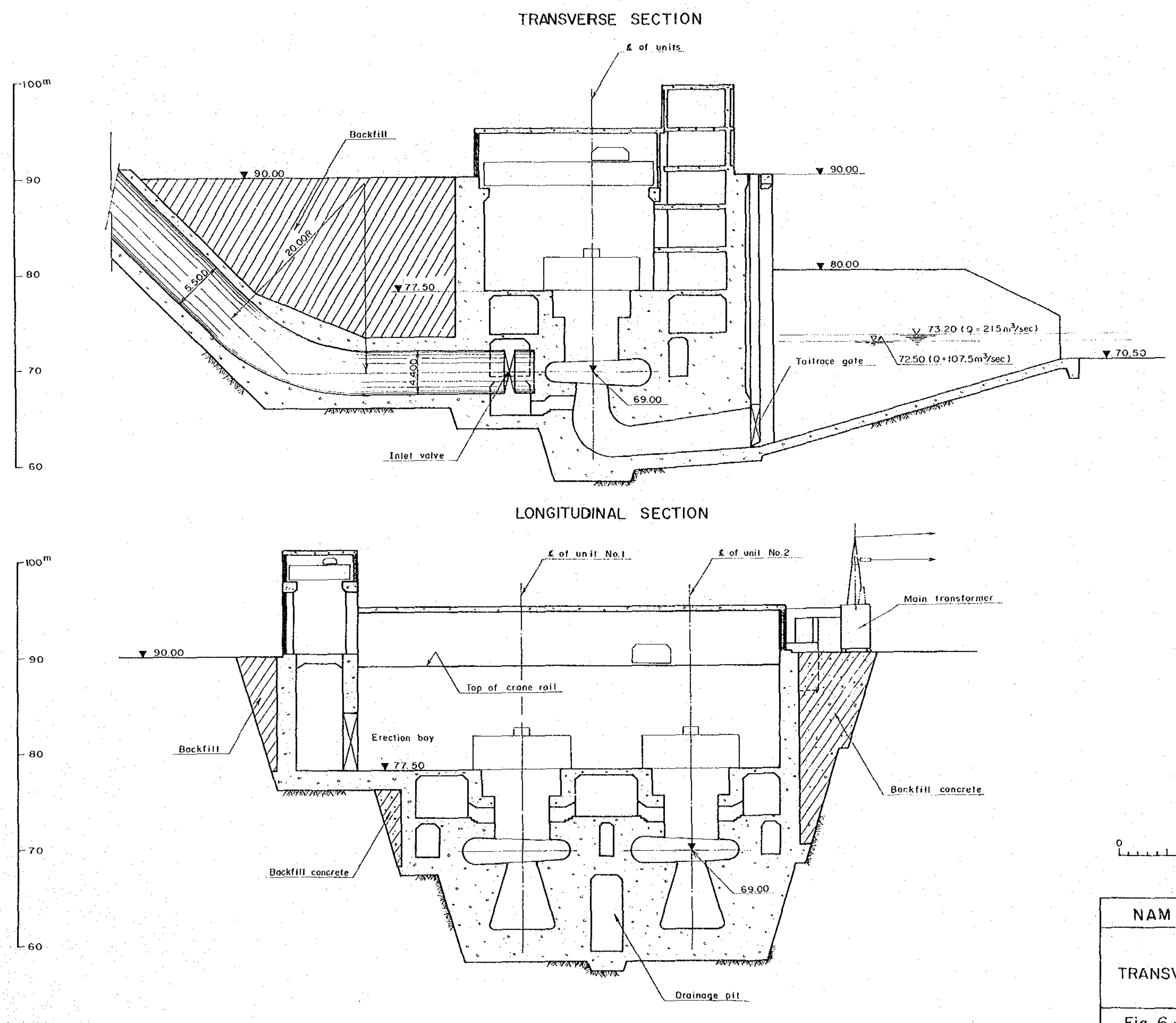
Fig. 6 - 2 | July ,1983



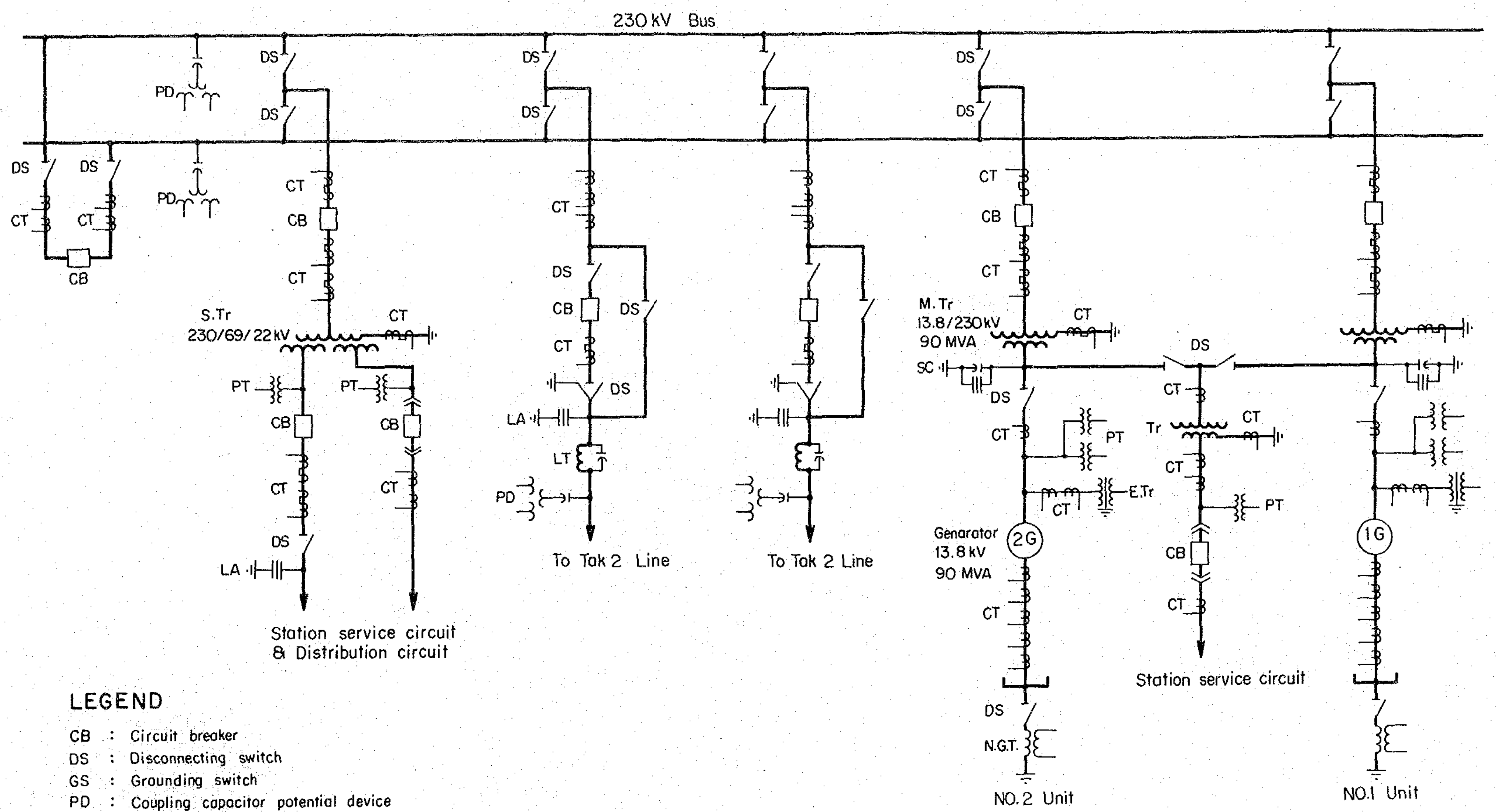
PROFILE
Axis of dam
Spillway gate
H.W.L. 170.00
176.00
158.00
150.00
20.00R
Original ground surface
Assumed rock surface
1: 7.75
50.00R
1: 3.75
50.00R
1: 6.0
100.00
90.00
70.50
30.00
154.15
155.78
40.07
380.00
200m
150
100
50
SECTION A-A
Original ground surface
Assumed rock surface
60.00
176.00
Dam
158.00
150.00
Spillway gate
12.0 m (B) x 13.0m (W)
250m
200
150
SECTION C-C
Variable
Original ground surface
Assumed rock surface
200m
150
100
SECTION E-E
40.00
100.00
90.00
Original ground surface
Assumed rock surface
150m
100
50
SECTION B-B
Original ground surface
60.00
Assumed rock surface
Dam
250m
200
150
SECTION D-D
40.00
Original ground surface
Assumed rock surface
150m
100
50
0
100m
NAM YUAM PROJECT
SPILLWAY
PROFILE & SECTIONS
Fig. 6-3
July , 1983



NAM YUAM PROJECT	
WATERWAY PROFILE & SECTIONS	
Fig. 6-4	July, 1983



NAM YUAM PROJECT	
POWERHOUSE TRANSVERSE & LONGITUDINAL SECTIONS	
Fig. 6 - 5	July , 1983



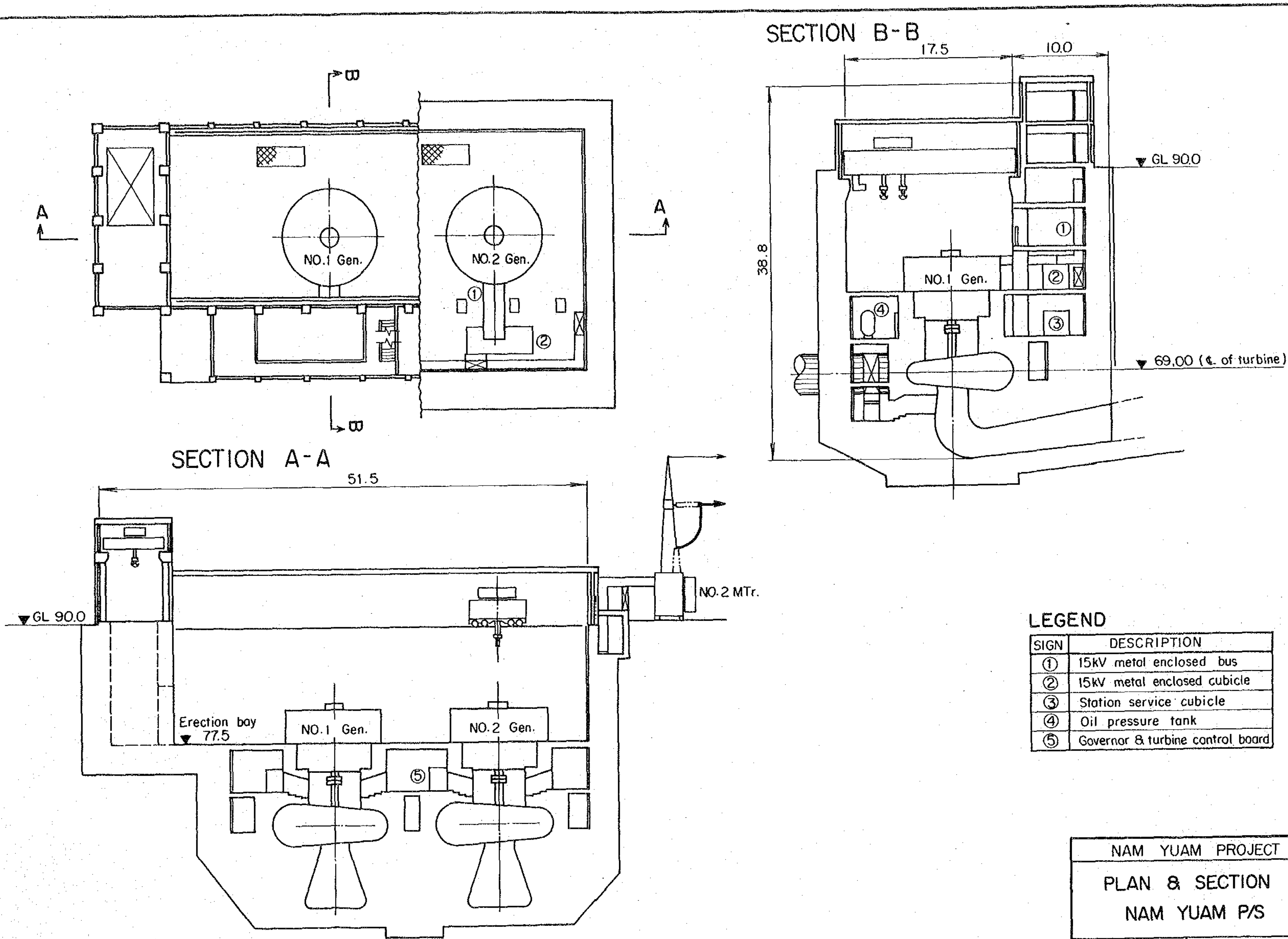
LEGEND

CB : Circuit breaker
DS : Disconnecting switch
GS : Grounding switch
PD : Coupling capacitor potential device
PT : Potential transformer
CT : Current transformer
LA : Lightning arrester
LT : Line trap
SC : Static condenser
M.Tr : Main transformer
E.Tr : Excitation transformer
N.G.T. : Neutral grounding transformer
S.Tr : Station service transformer

NAM YUAM PROJECT

SINGLE LINE DIAGRAM

Fig. 6-6 | March, 1984



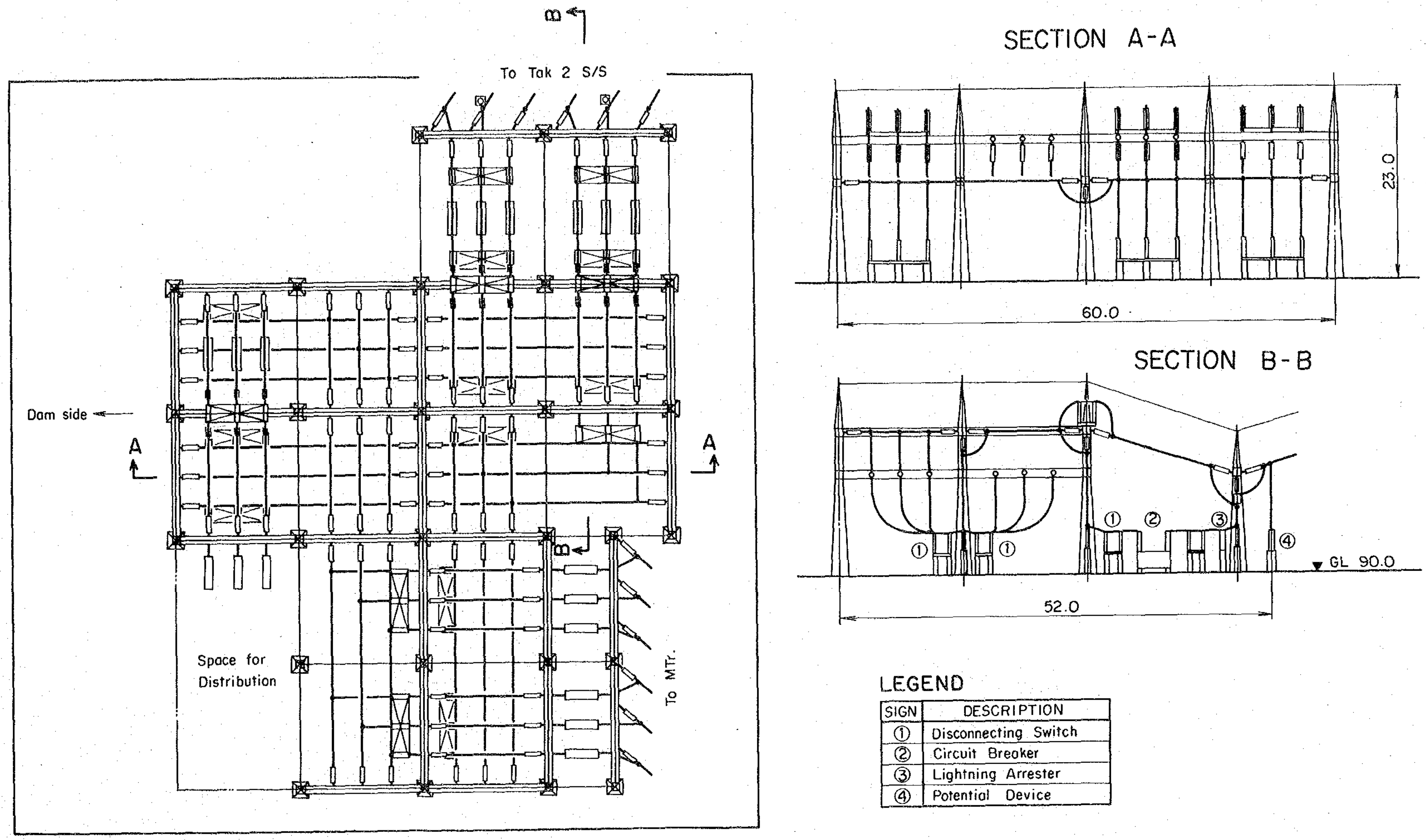
LEGEND

SIGN	DESCRIPTION
①	15kV metal enclosed bus
②	15kV metal enclosed cubicle
③	Station service cubicle
④	Oil pressure tank
⑤	Governor & turbine control board

NAM YUAM PROJECT

PLAN & SECTION
NAM YUAM P/S

Fig. 6-7 March, 1984



LEGEND

SIGN	DESCRIPTION
①	Disconnecting Switch
②	Circuit Breaker
③	Lightning Arrester
④	Potential Device

NAM YUAM PROJECT

PLAN & SECTION SWITCHYARD

Fig. 6-8 March, 1984

CHAPTER 7.

TRANSMISSION LINE SCHEME

CHAPTER 7. TRANSMISSION LINE SCHEME

7.1 Power Transmission System

The Nam Yuam project can be regarded to have a large effect mainly on two areas of major transmission system in Thailand i.e. the northern part (Region No. 4 of EGAT) and the Bangkok area (Region No. 1 of EGAT).

The outline of the power transmission system in these regions, power system development plan in future, and the demand forecast of each substation worked out by EGAT are summerized in Figs. 7-1 and 7-2.

1) Selection of power transmission scheme

In case the Nam Yuam project is put into the power transmission system, the various items considered in examining the required transmission system are as follows:

(i) The electric power generated by Nam Yuam project is to be mainly transmitted to Bangkok area that is the center of demand.

(ii) The transmission line should be the most advantageous taking its construction cost, convenience of maintenance and inspection, and transmission losses into consideration. Moreover, it is essential that power can be transmitted even during faulting outage of a single-circuit.

(iii) The transmission system should be comprehensively advantageous planning, considering the method of power transmission of Mae Pai and Mae Chaem project Ing-Yom Diversion Stage I to III project and other projects which are planned to be developed in the northern district after 1991 except Nam Yuam project.

(iv) For connecting to the power transmission system in Region 4 which consists of many long-distance transmission lines, it is necessary to consider not to deteriorate the existing transmission system's reliability.

The transmission distance, assuming that the transmission line from Nam Yuam power station is connected to the nearest power station or substation existed or planned, is more than 250km to Mae Moh power station, more than 195km to Chiang Mai 3 substation toward the north or the northeast, and more than 185km to Tak 2 substation toward the south.

For assuring highly reliable transmission, it is judged necessary to construct a 230kV, two-circuit, ACSR 1272 MCM transmission line after the various studies concerning optimum transmission voltage, corona disruptive critical voltage, conductor size, number of circuit, etc. as described in Clause 7.2 later.

The transmission system required to add for reinforcement for the Nam Yuam project should be examined by several methods of the connections, such as connecting to a power station or a substation existed or planned of norminal voltage of 230kV, or a substation of norminal voltage of 115kV together with the 230/115kV bus-tie transformer.
In consideration of new construction of a 230kV, two-circuit transmission line, the following three alternatives were examined:

A. Northern route

(a) Pattern N-①

Construction of a Chiang Mai 3 substation (230kV) and a

230kV, two-circuit, ACSR 1272 MCM transmission line from Nam Yuam power station to this substation.

(b) Pattern N-②

Construction of a 230kV, two-circuit, ACSR 1272 MCM transmission line from Nam Yuam power station to Mae Moh power station.

B. Southern route

(a) Pattern S-①

Construction of a 230kV, two-circuit, ACSR 1272 MCM transmission line from Nam Yuam power station to Tak 2 substation.

2) Comparison of power transmission scheme

The result of economic comparisons made for the various system's patterns, i.e., N -①, N -2, and S -① schemes, for the northern route and the southern route are as shown in Table 7-1.

The relationship between each system's pattern and EGAT's power development plan in the northern district in future are also shown in Figs. 7-3, 7-4 and 7-5, respectively.

Scheme N-① is such, as shown in Fig. 7-3, that a facilities of norminal voltage of 230kV is to be constructed newly in Chiang Mai 3 substation (115kV) at Chiang Mai region that is the center of power demand in the northern district, and is to connect the 230kV transmission line from Nam Yuam power station. This substation (230/115kV) should be completed before the Nam Yuam power station is put into power transmission system.

In case of connecting Nam Yuam power station to Chiang Mai 3 substation by the 230kV transmission line, peak load in 1993 at the district lying north of Mae Moh power station is about 350MW while the supply capability by the northern hydropower stations, assuming that Nam Pai, Kud, Mae Kok, Mae Chaem and Nam Yuam power station have been all completed, reaches 750MW in total by the above power station. Therefore, about half of the produced power by these hydropower stations should be transmitted to Bangkok area, the center load, from Mae Moh power station.

For this scheme, transmission loss is relatively large because the electric power generated by Nam Yuam power station is sent to the area going away from the center load.

For N-② scheme, the 230kV transmission line to be connected from Nam Yuam power station to Mae Moh power station holding the facilities of norminal voltage of 230kV as the northern route, as shown in Fig. 7-4, the transmission distance is the longest, the construction cost is thus the highest and transmission loss is the largest among three schemes.

For S-① scheme, as shown in Fig. 7-5, the 230kV transmission line to be connected to Tak 2 substation of which construction is under planning, the load center is the nearest and the transmission distance is the shortest and therefore, the construction cost is the least and transmission loss is also the smallest among three schemes. Since Tak 2 substation planned by EGAT is a plan by a single-circuit π-branch from one of three-circuit of 230kV transmission lines between Bhumibol power station and Nakhon Sawan substation, it is necessary to modify the system configulation to three-circuit π-branch.

This scheme, namely, the 230kV transmission line to be connected to Tak 2 substation newly planned between Bhumibol power station and Nakhon Sawan substation of the long distance 220.6km transmission line, can safely send the electric power generated by Nam Yuam power station attempting to improve the stability by increasing the bus voltage at Tak 2 substation, and also is possible to interconnect between other power stations or substations such as Mae Moh power station in future. Therefore, it is judged to be the most advantageous scheme among three ones.

The modification from a single-circuit π-branch to three-circuit π-branch shall be completed before the Nam Yuam project is connected to this substation.

Comparing the respective schemes with the annual cost including the transmission losses, the scheme S-① will be the most economical and the scheme N-② will be the most costly.

Even if taking only energy loss into account as the transmission loss, the annual cost inclusive of transmission loss, the scheme S-① in which transmission distance is the shortest will also be economical and the scheme N-② will be the highest.

3) Power system analysis

Reinforcement for transmission of the electric power generated by Nam Yuam power station requires to construct the transmission line of norminal voltage of 230kV as mentioned above. However, in respect of each route, the northern route plan cannot be said to be advantageous compared with the southern route plan.

Therefore, the route for Nam Yuam project is to be southern plan where the transmission line of 230kV, two-circuit, ACSR 1272 MCM is constructed, and stability calculation for the scheme S -① were carried out.

(i) Power flow and voltage regulation

Power flow calculations were carried out based on EGAT's power development plan and load forecast in 1991. The results are indicated in Figs. 7-6 and 7-7, respectively.

Regarding power flow calculation, the load side voltage of each power station and substation were mainly examined to be kept in 95 to 105% of norminal voltage on major power transmission system of Region 4 and Region 1.

a) Peak time

In case the load-side voltage of transformer sets to 96%, except that 69kV systems of Saraburi 2 substation and Rangsit substation are necessary to equip power capacitor, the generator voltage and bus voltage of each power station and substation are kept at 95 to 105% of norminal voltage except the bus voltage of norminal voltage of 230kV of Saraburi 2 substation.

b) Off peak time

Tha Tako substation is necessary to equip with shunt reactor to keep less than 104.5% of norminal voltage of 500kV. And Nam Yuam power station is necessary to have the ability of leading power factor operation. Except for the bus voltage of Lom Sak substation connected to the system of Region 2, the generator voltage and bus voltage of each power station and substation in Region 4 and Region 1 are kept at 95 to 105% of norminal voltage.

The voltage regulation of the entire power system in Thailand was not throughly studied because the study is out of the scope of works. Accordingly, in this examination, the influence especially, concerning voltage aspects, is coming on Lom Sak substation and Saraburi 2 substation connected to the system in Region 2. The voltage regulation of the entire power system should be separately studied.

The scheme S-① will not have parts which will become overload even though there may be faulting and outage of one-circuit of the transmission system between Nam Yuam power station and Tak 2 substation.

(ii) Stability study

Transient stability calculation was carried out for the power system at peak time in 1991. The study led to the conclusion that this scheme have no generators stepping-out and have no problem as to stability. Transient stability calculation at the off peak time in 1991 was not carried out.

In the transient stability calculation, a change of an angular position of each rotor succeeding to a disturbance in the power system were calculated based on a time when a three-phase fault of one-circuit with a fault-clearing time of 5 cycles which is thought to give the most severe effect to transient stability generated near the 230kV bus of Nam Yuam power station side of the transmission line between Nam Yuam power station and Tak 2 substation. The results is shown as a function of time (swing curves) in Fig. 7-8.

Judging from the swing curves, no generator stepping-out were found out within two-second of the calculating time but curves indicate some tendency of diverging. As for this tendency, it is judged there is no problem because this transient stability calculation were carried out based on the most severe condition, namely, back voltage behind x_d' is constant, damping characteristics, AVR effects and governor effects are not included.

4) Conclusion

The following plans are recommended measures for the necessary strengthening of the system related to the development of the Nam Yuam project.

(i) Construction of a 230kV, two-circuit, ACSR 1272 MCM transmission line from Nam Yuam power station to Tak 2 substation.

(ii) Tak 2 substation changes the plan from a single-circuit π-branch plan, originally prepared by EGAT, to a three-circuit π-branch, and connects the 230kV, two-circuit, ACSR 1272 MCM transmission line coming from Nam Yuam power station.

The following plans are also recommended measures for the necessary strengthening of the system related to the future development of hydropower, pumped storage power, and increased power of the existing power stations, in the northern district.

(i) It is preferable from the standpoint of supply reliability, voltage, and power flow aspects, to strengthen up from the existing 230kV, two-circuit transmission line to three-circuit transmission line between Nakhon Sawan substation and Ang Thong 2 substation.

(ii) It is preferable that the generator of Nam Yuam power station can be operated for synchronous condenser operation of about 75 MVar according to the system analysis, otherwise, equivalent shunt reactor will be necessary to be installed in the vicinity.

7.2 Preliminary Design of Transmission Line

1) Transmission line route

As a method for connecting electric power of 162MW generated by Nam Yuam power station to the nationwide supply grid, as stated hereinbefore, the north-directed and south-directed routes have been taken as the object of examination, and it has been ascertained that the south-directed route connected to 230kV transmission line existing between Bhumipol power station and Nakhon Sawan substation is more advantageous than the north-directed route.

The south-directed route to be constructed in this project is outlined hereunder. Reference is to be made to Fig. 7-8.

When constructing the transmission line, the availability of the existing roads which can be utilized for transporting the machines and materials has great effect on the construction costs. Nam Yuam power station site is situated in the most under-developed mountaineous area northwest in Thailand and the conditions having access there are impressively poor. A section of about 30km ranging from the power station to Ban Tha Song Yong is covered with steep mountains and jungles, and there are none of the existing roads allowing the vehicles to enter. This section is the worst of the whole route in view of access conditions.

Next 50km section of Ban Tha Song Yang to Tha Song Yang, the route runs in parallel with the borderline of Thailand and Burma. Although a few straggling hamlets are seen in this section, no good access conditions are expected.

Following 40km from Tha Song Yong to Mae Ramat, the route runs in parallel with the well paved national highway. No difficulty in the construction will be encountered in this section.

The route begins to run apart from the borderline at the point of Mae Ramat. The route is also arranged to take the shortest cut between Mae Ramat and Tak 2 substation site. Although the route stretching for 65km passes through undulated but fairly developed areas, no serious problems are encountered in access thereto.

When the F/S mission visited the project site in December, 1982, the new road from Mae Sariang of Mae Hongson Province to Tha Song Yong of Tak Province were under construction. The section of Mae Sariang to Ban Sop Ngao had already been completed. In case the remaining sections of the road are to be completed before the biginning of construction of the transmission line, by means of this road, greater advantages could be expected. It is shown by dotted line in Fig. 7-9.

Therefore, it is recommended that the implementing agency of the Yuam project familiarizes themselves with the actual condition of the said road project and reflect the results of such informations in the selection of transmission line route.

In selecting Tak 2 substation site, it is essential that deliberate considerations be given to relation with the proposed

115kV transmission lines, connecting route of one circuit 230kV line and to coordination with residential areas etc.

2) Transmission line voltage and number of circuits

In order to transmit stably 162MW of Nam Yuam generated power via 185km line, 115kV is not sufficient. 230kV, one step higher voltage in the system is required. As for the number of circuits, two circuits would be required by reference to the criteria currently adopted by EGAT in connection with operation of their transmission line facilities.

3) Phase conductor

The size of conductor is determined in view of ampacity which corresponds with 162MW power of the Nam Yuam, line stability and corona disruptive critical voltage etc. Corona disruptive critical voltage was a dominant factor for the said feature incorporated in this project. ACSR 1272 MCM was selected upon examination of EGAT's standards as well.

4) Lightning protection

According to the observation data of lightning covering from the northern to the central district in Thailand in 1951 to 1975, the values of minimum IKL (isokeraunic level) 65 at Utaradit and maximum IKL 113 at Don Muang have been recorded, respectively. Since it is believed the area where the transmission line passes through has frequent thanderstorms, two wires of $70mm^2$ GSW are to be installed on the top of a steel tower with a shield angle of less than 15° and is expected to produce 100% shielding effect.

Besides the above, arching horns are also to be installed on every insulator string in order to protect insulators from breakage due to flashover.

5) Types and number of insulators fitted

The insulation design of 230kV transmission line has been examined as an effective grounding system with the maximum line voltage of 240kV and route elevation of less than 1,000m.

Since the route passes inland, it can be judged that there is no possibility of contamination due to damage by salt, therefore a switching surge unusual voltage becomes a determinant of the number of insulators fitted.

As for the number of insulators, maintaining favorable coordination with the existing facilities of EGAT, it has been decided that 14 pieces of 250mm standard suspension insulator are fitted to the suspension device and 15 pieces, to the strain device, respectively.

6) Support structure

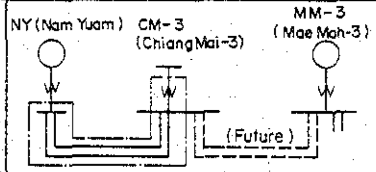
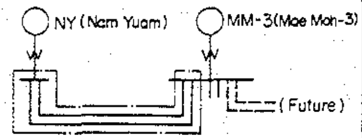
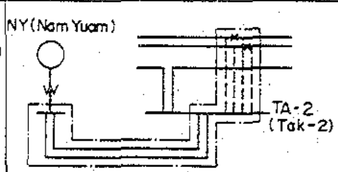
According to EGAT's design criteria on transmission line steel tower, the design wind velocity as stipulated herein is 29m/sec corresponds with 52.5kg/m^2 for overhead wires and 70kg/m^2 x 2.6 = 182kg/m^2 for steel towers. Since this values are considered reasonable, judging from meteorological records in Thailand, the same criteria are to be applied for this preliminary design. Fig. 7-10 shows a standard suspension tower for this Project.

7) Features of transmission equipment

The transmission line to be constructed in this project is outlined below.

Section	: From Nam Yuam power station to Tak 2 substation
Distance covered	: Approx. 185km
Voltage	: 230kV
Electrical system	: Three-phase, three-wire, 50Hz
Number of circuits	: 2
Conductor	: Aluminum Conductor Steel Reinforced (ACSR) 1,272 MCM single conductor
Overhead ground wire	: Galvanized steel stranded wire of $70mm^2$ x 2 lines
Insulator	: 250mm standard suspension type insulator x 14 pcs. connected
Support	: Angle tower with vertically-arranged 2 circuits

Table 7-1 Economic Comparison for the Selection of 230kV Power System for Nam Yuam Project

Items \ Pattern	N - ①	N - ②	S - ①
Power System Diagram			
Transmission Line			
Voltage kV	230	230	230
Number of circuit	2	2	2
Conductor size	1272 MCM ACSR	1272 MCM ACSR	1272 MCM ACSR
Distance km	195	250	185
1 Construction Cost (M฿)			
(1) Lines	600.8	770.3	619.3
(2) Equipment of station	84.9	16.8	50.3
(3) Total	685.7	787.1	670.6
2 Annual Cost (M฿)	81.6	92.6	79.2
3 Line Losses			
(1) Power (MW)	2.9	3.7	2.7
(2) Annual energy (GWH)	13.1	16.8	12.5
4 Cost of Losses (M฿)			
(1) Power	5.5	6.8	5.1
(2) Annual energy	14.3	18.1	13.5
(3) Total	19.8	24.9	18.6
5 Total Annual Cost Including Line Losses (M฿)			
2 + 4(3)	101.4	117.5	97.8
2 + 4(2)	95.9	110.7	92.7

Note : 1. ⌐⌐ Planned transmission line and or substation for Nam Yuam
2. Annual Cost Factor 0.1173 for lines
0.1302 for equipment
3. Cost of Losses 1.1 M฿/MW for Gas Turbine
3.0 M฿/MW for Coal Fired Thermal
3. Cost of Losses 3.21 ฿/KWH for Gas Turbine
0.68 ฿/KWH for Coal Fired Thermal
4. Construction Cost includes the cost for the line bays CM-3, MM-3, and TA-2, the cost for the increased lines TA-2, and the cost for the substation CM-3
5. Line Losses for the increased lines of TA-2 is not included

Fig.7-1 Electric Power System of Main Part of Thailand in 1990

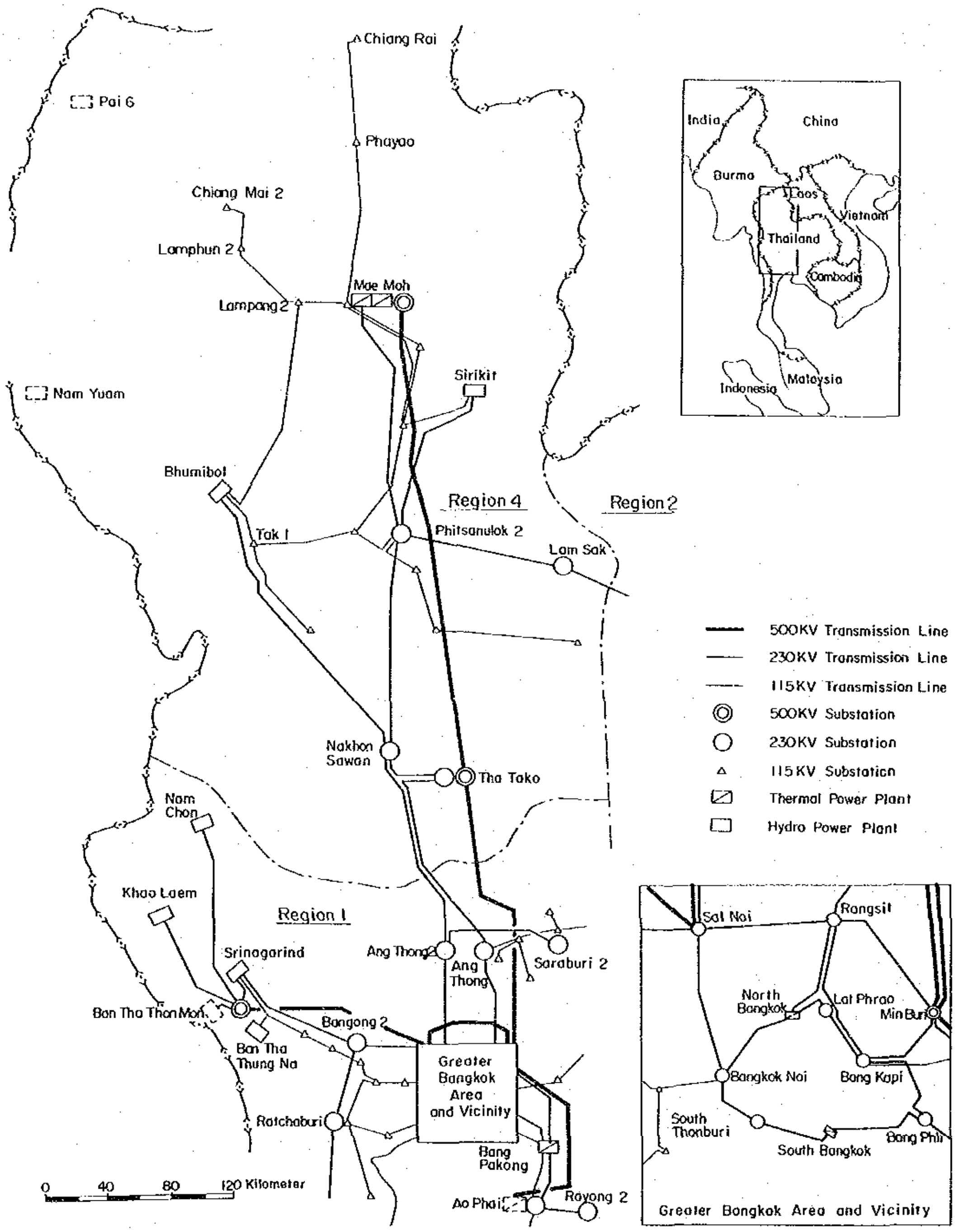


Fig. 7-2 EGAT'S Power System Development Plan (1991-1995)

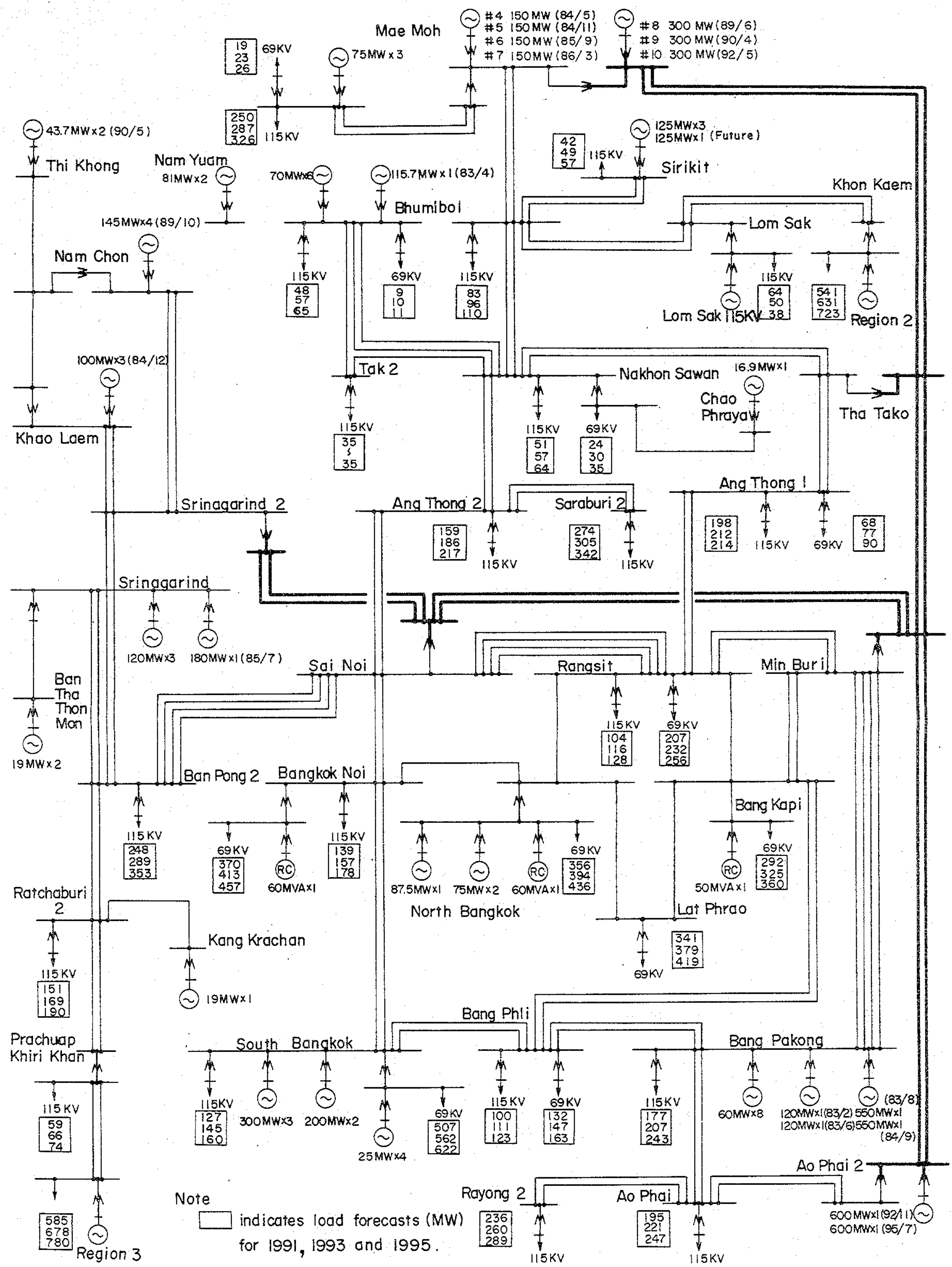


Fig. 7-3 Pattern N-①

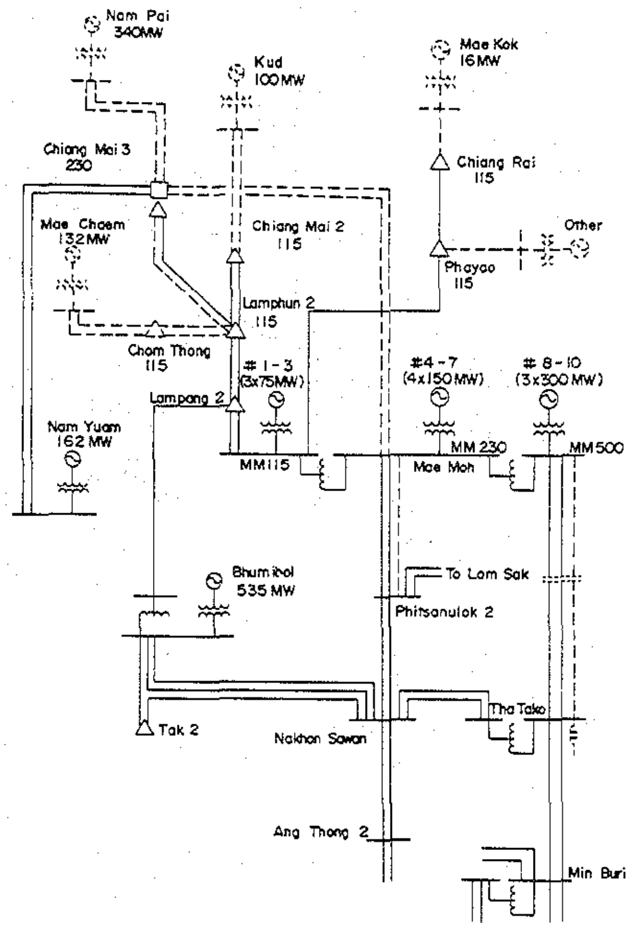


Fig.7-4 Pattern N-②

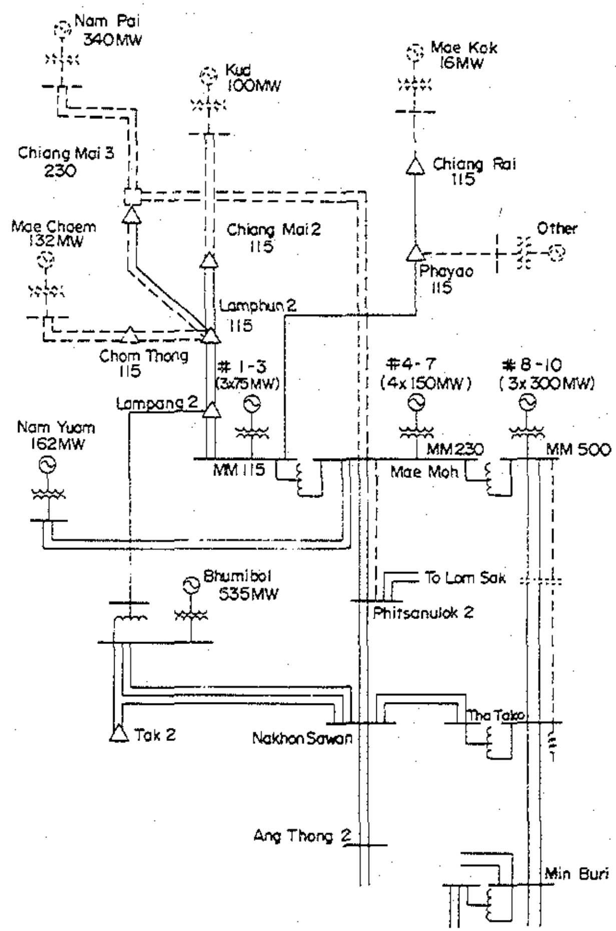


Fig. 7-5 Pattern S- ①

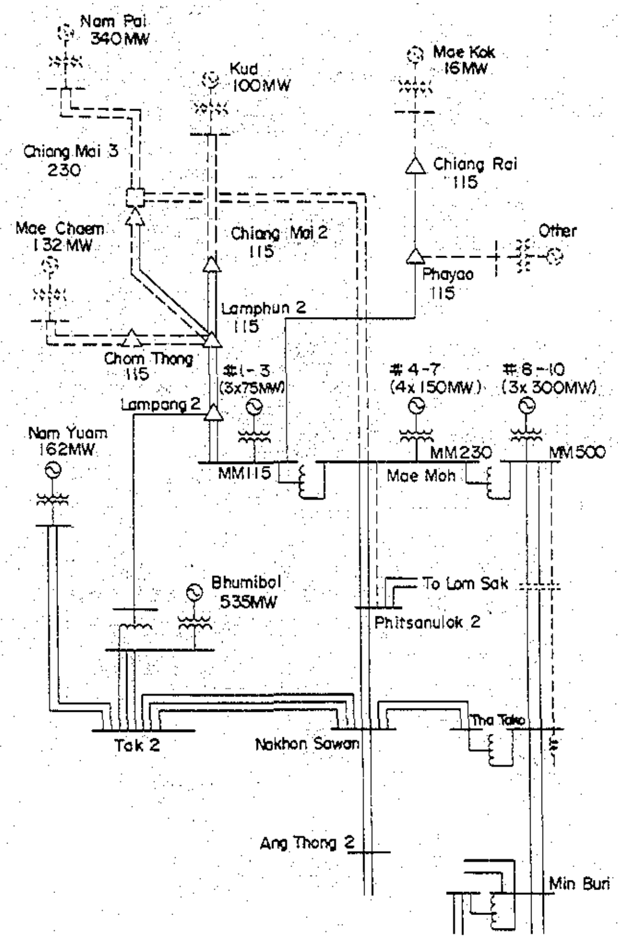
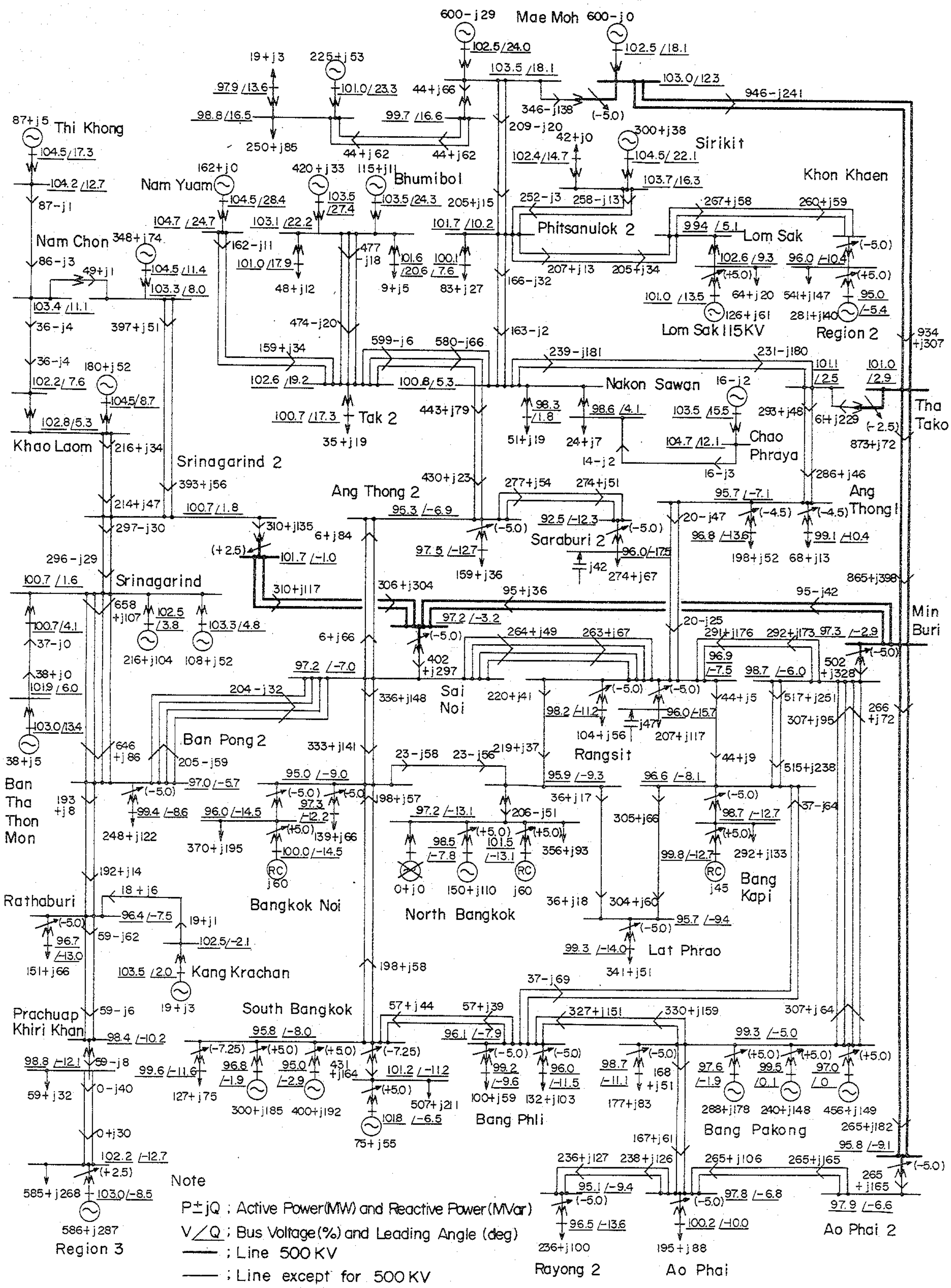


Fig. 7-6 Power Flow Peak Time in 1991



Note

P±jQ ; Active Power(MW) and Reactive Power (MVar)

V/Q ; Bus Voltage(%) and Leading Angle (deg)

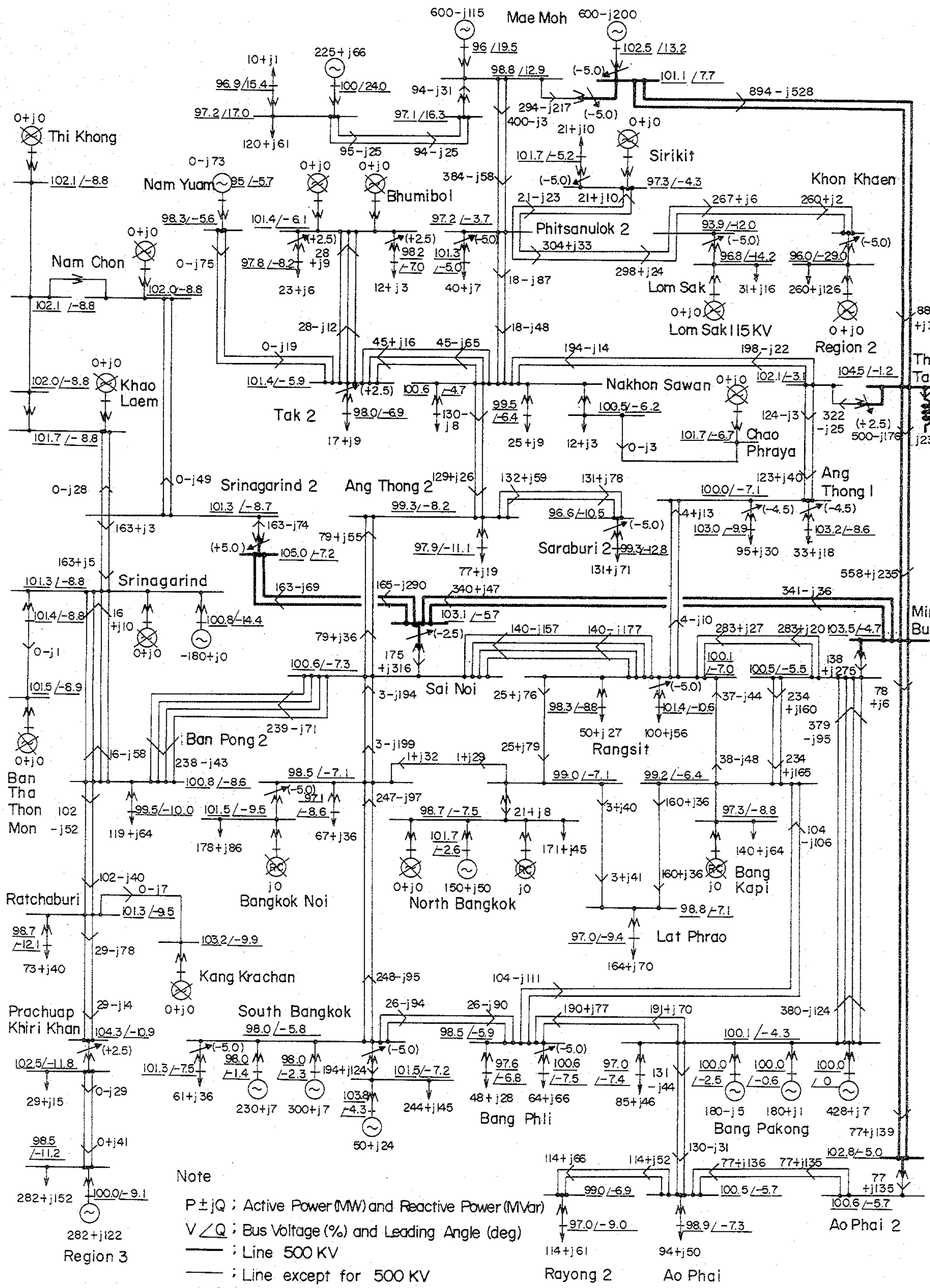
━━ ; Line 500 KV

—— ; Line except for 500 KV

↗( ) ; % Tap

Total Loss ; P±jQ = 144 - j296

Fig.7-7 Power Flow Off-Peak Time in 1991



Note

P ± jQ ; Active Power (MW) and Reactive Power (MVar)

V ∠ Q ; Bus Voltage (%) and Leading Angle (deg)

—— ; Line 500 KV

—— ; Line except for 500 KV

↗ ( ) ; % Tap

Total Loss ; P ± jQ = 62 - j1675

Fig. 7-8 Transient Stability Study for Nam Yuam Project Transmission System

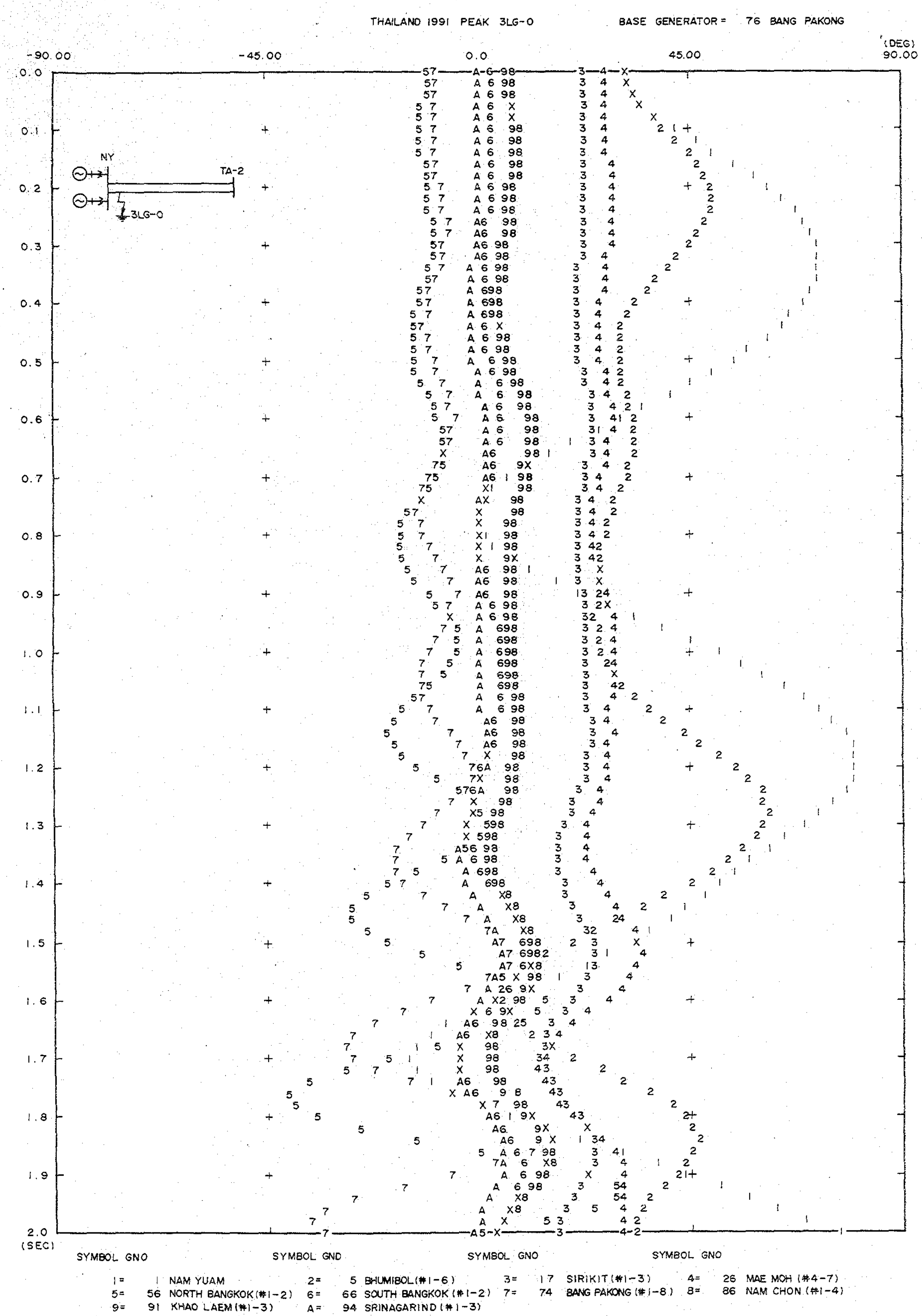


Fig. 7 - 9 230kV Transmission Line Route

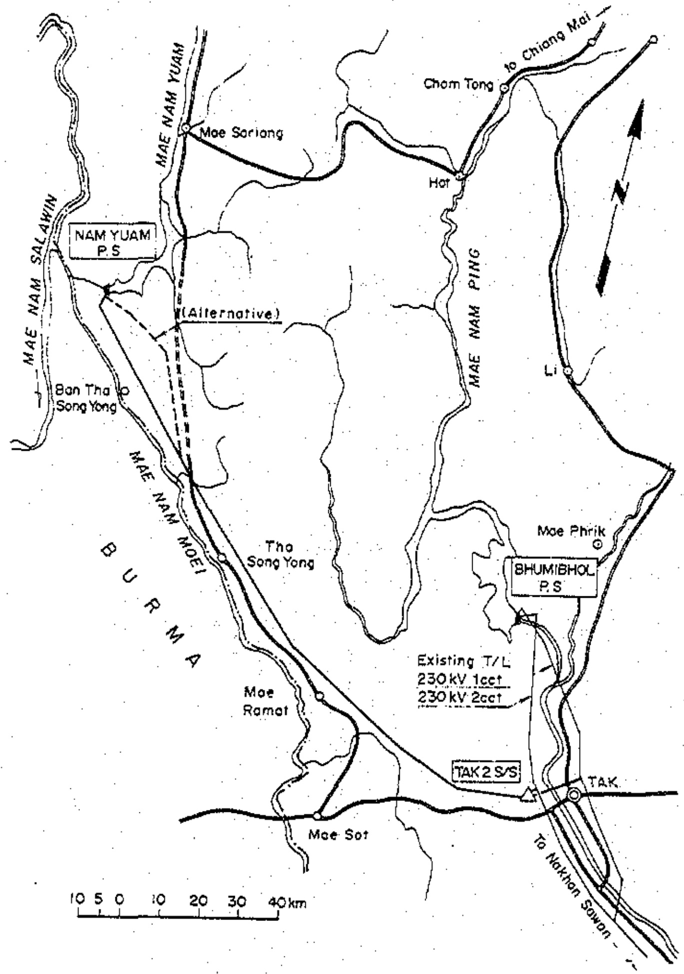
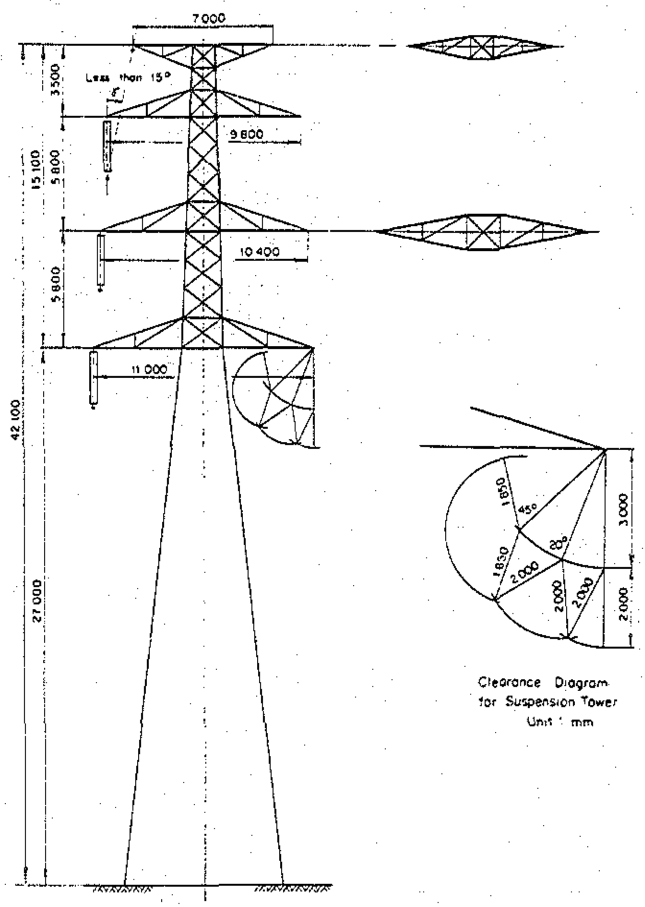


Fig. 7 - 10 230kV Transmission Line Standard Suspension Tower



CHAPTER 8.

CONSTRUSTION PLANNING AND COST

CHAPTER 8. CONSTRUCTION PLANNING AND COST ESTIMATION

8.1 Construction Planning

Fig. 8-1 shows the construction schedule of this project. This was made, taking into consideration the construction scale, its methods, locations of structures, weather conditions, etc.. It takes 5 years and a half (5.5 yr) in total for construction, i.e., from the starting of construction to that of operation of power plants. The condition for carrying this schedule out is that making roads for construction and arranging camping facilities should be completed beforehand.

The following is the outline of the construction as well as about roads for construction. As shown in Fig. 1-2 "Location Map of the Project", two alternative routes for construction road are planned.

Alternative Route 1 crosses Yuam river to the right bank at around Ban Mae Khatuan (2.1km in length), and then from Ban Mae Khatuan to Ban Tha Rua, the existing road which has been constructed by the Department Mineral Resources (24.5km in length) can be used after improving the present road condition. Further new construction road (19.3km in length) has to be constructed along the right bank up to the projected sites. This route takes 45.9km in total length.

Alternative Route 2 crosses the Yuam river at the junction with the Ngao river, and then goes to Ban Tha Rua through the road to be built newly along the right side of the Yuam river (11.1km in length), and takes the same route as Route 1 to the site. This route takes 30.4km in total length.

Comparing these two routes, Route 2 has been judged appropriate. Although Route 1 advantageously has shorter distance of newly constructed road, the existing portion of the route is poor in its alignment and longitudinal gradient which should be improved for heavy equipment and thus requires large amount of improvement cost rendering the total cost thereof higher than of Route 2. In addition, Route 1 passing over a mountain of 800m in elevation would have difficulties in maintenance and repair during the project's construction period. The road in Route 2 should be completed before the commencement of the main construction works.

Diversion tunnel construction works start at the beginning of the dry season of the first year, and is to be completed by the beginning of the dry season of the second year. At this point, the river flow is to be diverted into the diversion tunnel. The excavation of the dam foundation is to be started from the upper part, and after turning the river flow into diversion tunnel, excavation works of the river bed is to be started. The embankment work of the dam starts from the upstream cofferdam, and successively moves to the main body of the dam. Three years and a half (3.5 yr) are estimated for the dam embankment work, and this work is to be completed by the beginning of the dry season of the fifth year. During this period, foundation treatment of the dam and construction of spillway are going on in parallel.

For rock material, quarry of calcareous sandstone is considered, which found on the left bank of the river, about 1km upstream from the damsite. Also, the excavated rock from spillway construction and other construction's should be fully used. As for filter material and concrete aggregate, there is no natural ones nearby, and so they should be made artificially. Core material is full in talus deposit of weathered shale, and in soil on the surface of spillway, and in the quarry.

Immediately after the dam is completed, the installation of the outlet works are to be started and are to be completed by the end of the dry season of the sixth year.

As for the filling reservoir, the average discharge at Ban Tha Rua Gauging station indicates that, the filling reservoir is started from April, thus the reservoir surface level will be able to reach up to the NHWL by the middle of July. Construction works for intake, headrace, surge tank, penstock, etc. are started from the second year respectively, and are to be carried out in parallel. As for the construction of power station, after the installation of the overhead crane, as the construction progresses, the installation works of turbine and generator are to be started and to be completed within about one year and a half (1.5 yr). After the various test for the commencement of operation which are to be performed while reservoir filling, the operation of power plants could be in service in the middle of July of the last year (6th yr.).

It is planned that the construction of power transmission lines and switchyard are to be carried out during the installation of turbine and generator and to be completed at the same time as turbine and generators are completed.

8.2 Construction Cost and Financial Program

Construction cost of this project is estimated refering to the labor wages, unit prices of construction materials, unit construction cost of the similar projects, etc., as of December 1982 price level in Thailand. Among labor wages, material costs, machinery costs, etc., those which can be provided in Thailand are estimated in local currency, and the others are estimated in foreign currency.

Yearly financial program is figured out over the whole construction period, assuming the actual amount of payment in each year being calculated on the basis of construction schedule, and procedure of payment familiar in Thailand being taken into consideration. These considerations were also taken in the case of hydraulic equipment, electrical equipment, etc.. These are on Table 8-1 and 8-2.

8.3 Investigations Necessary Hereafter

1) Topographical mapping

For the layout of roads for construction, a topographical map in a scale of 1:2000 or of 1:5000 is necessary. Preferably, the mapping is to be made along the Route 2 by interpretation of aerial photograph.

2) Geological investigation

Along the planned route, geological investigation by reconnaissance is necessary. Also, investigation, preferably by boring, is necessary where construction of long spaned bridges is planned.

Table 8-1 Construction Cost

Unit: 10^6 Baht

Item	Total	Currency	
		Foreign	Local
Preparation Works Camp, Road, Compensation Clearing, Contingency	610.0	98.6	511.4
Civil Works			
Diversion & Care of River	261.0	58.9	202.1
Dam	893.0	467.7	425.3
Spillway	519.0	81.0	438.0
Outlet Works	41.0	5.9	35.1
Intake	25.0	2.7	22.3
Head-race	49.0	10.0	39.0
Surge Tank	32.0	2.8	29.2
Penstock	69.0	13.0	56.0
Power Station	213.0	20.9	192.1
Tail-race	31.7	5.2	26.5
Miscellaneous	93.8	35.5	58.3
Contingency	222.5	70.4	152.1
Sub-total	2,450.0	774.0	1,676.0
Hydraulic Equipment			
Diversion Gate	9.8	0.5	9.3
Spillway Gate	43.8	34.2	9.6
Intake Gate	25.4	21.6	3.8
Tail-race Gate	8.0	6.8	1.2
Outlet Valve	19.5	16.6	2.9
Penstock	90.0	67.5	22.5
Surge Tank	66.0	49.5	16.5
Contingency	26.5	19.3	7.2
Sub-total	289.0	216.0	73.0

Item	Total	Currency	
		Foreign	Local
Electrical Equipment	628.8	534.5	94.3
Telecommunication & Transmission Line	606.6	424.6	182.0
Engineering Fee	137.6	82.6	55.0
Total	4,722.0	2,130.3	2,591.7
Interest during Construction	1,026.0	—	1,026.0
Total Project Cost	5,748.0	2,130.3	3,617.7

Table 8-2 Financial Program

Unit: 10^6 Baht

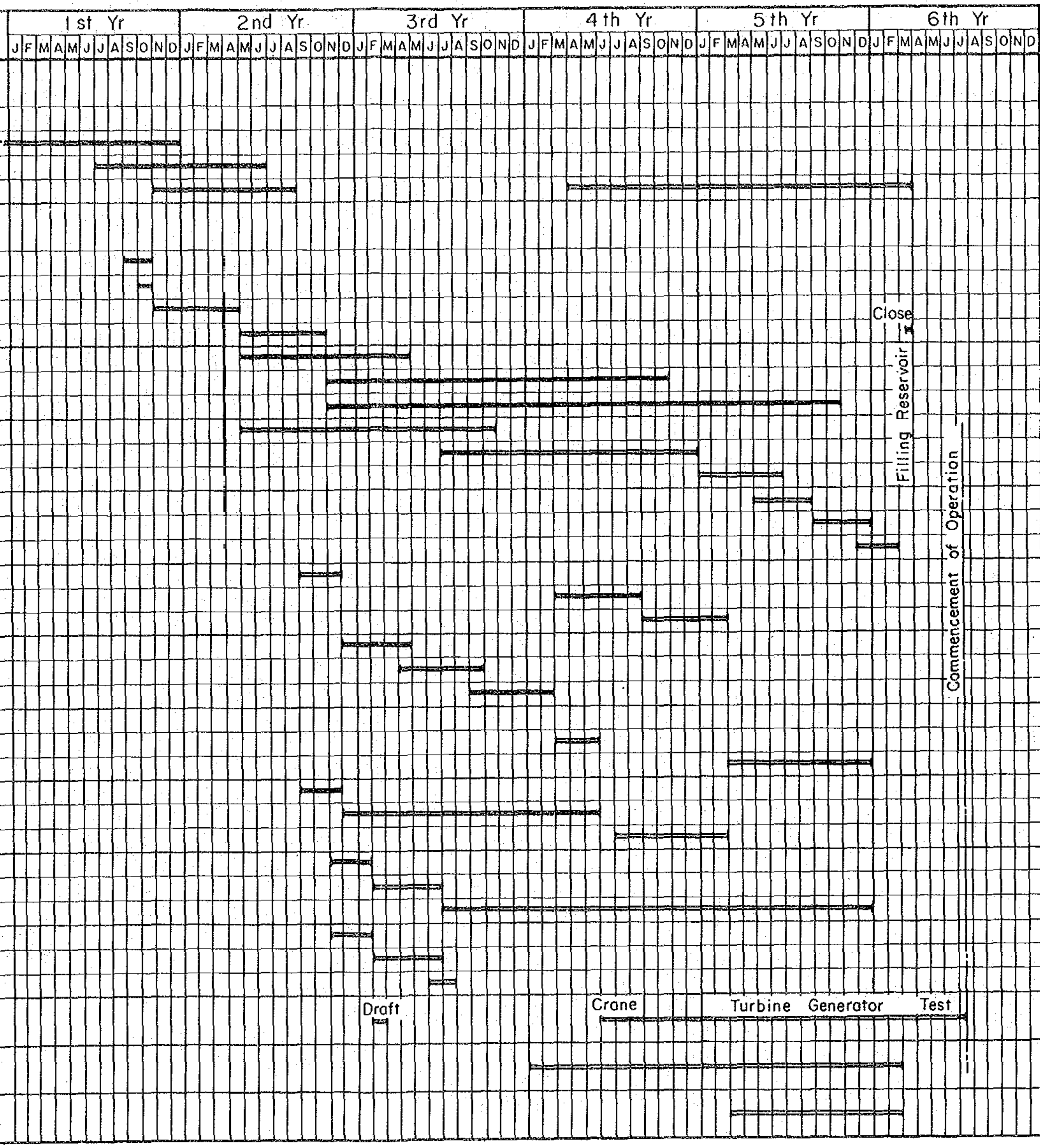
Year	Total	Foreign	Local	Remark
1st Yr	871.2	166.5	704.7	
2nd Yr	598.0	124.3	473.7	
3rd Yr	1,132.9	361.9	771.0	
4th Yr	1,832.1	742.1	1,090.0	
5th Yr	1,127.5	614.9	512.6	
6th Yr	186.3	120.6	65.7	
Total	5,748.0	2,130.3 (92.62 million $)	3,617.7	

These amount are based on the price level as of December, 1982.

1US$ = 23 Baht

Fig. 8-1 Construction Schedule of Nam Yuam Project

Description	Item	Unit	Quantity	Notes
Preparation Works				
Road. Replacement		km	23.4	
Road. Access		km	30.4	
Camp Facilities		L.S	1	
Clearing		L.S	1	
Civil Works				
Care of River		L.S	1	
Diversion Tunnel	Ex (Open)	m³	74,000	
	Ex (T)	m³	138,000	
	Con (T)	m³	28,000	
Dam	Ex	m³	260,000	
	Graut	L.S	1	
	Em	m³	4,652,000	
Spillway	Ex	m³	1,497,000	
	Con	m³	102,000	
	Gate	L.S	1	
Outlet Works	Ex	m³	14,100	
	Con	m³	11,800	
	Valve	L.S	1	
Intake	Ex	m³	19,000	
	Con	m³	6,000	
	Gate	L.S	1	
Headrace	Ex	m³	17,000	
	Con	m³	5,100	
	Graut	L.S	1	
Surge Tank	Ex	m³	—	
	Con	m³	9,000	
	S. Tank	L.S	1	Steel Tank
Penstock	Ex	m³	200,000	
	Con	m³	13,500	
	S. Pipe	L.S	1	Steel Pipe
Power House	Ex	m³	75,000	
	Con	m³	40,000	
	S.S	L.S	1	Super Structure
Tailrace	Ex	m³	103,000	
	Con	m³	6,500	
	Gate	L.S	1	
Electrical Equipment		L.S	1	
Transmission Line		L.S	1	
Switchyard Equipment		L.S	1	



CHAPTER 9.

LOAD FORECAST

CHAPTER 9. LOAD FORECAST

9.1 Present Condition and Transition of Power Demand

Although there has been a momentary depression in power demand in present Thailand, due to oil crisis etc., the growth rate of the demand is as high as more than 13% on the yearly average of 1970's. The growth rate has been reducing thereafter in 1980's, due to the energy policy and the price raising of electric tariff, still it keeps more than 7%.

The growth rate of power demand is higher at local cities and rural districts than at the metropolis. The average growth rate is 6.7% during 1977-1981 at the metropolis, whereas it is 11% at local cities and rural districts. As, on the contrary, the electrification rate is 76% at the metropolis as of September 1981 and only about 34% at local cities and rural districts (It is supposed 40% all over Thailand), high growth rate of power demand is still expected with continuous electrification at these districts.

Also in the 5th five year National Economic and Social Development Plan, which started in October 1981, the conversion from the agricultural to the industrial country is planned, starting with the exploitation of natural gas at Siam Bay. Such is the fact that the growth rate of power demand in Thailand is supposed to still keep more than 6% on the yearly average until 1991.

9.2 Load Forecast

The load forecast in Thailand is schemed by Load Forecast Working Group for Power Tariff Study Sub-Committee organized by the representatives of NEA, EGAT, MEA, PEA, and NESDB, and technically, the comparative checking system of micro and macro forecast is applied.

In micro forecast, the energy sales by type of consumer in each supply district of MEA and PEA is predicted on the basis of the trend of each type in time series. As for PEA district, more realistic phenomena are taken into account such as transition of economic development rate, the correlation between GDP per capita and the consumed power volume per capita, operation pattern of new industry project, regional population increase and decrease, condition of progression of housing development plans, etc.

In macro forecast as their checking, demanders are divided into five categories such as housing, commerce, industry, street-lamps, and other, and the correlation between GDP per capita and consumed power volume per capita is analysed, and also total demand up to 1991 is predicted.

Since the results of micro and macro forecast share the similar tendency, and this load forecast has been repeatedly reviewed in every year based on the actual load increase, this load forecast seems to be highly reliable (refer to Fig. 9-1). Therefore, the load forecast of Nam Yuam project, too, is studied on the basis of its forecasted results.

9.3 Power Development Plan

EGAT prepares supply-plan up to 1996 on the basis of the load forecast above, and it has large projects such as building hydroelectric power stations in Khao Laem (300MW) and in Chrew Larn (240MW) and planning one in Upper Quae Yai (580MW). As for thermal electric power plants, large-sized ones are planned such as one in Bang Pakong (1,340MW) using natural gas in Siam Bay, Mae Moh thermal powers (1,500MW) using lignite in the north of Thailand, and one in Ao Phai (1,800MW) in the east. The future development plan of EGAT is shown in Fig. 9-2.

So far, hydro power is not planned except those above and the other miscellaneous hydros of 700MW in eleven points during 1990-1996. (refer to Fig. 9-2). Due to the establishment of large-sized thermal power plants, the importance of developing hydroelectric power that has enough capacity to cope immediately with peak load is growing up in the future.

9.4 Demand-Supply Balance

In development plan in Chapter 5, the inquiry went on, not taking into consideration choice of commencement time, the balance between operation and demand, and other development plants as a whole. But it is due necessary to inquire into the balance with other development plans predictable, and load forecast.

Fig. 9-2 is the prospect of EGAT development plan, and Fig. 9-3 shows the yearly development of reserved capacity ratio as its result. It is difficult to decide reserved capacity ratio, but it seems reasonable that the present ratio could be one standard to maintain.

Looking at the total reserved capacity ratio in peak balance, and even if 2 units of largest-class thermal power plant are lacking, the reserved capacity is overfull up to 1990 and thereafter gradually it reduces.

If those which are planned as miscellaneous hydro would not be developed after 1991, the reserved capacity ratio overrides the present standard.

Therefore, it seems to be a proper schedule to include the Yuam project and Pai No. 6 project during 1991-1994. Based on this fact, the final economic evaluation goes, on assumption that they will start in 1991, and that all dependable capacity will be effective.

Fig. 9 - 1 Comparison of Micro and Macro Forecast

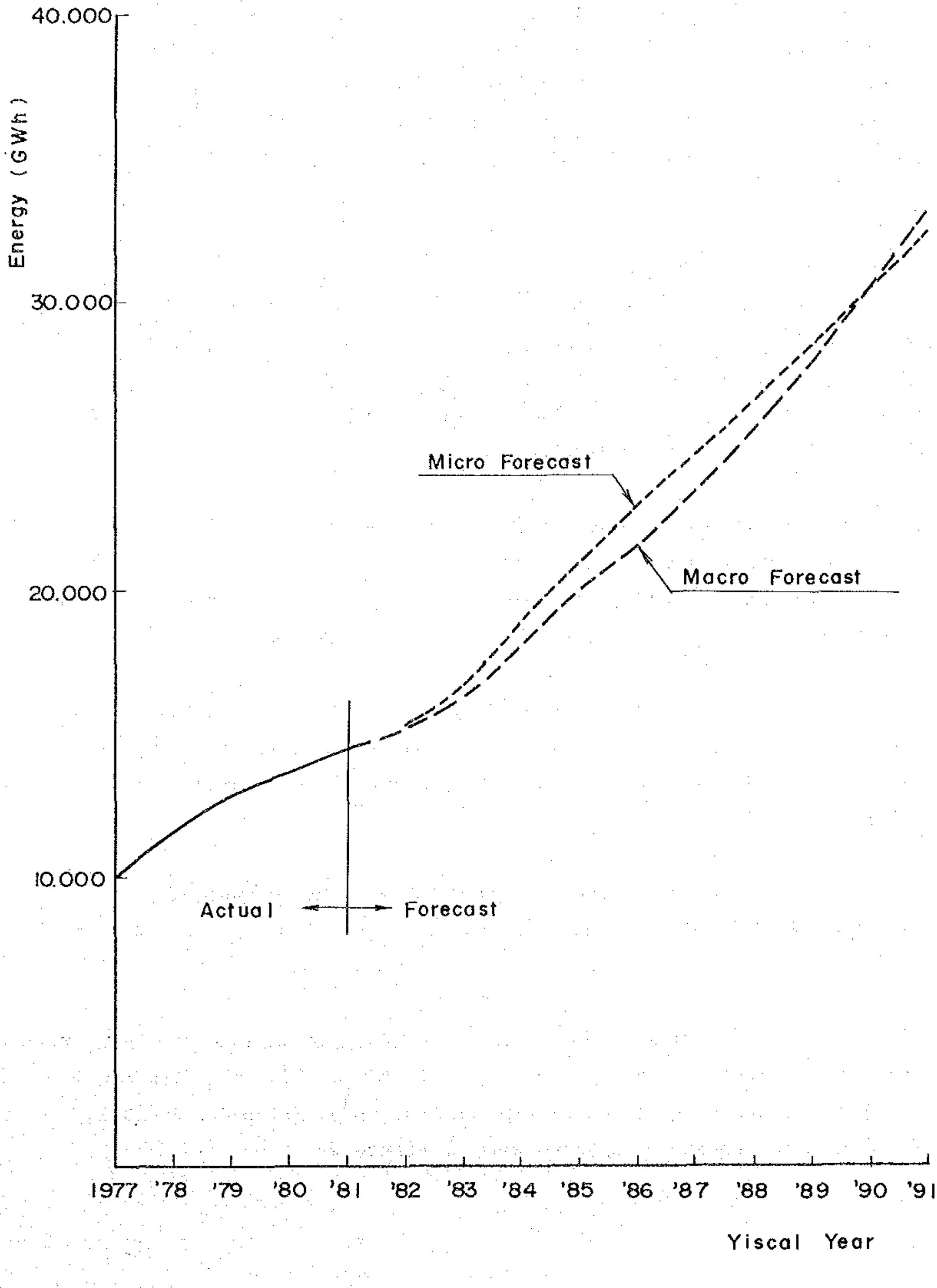


Fig. 9-2 EGAT Power Development Plan

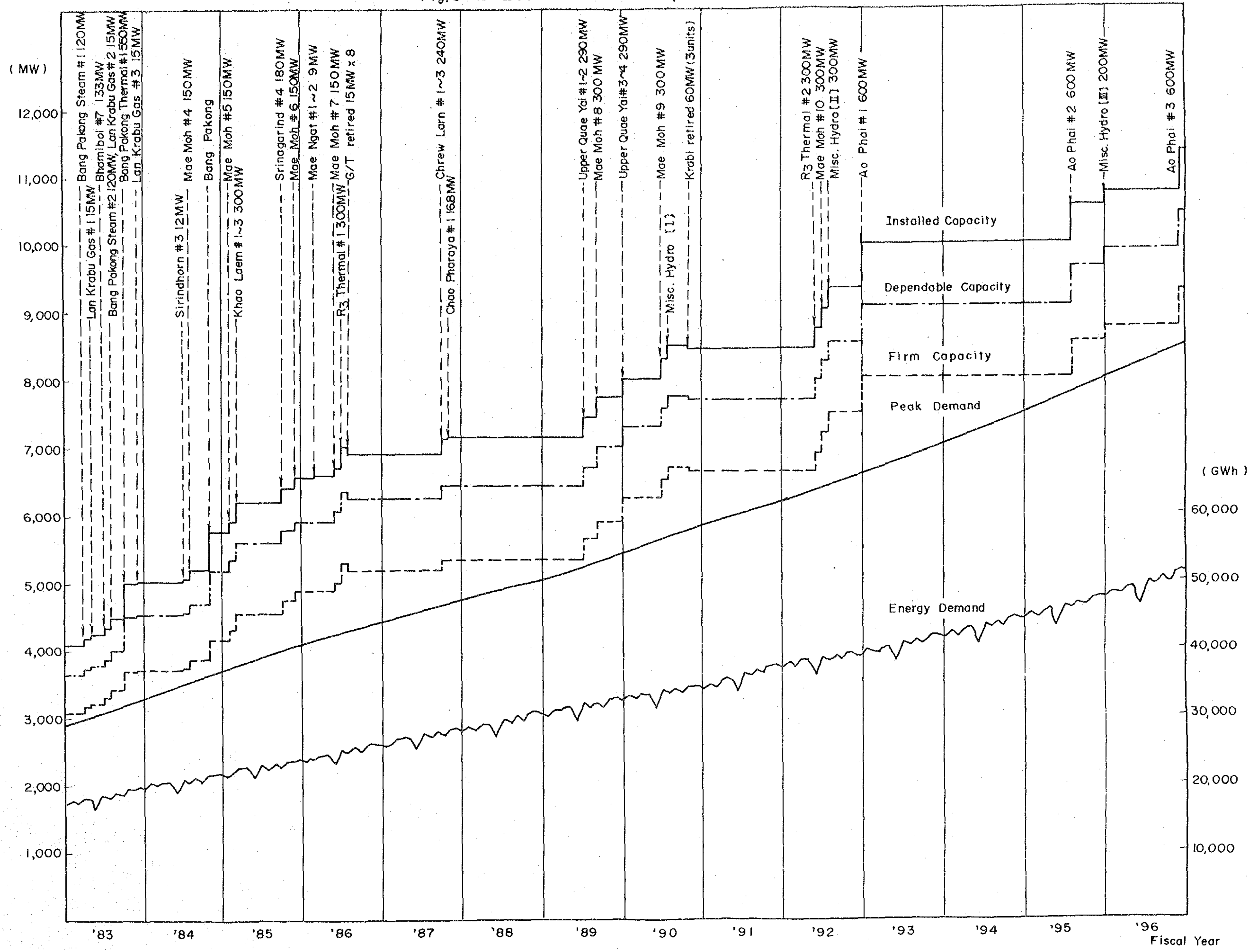


Fig. 9-3 Reserved Capacity Ratio in Peak Balance

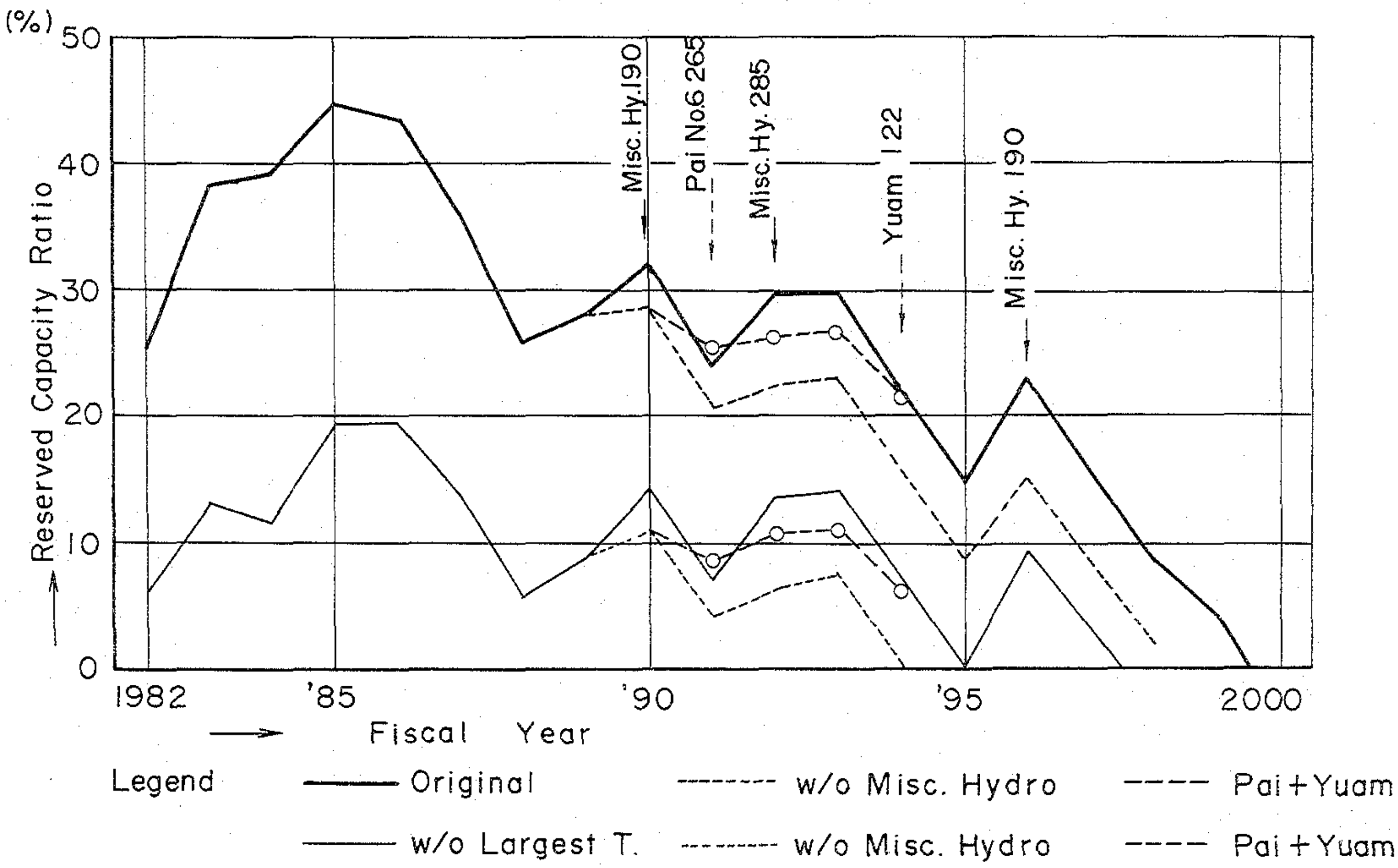


Table 9-1 Peak Balance

FY	Peak Demand A	Total Installed Capacity						Total Dependable Capacity						Reserve Capacity B - A	Reserve Capacity Ratio(%) (B-A)/A	1st & 2nd Largest units	Reserve Capacity Less Large units
		Hydro	Thermal	Lignite	G/T	Diesel	Total	Hydro	Thermal	Lignite	G/T	Diesel	Total				
1982	2,891	1,380	1,643	285	745	35	4,088	1,172	1,560	268	605	28	3,633	742	25.7	570	172
1983	3,292	1,513	2,433	285	790	35	5,056	1,283	2,311	268	645	28	4,535	1,243	37.8	808	435
1984	3,708	1,525	2,983	435	790	35	5,768	1,294	2,833	410	645	28	5,170	1,462	39.4	1,045	417
1985	4,070	2,005	2,983	735	790	35	6,548	1,728	2,833	695	645	28	5,889	1,819	44.7	1,045	774
1986	4,415	2,014	3,283	885	790	35	6,972	1,728	3,118	838	645	28	6,317	1,902	43.1	1,045	857
1987	4,750	2,271	3,283	885	670	35	7,144	1,905	3,118	838	537	28	6,426	1,676	35.3	1,045	631
1988	5,114	2,271	3,283	885	670	35	7,144	1,905	3,118	838	537	28	6,426	1,312	25.7	1,045	267
1989	5,469	2,561	3,283	1,185	670	35	7,734	2,193	3,118	1,123	537	28	6,999	1,530	28.0	1,045	485
1990	5,837	2,851	3,283	1,425	670	35	8,264	2,481	3,118	1,354	537	28	7,518	1,681	28.8	1,045	636
1991	6,217	2,851	3,283	1,425	670	35	8,264	2,481	3,118	1,354	537	28	7,518	1,301	20.9	1,045	256
1992	6,621	2,851	3,583	1,725	670	35	8,864	2,481	3,403	1,639	537	28	8,088	1,467	22.2	1,045	422
1993	7,050	2,851	4,183	1,725	670	35	9,464	2,481	3,973	1,639	537	28	8,658	1,608	22.8	1,093	515
1994	7,506	2,851	4,183	1,725	670	35	9,464	4,481	3,973	1,639	537	28	8,658	1,152	15.3	1,093	59
1995	7,991	2,851	4,783	1,725	670	35	9,464	2,481	4,543	1,639	537	28	9,228	1,237	15.5	1,140	97
1996	8,506	2,851	5,383	1,725	670	35	10,664	2,481	5,113	1,639	537	28	9,798	1,292	15.2	1,140	152
1997	9,053	2,851	5,363	1,725	670	35	10,664	2,481	5,113	1,639	537	28	9,798	745	8.2	1,140	Δ 395
1998	9,634	2,851	5,383	1,725	670	35	10,664	2,481	5,113	1,639	537	28	9,798	164	1.7	1,140	Δ 976
1999	10,251	2,851	5,383	1,725	670	35	10,664	2,481	5,113	1,639	537	28	9,798	Δ 453	Δ 4.4	1,140	Δ 1,593
2000	10,906	2,851	5,383	1,725	670	35	10,664	2,481	5,113	1,639	537	28	9,798	Δ1,108	Δ10.2	1,140	Δ 2,248

Table 9-2 Energy Balance

FY	Energy Demand A	Load Factor (%)	Firm Energy					Average Energy		Reserve Energy for Firm		Reserve Energy for Average	
			Hydro	Thermal	Lignite	G/D	Total B	Hydro	Total C	B - A	(%)	C - A	(%)
1982	17,490	69.06	2,968	11,108	1,777	2,795	18,648	4,260	19,940	1,158	6.6	2,450	14.0
1983	19,330	67.03	2,968	16,215	1,777	2,834	23,794	4,260	25,086	4,464	23.1	5,756	29.8
1984	21,530	66.28	2,968	20,065	2,762	2,834	28,629	4,260	29,921	7,099	33.0	8,391	39.0
1985	23,761	66.64	3,393	20,065	4,732	2,834	31,024	5,018	32,649	7,263	30.6	8,888	37.4
1986	26,017	67.27	3,393	21,641	5,717	2,730	33,481	5,046	35,134	7,464	28.7	9,117	35.0
1987	28,048	67.41	3,872	21,641	5,717	2,730	33,960	5,674	35,762	5,912	21.1	7,714	27.5
1988	30,245	67.51	3,872	21,641	5,717	2,730	33,960	5,674	35,762	3,715	12.3	5,517	18.2
1989	32,384	67.60	4,398	21,641	7,687	2,730	36,456	6,222	38,280	4,072	12.6	5,896	18.2
1990	34,611	67.69	4,924	21,641	9,357	2,730	38,652	6,769	40,497	4,041	11.7	5,886	17.0
1991	36,929	67.81	4,924	21,641	9,357	2,730	38,652	6,769	40,497	1,723	4.7	3,568	9.7
1992	39,366	67.87	4,924	23,217	11,327	2,730	42,198	6,769	44,043	2,832	7.2	4,677	11.9
1993	41,944	67.92	4,924	27,157	11,327	2,730	46,138	6,769	47,983	4,194	10.0	6,039	14.4
1994	44,670	67.94	4,924	27,157	11,327	2,730	46,138	6,769	49,078	1,468	3.3	4,408	9.9
1995	47,560	67.94	4,924	31,097	11,327	2,730	50,078	6,769	51,923	2,518	5.3	4,363	9.2
1996	50,632	67.95	4,924	35,037	11,327	2,730	54,018	6,769	55,863	3,386	6.7	5,231	10.3
1997	53,898	67.96	4,924	35,037	11,327	2,730	54,018	6,769	55,863	120	0.2	1,965	3.6
1998	57,374	67.98	4,924	35,037	11,327	2,730	54,018	6,769	55,863	Δ3,356	Δ5.8	Δ1,511	Δ2.6
1999	61,075	68.01	4,924	35,037	11,327	2,730	54,018	6,769	55,863	Δ7,057	Δ11.6	Δ5,212	Δ8.5
2000	65,014	68.05	4,924	35,037	11,327	2,730	54,018	6,769	55,863	Δ10,996	Δ16.9	Δ9,151	Δ14.1

CHAPTER 10.

ECONOMIC EVALUATION

CHAPTER 10. ECONOMIC EVALUATION

10.1 Method for Economic Evaluation

Generally, economic evaluation of hydro power project is done in the form of comparison in cost between hydro power and alternative thermal power with the capacity of the same level. In this case, the electricity generation cost of thermal power is regarded as a benefit of hydro power project.

In economic evaluation of this project, electricity generation cost and benefit by alternative thermal power is compared by discounted cash flow method, and also sensitivity analysis is done as to how the changes of fuel price and discount rate affects the economy of this project.

Since the Nam Yuam power plant is of hydroelectric coping with peak load, the alternative thermal is to be a combination of gas turbine and steam thermal which are for peak and base load, respectively. Table 10-1 and 10-2 indicates outline of the projects considered in the economic evaluation and basic criteria for the study.

10.2 Cost for the Project

Economic analysis has been performed for the period of fifty-seven years, and the total cost for operation & maintenance and investment for equipments is taken as the annual cost of the project. The cost is converted into present value, and its total for the fifty-seven years is taken as the cost for the project. Operation & maintenance cost is calculated by the following ratio against construction cost.

Equipment	Operation & maintenance cost rate
Dam and Reservoir	1.5%
Power Station	
Transmission Line	

10.3 Benefit of Project

1) Alternative thermal power

The followings are the outline of features of alternative thermal power chosen as the criteria for economic evaluation of this project.

(i) The utility rate of plants of thermal power and gas turbine is as follows.

thermal power : 70%
gas turbine : 7%

(ii) The scale of alternative plants is taken as having the same capacity as this project. (refer to Table 10-5)

(iii) Construction cost is computed on the basis of the construction unit price of the present thermal power plants in Thailand.

For the reasons below, the combination of alternative thermal power was decided as follows.

Case A. Gas turbine using diesel oil and thermal power using imported coal.

Case B. Gas turbine and thermal power using natural gas.

a) Lignite, as fuel, costs least, but is not very rich resources.

b) Oil price had kept rising since 1973, and fell in 1983, but it still keeps a high level, and its supply is unstable.

c) Imported coal costs the next least to lignite, and is rich resources and is available over the world. Consequently, its supply is expected to be stable.

d) Natural gas in Siam Bay has been utilized since September 1981. So far there is no plan to apply it for new thermal power, but it is widely applicable as substitute for imported oil.

Yearly operation & maintenance cost rate of the alternative thermal power goes as follows.

Coal Thermal Power	:	3%
Natural Gas Thermal Power	:	2.5%
Gas Turbine	:	3%

2) Fuel cost

Crude oil price, which had been rising since the autumn of 1973, fell by about 15% (FOB price) in 1983, due to miscontrol of product and depression in demand. This also influences coal price. At any rate, this study uses fuel price as of 1982 (refer to Table 10-3). As for coal price, taking into consideration the conditions of coal in Australia and South Africa, its price is predicted as 70 US$/t in CIF price (45 US$/t in FOB price, 25 US$/t as charge for shipping and staying, insurance etc.).

Fuel price still fluctuates, and so the sensitivity analysis of the project is done as well.

10.4 Economic Evaluation

The result of economic evaluation by cash flow is shown in Table 10-6 to 11, and the Nam Yuam project has enough economy for any combination of alternative thermal power.

Also as the result of sensitivity analysis in Fig. 10-1 to 8 shows it can keep its economy regardless of some changes in discount rate, fuel price, etc..

Also, if coal price (FOB) would be reduced by the same rate as OPEC Standard Crude Oil Price being reduced in March 1983 (34 US$/Ballel to 29 US$/Ballel), coal price will be about 63.4 US$/t in CIF price (which corresponds to the reduction by about 9.5%). At any rate, even in this case, it retains enough economy.

10.5 Financial Evaluation

According to the EGAT Annual Report 1982, cost of energy at a power station is calculated to be 0.89 B/kWh. This is an average cost based on whole energy demand which is characterized by an annual load factor of 67% and a load factor on a heavy load day of 73.7%. Then, in case that all the new demand will be met by newly constructed thermal power plants and that the thermal power plants will be operated by an average plant factor of 70%, the cost of energy is to be 1.27 B/kWh.

On the other hand, cost of energy of the alternative thermal power plant for the Nam Yuam Project is 1.33 B/kWh which has been collected by appropriate factors. Therefore, power tariff of the Nam Yuam Project is derived as follows, on the basis of the present cost of energy.

$$0.89 \times \frac{1.33}{1.27} = 0.93 \text{ B/kWh}$$

The resultant cash flow is shown in Table 10-13. Despite of the slight escalation rate, i.e. 3%, for the power tariff as well as for the construction cost and operation & maintenance cost, the investment of the Nam Yuam Project gives Financial Internal Rate of Return (FIRR) of about 10% for the entire service life.

Table 10-1 Proposed Project Outline for Economic Evaluation

Item	Unit	Nam Yuam Project
Maximum Output Power	(MW)	162
Firm Power (at generator end)	(MW)	128
Loss Rate	(%)	2
Firm Power (at primary substation)	(MW)	125
Annual Energy Production	(10^6kWh)	565
Utilization Factor	(%)	97
Annual Available Energy	(10^6kWh)	537
Construction Cost	(10^6฿)	5,748

Table 10-2 Basic Criteria for Economic Study

Method of Analysis	:	Discounted Cash Flow Method		
Study Period	:	57 years (1982 - 2038)		
Discount Rate	:	10%		
Escalation				
		Case 1	Case 2	Case 3
O & M Cost	:	not considered	not considered	not considered
Fuel Cost	:	not considered	3%	3%
Replacement Cost	:	not considered	not considered	5%
Shadow Price Factor				
Foreign Currency	:	110%		
Local Currency for Hydro	:	85%		
Local Currency for Thermal	:	95%		
Fuel Price	:	100%		
Service Life of Facilities				
Dam & Reservoir	:	50 years		
Hydro Power Plant	:	25 years		
Thermal Power Plant	:	25 years		
Gas Turbine Power Plant	:	20 years		
Transmission Line	:	40 years		
Conversion Rate of Currency	:	US$1.00 = ฿23.0		

Table 10-3 Fuel Cost of Alternative Thermal Power Plants

	Steam Turbine		Gas Turbine	
	Imported Coal	Nutural gas	Diesel oil	Natural gas
Fuel calorie	6,300 (kcal/kg)	8,000 (kcal/m^3)	10,800 (kcal/kg) (9,300 kcal/kl)	8,000 (kcal/m^3)
Annual thermal efficiency	36% x 0.96	37% x 0.96	25%	25%
Required calorie	2,488 (kcal/kWh)	2,421 (kcal/kWh)	3,440 (kcal/kWh)	3,440 (kcal/kWh)
Fuel consumption rate	0.395 (kg/kWh)	0.303 (m^3/kWh)	0.37 (l/kWh)	0.43 (m^3/kEh)
Fuel price (FOB)	45 (US$/t)	-	-	-
Fuel price (CIF)	70 (US$/t)	-	-	-
Fuel price at plant	0.07 (US$/kg)	2.79 (B/m^3)	6.70 (B/ℓ)	2.79 (B/m^3)
Fuel cost of power generation	0.636 (B/kWh)	0.845 (B/kWh)	3.02 (B/kWh)	1.2 (B/kWh)

Table 10-4 Unit Construction Cost of Alternative Thermal Power Plants

Imported coal-fired thermal	840 (US$/kW)
Natural gas-fired thermal	560 (US$/kW)
Gas turbine (diesel oil, Natural gas)	270 (US$/kW)

Note: Interest during construction is not included in the avove cost.

Table 10-5 Alternative Thermal Power Plant

Item	Unit	Gas Turbine	Steam Thermal
Required Installed Capacity	(MW)	89	64
Firm Capacity of Hydro Nam Yuam	(MW)	74	51
Annual Energy Production	(10^6kWh)	55	515
Station Service Power Use	(%)	2	6
Annual Available Energy	(10^6kWh)	54	483

Note: Required installed Capacity

$$= \text{Firm Capacity of Hydro Nam Yuam} \times \frac{1}{(1-SSt)} \times \frac{1}{(1-FOt)} \times \frac{1}{(1-OHt)}$$

where,

SSt : Station service power use = 2,6%
FOt : Forced outage rate = 4%
OHt : Overhaul rate = 12%

Table 10-6 Economy of Project

Case A: Alternative (Diesel Oil & Imported Coal)

	Discount Rate (%)	Base Case (with shodow price factor)	Alternative Case (without shadow price factor)
B/C	10	1.181	1.105
B-C	10	1,230 (10^6B)	744 (10^6B)
IRR	-	12.5 (%)	11.4 (%)

Cost escalation : not considered

Table 10-7 Economy of Project

Case B: Alternative (Natural Gas)

	Discount Rate (%)	Base Case (with shodow price factor)	Alternative Case (without shadow price factor)
B/C	10	1.127	1.061
B-C	10	865 (10^6B)	432 (10^6B)
IRR	-	11.7 (%)	10.8 (%)

Cost escalation : not considered

Table 10-8 Economy of Project

Case A. Alternative (Diesel Oil & Imported Coal)

	Discount Rate (%)	Base Case (with shodow price factor)	Alternative Case (without shadow price factor)
B/C	10	1.500	1.412
B-C	10	3,404 (10^6B)	2,917 (10^6B)
IRR	-	15.2 (%)	14.1 (%)

Cost escalation : Fuel cost 3%

Table 10-9 Economy of Project

Case B: Alternative (Natural Gas)

	Discount Rate (%)	Base Case (with shodow price factor)	Alternative Case (without shadow price factor)
B/C	10	1.471	1.392
B-C	10	3,207 (10^6B)	2,774 (10^6B)
IRR	-	14.5 (%)	13.7 (%)

Cost escalation : Fuel cost 3%

Table 10-10 Economy of Project

Case A: Alternative (Diesel Oil & Imported Coal)

	Discount Rate (%)	Base Case (with shodow price factor)	Alternative Case (without shadow price factor)
B/C	10	1.514	1.425
B-C	10	3,614 (10^6B)	3,106 (10^6B)
IRR	-	15.4 (%)	14.3 (%)

Cost escalation : Fuel cost 3% & Replacement cost 5%

Table 10-11 Economy of Project

Case B: Alternative (Natural Gas)

	Discount Rate (%)	Base Case (with shodow price factor)	Alternative Case (without shadow price factor)
B/C	10	1.472	1.393
B-C	10	3,319 (10^6B)	2,872 (10^6B)
IRR	-	14.6 (%)	13.8 (%)

Cost escalation : Fuel cost 3% & Replacement cost 5%

Table 10-12 Nam Yuam Cash Flow of Economic Analysis

Unit : 10^6 B

	Nam Yuam Project						Alternative Thermal P/P			
	C. cost			O/M cost			C.cost	O/M cost		
	G/F	T/F	Total	G/F	T/F	Total		O/M	Fuel	Total
1	0	0	0	0	0	0	0	0	0	0
2	671	0	671	0	0	0	0	0	0	0
3	464	0	464	0	0	0	0	0	0	0
4	732	182	914	0	0	0	0	0	0	0
5	1341	182	1523	0	0	0	537	0	0	0
6	801	182	983	0	0	0	537	0	0	0
7	107	61	168	0	0	0	715	0	0	0
8	0	0	0	76	10	86	0	55	465	520
9	0	0	0	76	10	86	0	55	465	520
10	0	0	0	76	10	86	0	55	465	520
11	0	0	0	76	10	86	0	55	465	520
12	0	0	0	76	10	86	0	55	465	520
13	0	0	0	76	10	86	0	55	465	520
14	0	0	0	76	10	86	0	55	465	520
15	0	0	0	76	10	86	0	55	465	520
16	0	0	0	76	10	86	0	55	465	520
17	0	0	0	76	10	86	0	55	465	520
18	0	0	0	76	10	86	0	55	465	520
19	0	0	0	76	10	86	0	55	465	520
20	0	0	0	76	10	86	0	55	465	520
21	0	0	0	76	10	86	0	55	465	520
22	0	0	0	76	10	86	0	55	465	520
23	0	0	0	76	10	86	0	55	465	520
24	0	0	0	76	10	86	0	55	465	520
25	0	0	0	76	10	86	0	55	465	520
26	0	0	0	76	10	86	0	55	465	520
27	0	0	0	76	10	86	0	55	465	520
28	0	0	0	76	10	86	553	55	465	520
29	0	0	0	76	10	86	0	55	465	520
30	0	0	0	76	10	86	0	55	465	520
31	0	0	0	76	10	86	0	55	465	520
32	0	0	0	76	10	86	0	55	465	520
33	629	0	629	76	10	86	1236	55	465	520
34	0	0	0	76	10	86	0	55	465	520
35	0	0	0	76	10	86	0	55	465	520
36	0	0	0	76	10	86	0	55	465	520
37	0	0	0	76	10	86	0	55	465	520
38	0	0	0	76	10	86	0	55	465	520
39	0	0	0	76	10	86	0	55	465	520
40	0	0	0	76	10	86	0	55	465	520
41	0	0	0	76	10	86	0	55	465	520
42	0	0	0	76	10	86	0	55	465	520
43	0	0	0	76	10	86	0	55	465	520
44	0	0	0	76	10	86	0	55	465	520
45	0	0	0	76	10	86	0	55	465	520
46	0	0	0	76	10	86	0	55	465	520
47	0	0	0	76	10	86	0	55	465	520
48	0	607	607	76	10	86	0	55	465	520
49	0	0	0	76	10	86	0	55	465	520
50	0	0	0	76	10	86	0	55	465	520
51	0	0	0	76	10	86	0	55	465	520
52	0	0	0	76	10	86	0	55	465	520
53	0	0	0	76	10	86	0	55	465	520
54	0	0	0	76	10	86	0	55	465	520
55	0	0	0	76	10	86	0	55	465	520
56	0	0	0	76	10	86	0	55	465	520
57	0	0	0	76	10	86	0	55	465	520
Present Worth	5403	737	6140	829	111	940	2152	600	5071	5672
	C = 7080						B = 7824			
	B / C = 1.105									

Note : Case A , 1

Table 10-13 Nam Yuam Cash Flow of Financial Analysis

Unit : 10^6 B

	F.Y	Income			Expense							(A)-(B)
		E/S (GWh)	P/R (G/kWh)	Income (A)	C cost			O/M cost			Expense (B)	
					G/F	T/F	Total	G/F	T/F	Total		
1	1984	0	0.99	0	0	0	0	0	0	0	0	0
2	1985	0	1.02	0	733	0	733	0	0	0	733	-733
3	1986	0	1.05	0	522	0	522	0	0	0	522	-522
4	1987	0	1.08	0	849	211	1060	0	0	0	1060	-1060
5	1988	0	1.11	0	1601	217	1819	0	0	0	1819	-1819
6	1989	0	1.14	0	985	224	1209	0	0	0	1209	-1209
7	1990	0	1.18	0	136	77	213	0	0	0	213	-213
8	1991	537	1.21	652	0	0	0	99	13	112	112	539
9	1992	537	1.25	671	0	0	0	102	14	116	116	555
10	1993	537	1.29	691	0	0	0	105	14	119	119	572
11	1994	537	1.33	712	0	0	0	108	15	123	123	589
12	1995	537	1.37	733	0	0	0	112	15	127	127	607
13	1996	537	1.41	755	0	0	0	115	15	130	130	625
14	1997	537	1.45	778	0	0	0	118	16	134	134	644
15	1998	537	1.49	801	0	0	0	122	16	138	138	663
16	1999	537	1.54	825	0	0	0	126	17	143	143	683
17	2000	537	1.58	850	0	0	0	129	17	147	147	703
18	2001	537	1.63	876	0	0	0	133	18	151	151	725
19	2002	537	1.68	902	0	0	0	137	18	156	156	746
20	2003	537	1.73	929	0	0	0	141	19	160	160	769
21	2004	537	1.78	957	0	0	0	146	20	165	165	792
22	2005	537	1.84	986	0	0	0	150	20	170	170	815
23	2006	537	1.89	1015	0	0	0	155	21	175	175	840
24	2007	537	1.95	1046	0	0	0	159	21	181	181	865
25	2008	537	2.01	1077	0	0	0	164	22	186	186	891
26	2009	537	2.07	1109	0	0	0	169	23	192	192	918
27	2010	537	2.13	1143	0	0	0	174	23	197	197	945
28	2011	537	2.19	1177	0	0	0	179	24	203	203	974
29	2012	537	2.26	1212	0	0	0	185	25	209	209	1003
30	2013	537	2.33	1249	0	0	0	190	25	216	216	1033
31	2014	537	2.39	1286	0	0	0	196	26	222	222	1064
32	2015	537	2.47	1325	0	0	0	202	27	229	229	1096
33	2016	537	2.54	1364	1718	0	1718	208	28	236	1954	-590
34	2017	537	2.62	1405	0	0	0	214	29	243	243	1163
35	2018	537	2.70	1447	0	0	0	220	30	250	250	1198
36	2019	537	2.78	1491	0	0	0	227	30	257	257	1233
37	2020	537	2.86	1536	0	0	0	234	31	265	265	1270
38	2021	537	2.95	1582	0	0	0	241	32	273	273	1309
39	2022	537	3.03	1629	0	0	0	248	33	281	281	1348
40	2023	537	3.12	1678	0	0	0	255	34	290	290	1388
41	2024	537	3.22	1728	0	0	0	263	35	298	298	1430
42	2025	537	3.31	1780	0	0	0	271	36	307	307	1473
43	2026	537	3.41	1834	0	0	0	279	37	317	317	1517
44	2027	537	3.52	1889	0	0	0	288	39	326	326	1563
45	2028	537	3.62	1945	0	0	0	296	40	336	336	1609
46	2029	537	3.73	2004	0	0	0	305	41	346	346	1658
47	2030	537	3.84	2064	0	0	0	314	42	356	356	1707
48	2031	537	3.96	2126	0	2584	2584	324	43	367	2950	-825
49	2032	537	4.08	2189	0	0	0	333	45	378	378	1811
50	2033	537	4.20	2255	0	0	0	343	46	389	389	1866
51	2034	537	4.33	2323	0	0	0	354	47	401	401	1922
52	2035	537	4.46	2392	0	0	0	364	49	413	413	1979
53	2036	537	4.59	2464	0	0	0	375	50	425	425	2039
54	2037	537	4.73	2538	0	0	0	386	52	438	438	2100
55	2038	537	4.87	2614	0	0	0	398	53	451	451	2163
56	2039	537	5.01	2693	0	0	0	410	55	465	465	2228
57	2040	537	5.16	2773	0	0	0	422	57	479	479	2295
FIRR* = .0995												

Note : Escalation 3 %

* : FIRR = Financial Internal Rate of Return

Fig. 10-1 Sensitivity Analysis

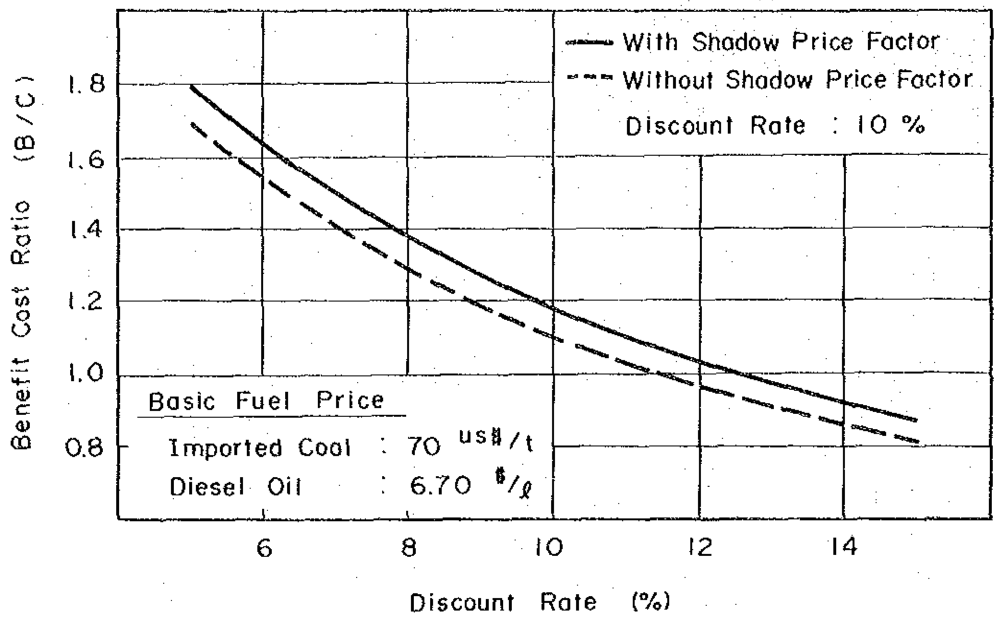


Fig. 10-2 Sensitivity Analysis

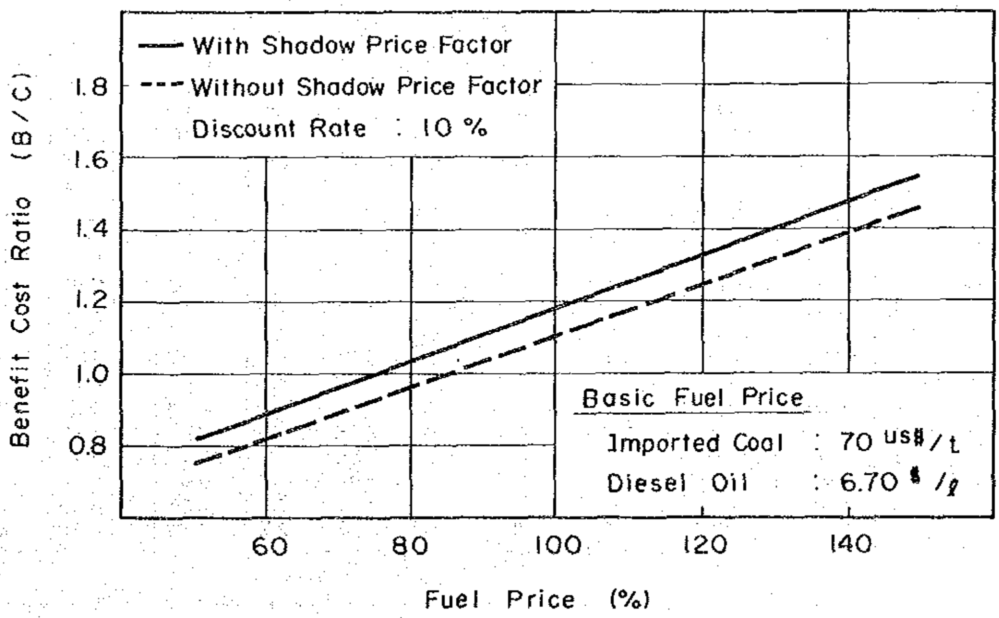


Fig. 10-3 Sensitivity Analysis

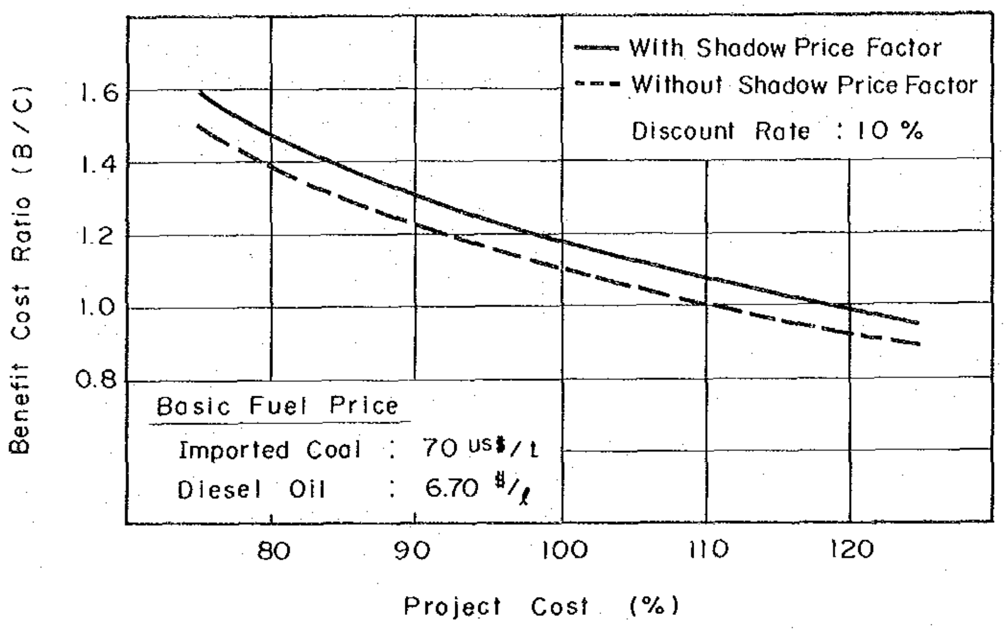


Fig. 10-4 Sensitivity Analysis

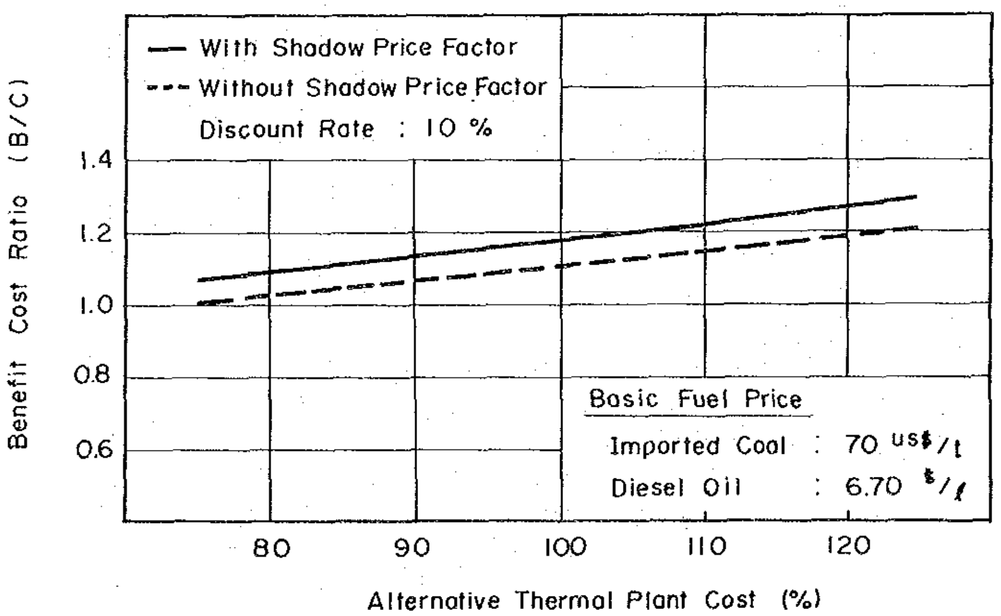


Fig. 10-5 Sensitivity Analysis (5)

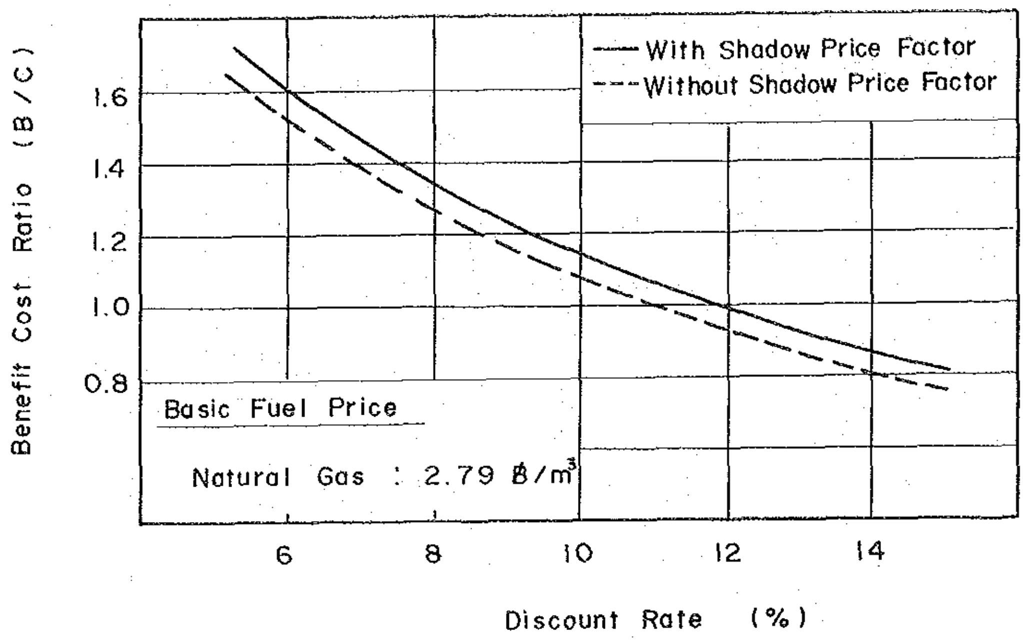


Fig. 10-6 Sensitivity Analysis (6)

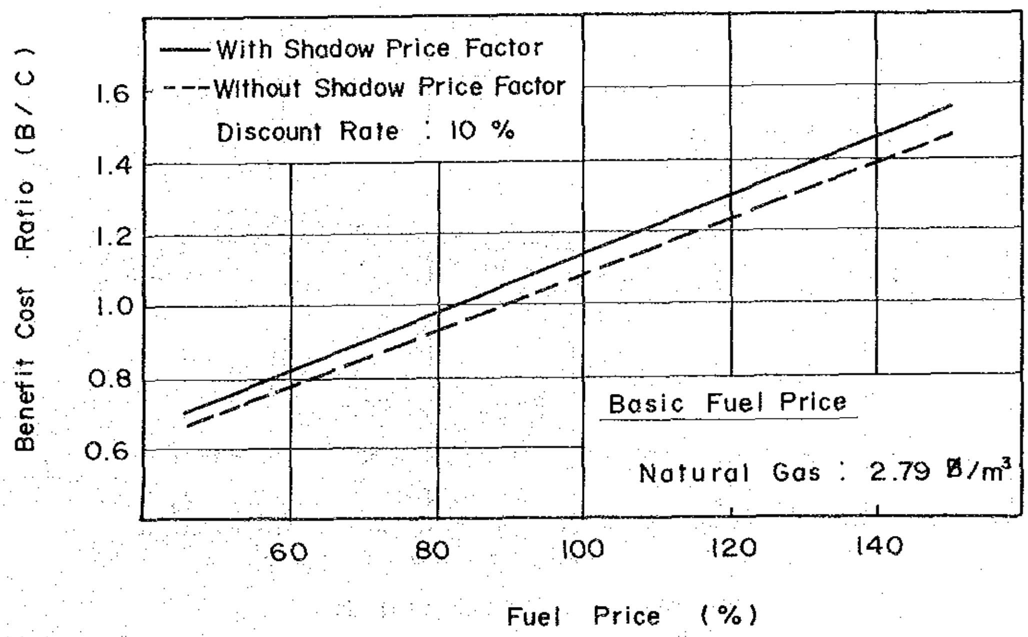


Fig. 10-7 Sensitivity Analysis (7)

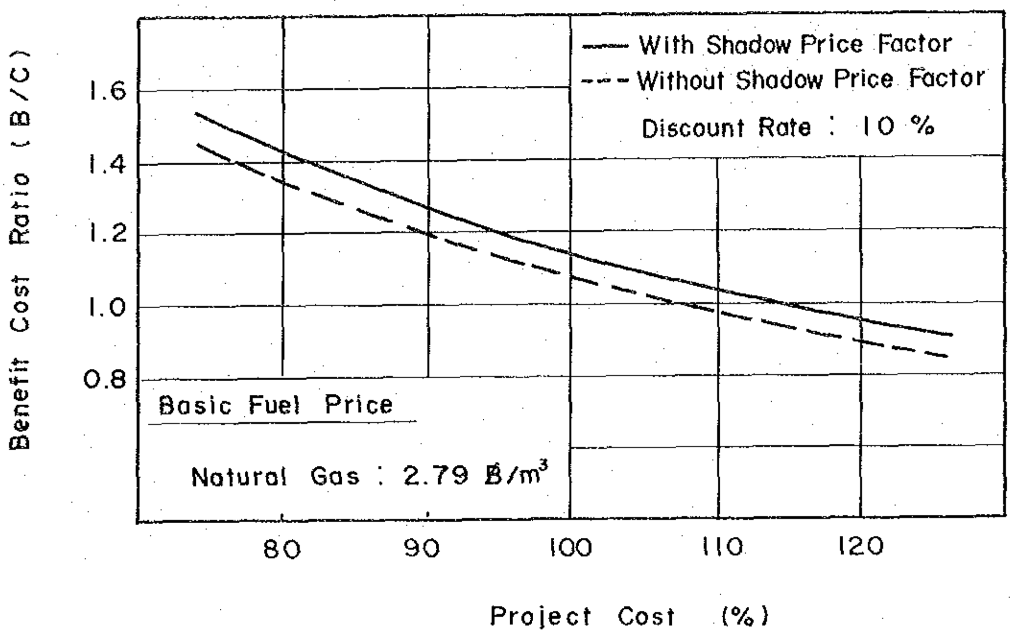
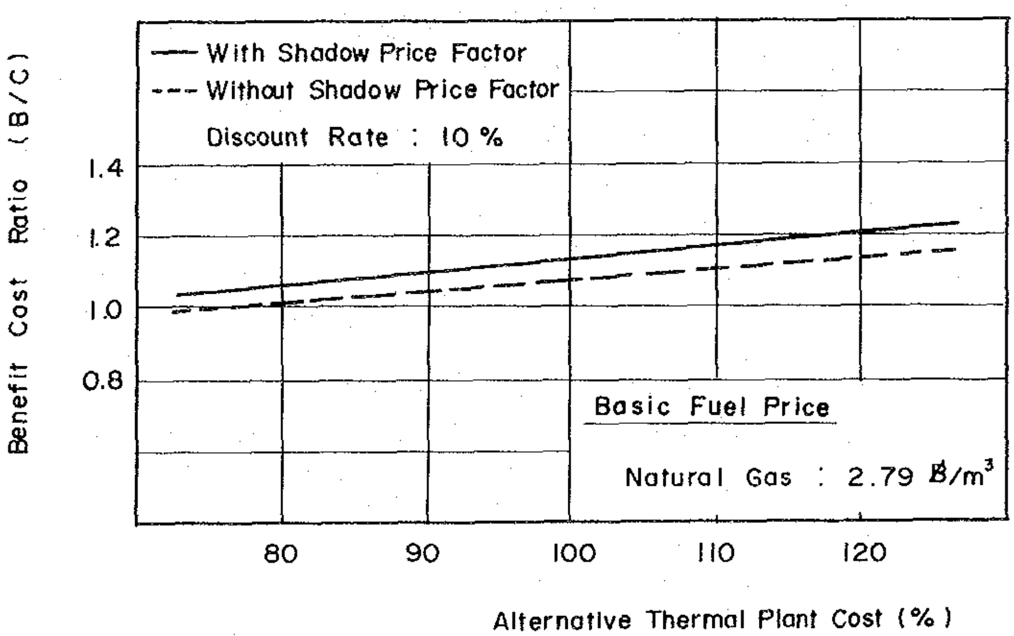


Fig. 10-8 Sensitivity Analysis (8)



CHAPTER 11.

IMPACT ON ENVIRONMENT

CHAPTER 11. IMPACT ON ENVIRONMENT

As development is practiced in large scale nowadays, more attention is being paid world-widely at its impact on environment.

In the beginning age, the attention was given to the harmful impact on environment by large-sized development and to the incongruency between development and preservation of environment. Nowadays however, the awareness is more dominant that both can and should go in harmony.

Generally, there are various types of impacts on environment by development, and the investigation and evaluations thereof require enormous amount of labor and time. Also, the methods for investigation and evaluation do not seem to be well-systematized yet. Basically, to deal with environment problem, works of the following types are to be included; full recognition of present conditions with the help of enough data and information, sufficient understanding of aims and methodology of the project in question, and then evaluation and judgement of the impact anticipated due to the project implementation based on the collected data. Harmful impact, if any, should be coped with by appropriate measures, and the impact resulted from the measures should also be evaluated. In cases when any change in project is necessary, evaluation of technical and economic availability for the change should be practiced. Taking all the works to be done as a whole, the possibility of the project is judged.

Investigation and evaluation of impacts of Nam Yuam project on environment are not included in the scope of this F.S.. At any rate, according to various references domestic and foreign, the followings are the points that are usually to be considered on, in those cases when development includes large-scaled dams and reservoir construction.

1) Geophysical Impact
   (i) Erosion
   (ii) Suspended and Bed Load, and Sedimentation
   (iii) Flood
   (iv) Slope Stability
   (v) Groundwater
   (vi) Induced Earthquake

2) Impact on Water
   (i) Physical, Chemical Features
   (ii) Temperature
   (iii) Turbidity
   (iv) River Flow and Water Table
   (v) Water Loss
   (vi) Evaporation

3) Impact on Flora and Fauna
   (i) Forest
   (ii) Fish
   (iii) Mammals, Birds, Insects, Reptiles and Amphibia
   (iv) Precious Species
   (v) Phyto and Zooplankton

4) Compensation and Resettlement
   (i) Land Acquisition
   (ii) Resettlement
   (iii) Compensation

5) Social and Economic Impact
   (i) Employment
   (ii) Income and Expense
   (iii) Population and Industrial Structure
   (iv) Transportation and Communication
   (v) Scenery, Tourism and Recleation
   (vi) Public Health and Sanitary

6) Archeology

JICA