REPORT
ON
THERMAL POWER SITE SURVEY AND PLANNING
IN
THE REPUBLIC OF INDONESIA

VOLUME II

METHOD OF PLANNING AND RESEARCH

DECEMBER 1973

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

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1. DEVELOPMENT PLANNING OF ELECTRIC POWER SOURCES

1-1 Characteristics of Demand and Combination of Various Kinds of Power Sources

Electric power has the destiny different from other industries that the production and the consumption can not but be done at the same time. This is due to the feature of the inability of electric power for storage and consequently the supply power must always be maintained corresponding to the demand.

And all the more, as the demand is changing in every second, the corresponding supply power has many functions in conformity with the kinds and shapes of power generation.

Therefore it is necessary to combine the sources of supply power most economically corresponding to these shapes of demand.

1-1-1 Load Curve of Demand

The load curves of West Jawa and East Jawa are shown in Fig. 1·1·1 and Fig. 1·1·2 and the ratio of the off-peak to the peak load is about 0.6. These two load curves show that this peak load appears in the evening when the lights are switched on and there is one hour time difference of sunset in East and West Jawa.

As is to be seen in these load curves, the daily load can be divided mainly into three sections,

(a) Peak load section

(b) Intermediate load section

(c) Base load section

(a) & (b) have smaller in kilowatt-hours in comparison with kilowatts, and (c) has kilowatt-hours of which are very large.

1-1-2 Combination of Various Kinds of Electric Power Sources

To supply electric energy economically to meet such demands, it is better in general to provide power from various power sources, each having different characteristics as described below, than to furnish it from a single power source.

(1) The adaptability of the supplying electric energy to each demand is stated below.

a. With regard to the peak load, the rapid change of the load requires the unit to have a wide-range load-adjustability, quick response to the load and the ability of frequent starts and stops. In addition, since the amount of kilowatt-hours is relatively small in comparison with that of kilowatts,

Fig. 1·1·1 Average Daily Load Curve for West Jawa

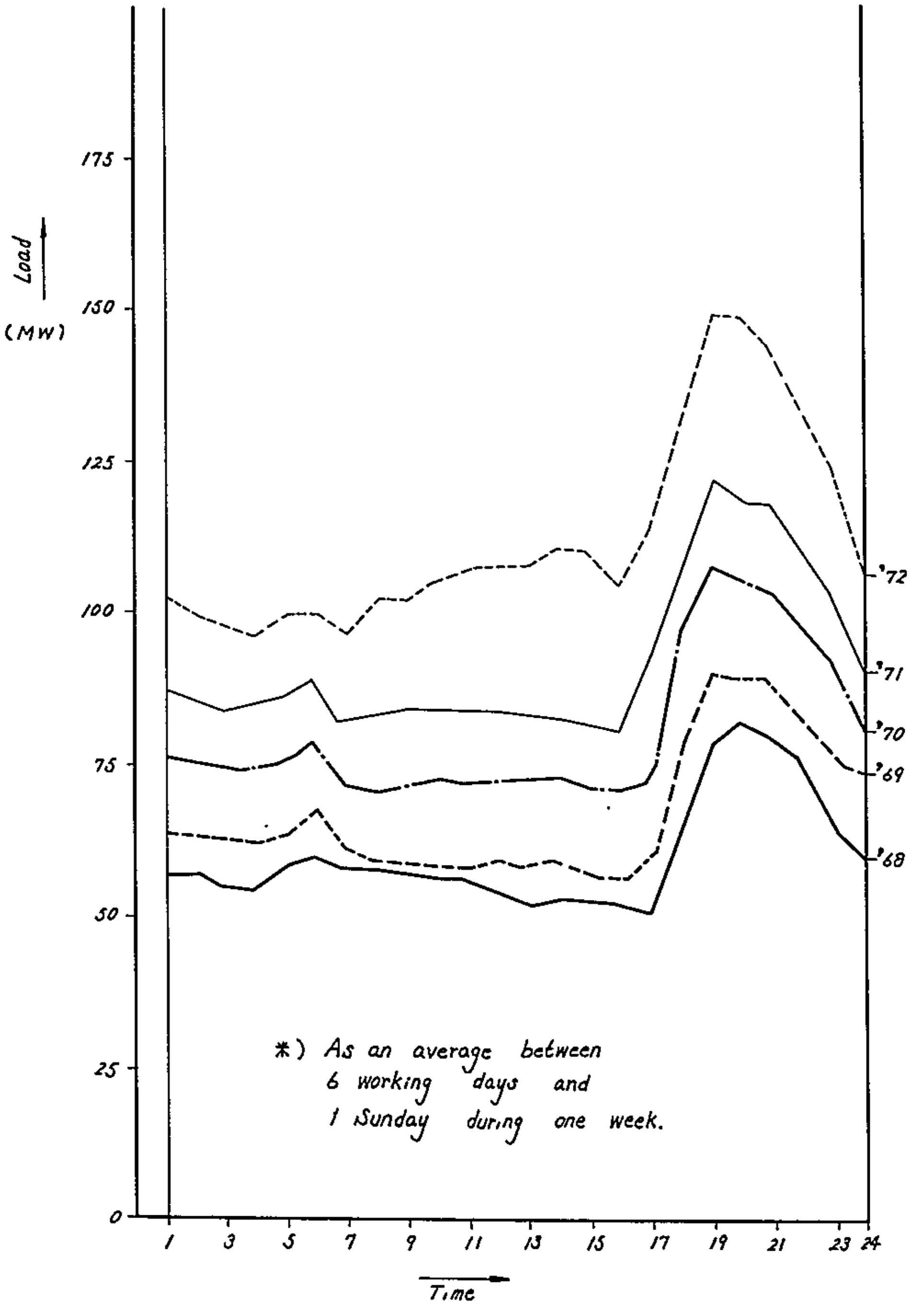
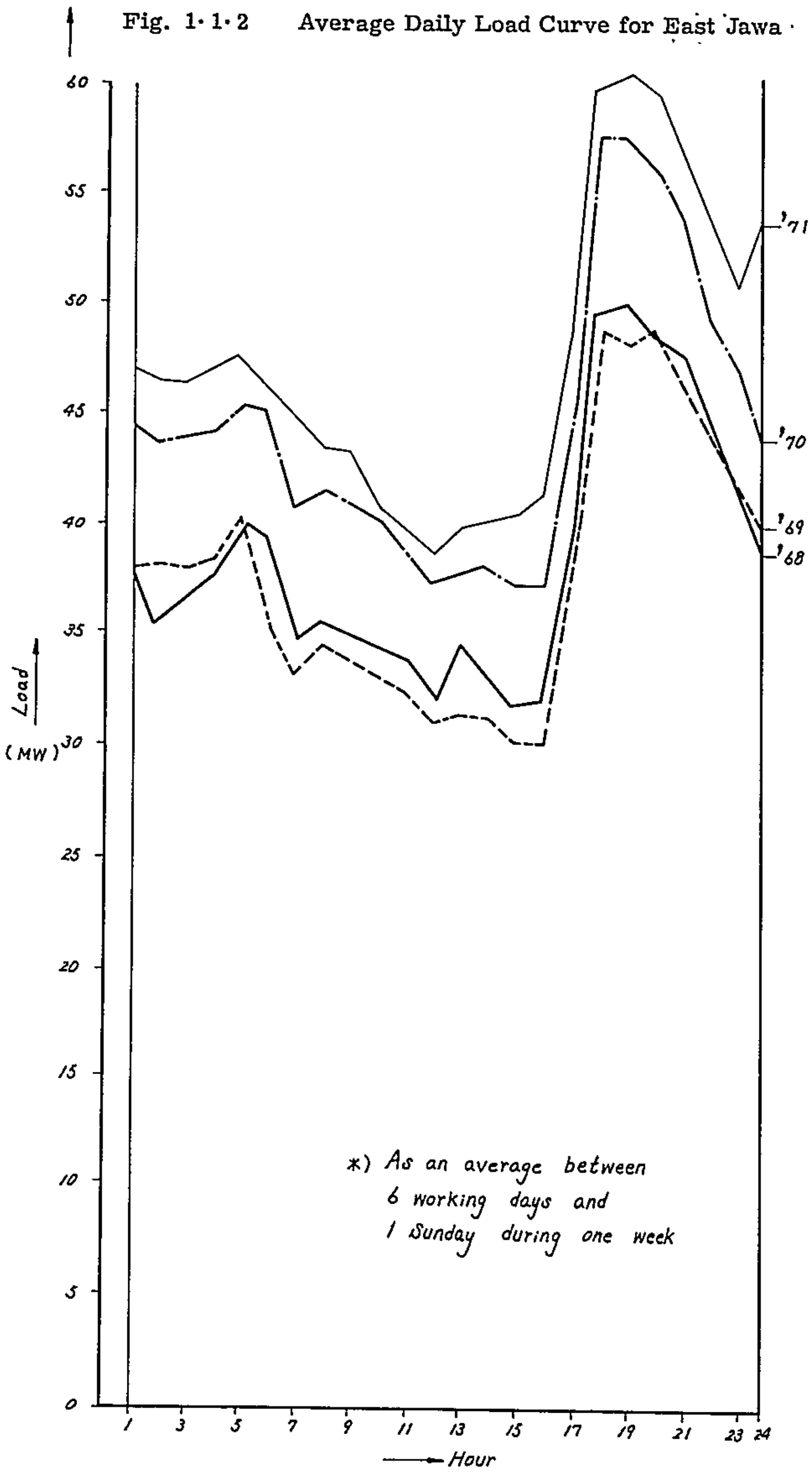


Fig. 1·1·2 Average Daily Load Curve for East Jawa



the variable cost (mainly fuel cost) has little effect on the overall operation cost.

Hence, even though the variable cost proved to be a little higher, a power source of less investment cost (mainly construction cost) is appropriate.

For example the gas turbine belongs to this type of power source.

b. With regard to the base load, the invariable load and consequently continuous operation inherent to this section result in large amount of kilowatt-hours in comparison with that of kilowatts. Consequently the variable cost has a marked effect on the operation cost.

Therefore, the types of equipment which require large investments in construction but incur less variable cost such as the large capacity hydraulic power plants of reservoir type, high efficiency thermal power plants, geothermal power plants and nuclear power plants are preferable.

c. With regard to the intermediate load, a power source having characteristics lying between the peak load and the base load is required.

(2) The features of supply power sources will be stated below for hydraulic, thermal, and gas turbine power.

a. The features of hydraulic power supply

(a) Power generation is influenced by the streamflow of the river. And still more, this steamflow changes considerably with the season and the amount itself is different from year to year.

(b) Whether there are regulating pondages or reservoirs and what their capacities are, give much influence upon the regulating function of power generation.

(c) The hydraulic power is easy for start up and shut down and also for power control. The response to the load change is excellent.

Because hydraulic power has the abovementioned features, special considerations have been paid to the calculation of the hydraulic power.

b. The features of thermal power supply

(a) For the maintenance of the equipments, a periodical inspection over quite a long time becomes necessary, which eargely influences the power supply.

In Japan, this inspection is to be performed once a year for boilers and once in two years for turbines.

(b) The probability of forced outage caused by troubles will be larger than with hydraulic power plants.
This must be considered to be an important factor when determining the required system capability margin in order to keep the balance between demand and supply.

(c) There are limitations for the speed and range of load change and start up and shut down of the plant requires a considerable time period. Besides, heat loss accompanies the start up and shut down of the plant.

(d) There is a limit to the minimum load and this is usually between one third and two third of the maximum capacity.

(e) There is a big difference in thermal efficiency between the large capacity unit of reheat type with steam conditions of high temperature and high pressure, and the small unit of old type.

(f) In comparison with the hydraulic power, the operation cost is higher.

Therefore, it is very important to take into consideration the aforementioned points for the development planning and operation of the power sources.

c. The features of gas turbine power supply

(a) Output varies with the ambient temperature.

(b) Time required for start up is shorter than that of steam power plants.

(c) The response to the load change is quick enough.

(d) Construction cost per KW is cheaper, but operation cost is higher than that of thermal power plants.

(e) Thermal efficiency is lower than that of steam power plants.

1-2 Power Supply Reliability and Power System Capability Margin

1-2-1 Power Supply Reliability

(1) Basic conception

Power Supply Reliability represents the degree of reliability in electric power supply and can be expressed with the degree of influence to consumers given by the failure of power supply.

The factors that are most closely related with the unpleasantness of the consumers are generally thought to be the frequency, scale and duration of black-out. These factors should be accounted for in the power supply reliability and the reliability must necessarily with the facilities, also in order to reflect the reliability on the individual planning of facilities.

However, it has not been established until now, how to express the reliability reflacting all these factors as a whole, the reliability is expressed in our company, separately for the power sources and for transmission and transformation systems.

As for the power sources, the reliability expresses the number of probable days during which power may fall short on account facilities outage, lack of water in rivers and the deviation of estimated demand; as for the transmission and transformation systems, the scale and the duration of black-out due to facilities outage are used to express the reliability.

The reliability for the power sources will be stated below.

(2) Expression for reliability

There are many ways of expressing the reliability, but we mostly use the one, which is already mentioned, i. e. the number of days in a month during which the power is expected to fall short.

This can be calculated by the maximum demand load duration curve and the probability of composite power decrease P (Ai).

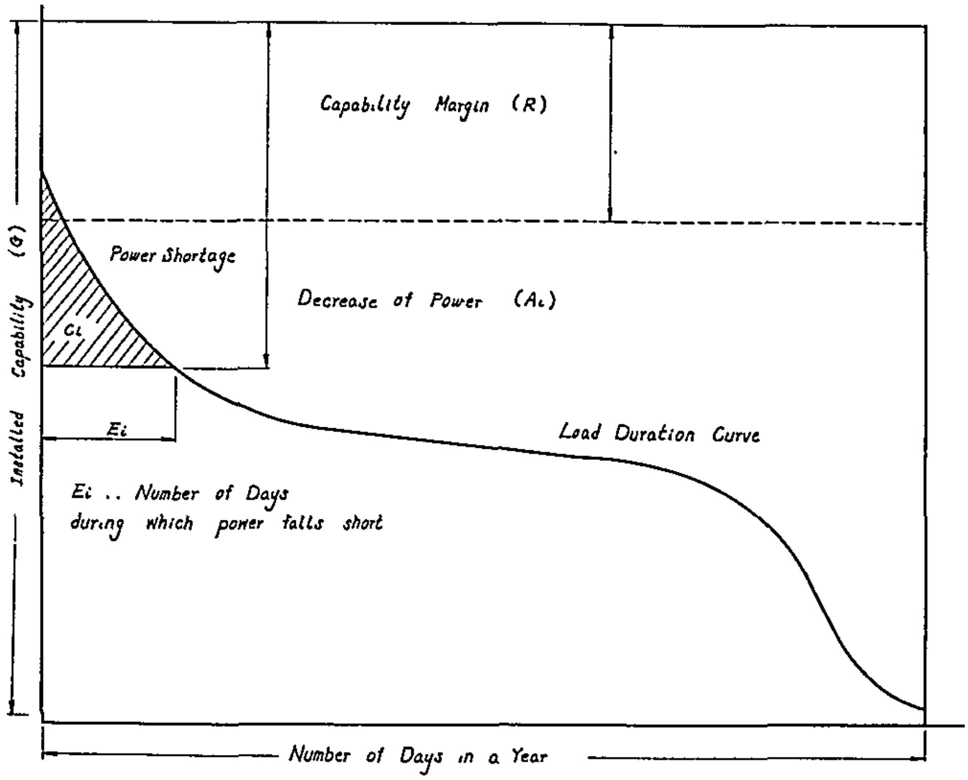
This P (Ai) is the composite probability at which the unforeseen load decrease in emergency occurs such as the facilities outage, lack of water and demand deviation.

In Fig. 1·2·1, G marks supply power including capability margin R and Ai means decrease of power including the error of demand estimation.

Then the available supply power (G-Ai) crosses the maximum load duration curve at the point Ei is number of days during which power falls short.

In case Ai is constant, and margin R is increased, there will be less days

Fig. 1·2·1 Demand Load Duration Curve and Number of Days for Power Shortage



with Ei. On the contrary, the less the margin R is, the more the number of days Ei becomes.

(3) Factors affecting the power supply reliability

Of all the factors affecting the reliability for power sources and requiring some considerations in drawing up the development planning, main factors are described below.

a. Composition of power sources

As hydraulic power plants have by far less facility troubles compared with other power sources, the ratio of hydraulic power to the total supply power sources, gives much influence to power supply reliability.

b. Capability margin

This margin represents the difference between system capability and demand, in order to provide for facilities outage, lack of water and deviation of demand.

As described above, this margin gives much influence to the power supply reliability and will be stated again later.

c. Ratio of the facilities outage of the power sources

As to the above ratio, the outage of relevant transmission line is also included.

As for thermal power facilities, there is much difference in this ratio between that of the beginning of the operation and that of the stable condition of the operation after several years.

Therefore, this must be considered necessarily for the influence to the reliability.

d. Size of the new power sources and scale of demand

The relation between size of the power generating units newly developed and the maximum demand at the beginning of their operation is also of great influence.

1-2-2 Capability Margin

(1) Meaning of capability margin

Electric power is indispensable energy for the improvement and development of national life, industry and economy, and all the more electric power must be supplied to the requested demand, abundantly, cheaply and in good quality. For this sake, it is necessary to construct and to operate the corresponding power supply facilities, after correctly calculating demand at present and in future.

The demand estimation in future varies in the long-range view with the industrial fluctuation and in the short-term view with the climatic conditions and so forth.

If an outage or lack of water occurs in the power source, capability decreases. Therefore, it is necessary to have surplus of capability over the estimated demand, because the unforeseen emergency occurs such as the facilities outage, lack of water and deviation of demand.

This surplus of capability is called capability margin.

(2) Calculation method of capability margin

a. Conception of calculation method

Factors for capability margin are considered as stated above to be facilities outage, lack of water, sudden increase of demand and so on. As the time of occurence and size of this emergency phenomena, however can not be foreseen, the number of occurence of these factors will be obtained by applying the law of probability.

Using this result, the relation between amount of margin and power supply reliability is to be investigated and then the appropriate amount of capability margin can be obtained.

That is to seek the individual distribution characteristics of the probability of occurrence, account being taken for the inequality of occurrence concerning the unforeseen factors such as the facilities outage, lack of water, error of demand estimation and so forth. Composing the total probability by these individual distribution characteristics of the probability of occurrence, the degree of influence to the demand and supply can be known.

b. Method of obtaining the composite probability of power decrease

The probability concerning the shut down amount of power generating units and the probability concerning the lack of water from a certain standard quantity (L5).

Now, let Fi (KW) be shut down amount of power generation due to the outage of the combination of n-number of generators, and P (Fi) be its probability of occurrence ; Dj (KW) be decrease of amount of hydraulic power due to reduced streamflow from a certain standard quantity and P (Dj) be its probability of occurrence. Then, the composite probability derived from the above-mentioned ones will represent the probability occurred for power decrease due to generator outage and lack of water. As the generator outage and the lack of water can be considered as independent events each other, power decrease Wm composed by the above-mentioned two events and its probability P (Wm) can be expressed in the following Formula (1-2-1)

$$Wm = Fi + Dj \qquad\qquad Dj = Wm - Fi$$

$$P(Wm) = \sum_{Fi=0}^{max} P(Fi) \cdot P(Dj = Wm - Fi) \quad \cdots\cdots\cdots\cdots \quad (1\text{-}2\text{-}1)$$

Likewise, let ej be error of demand estimation and P (ej) be its probability of occurrence, the amount of total power decrease Ai, composed by power decrease and error of demand estimation and its probability of occurrence P(Ai) can be obtained in the following Formula (1-2-2) as in the previous case.

$$A_i = W_m + e_j \qquad e_j = A_i - W_m$$

$$P(A_i) = \sum_{W_m = \min}^{\max} P(W_m) \cdot P(e_j = A_i - W_m) \quad \ldots\ldots\ldots\ldots \quad (1\text{-}2\text{-}2)$$

If there is amount of capability margin R, the shortage of supply power to the demand is (Ai− R), and the probability of occurrence is P (Ai).

1-3 Procedure for Selecting the Most Adequate Plan in Development Planning of Power Sources

In drawing up the long-range development planning of power sources, it is necessary to take the above-mentioned items into consideration and to maintain the appropriate capability margin against the demand so as to keep the target of the reliability of supply power, and then to develop the power sources corresponding to the demand increase.

1-3-1 Maintaining a Balance between Demand and Supply

The amount of power sources developed and the timing of commercial operation should be determined such that the ratio of capability margin defined in Formula (1-3-1) should satisfy the target value.

$$\text{Capability Margin Ratio} = \frac{\text{Capability} - \text{Demand}}{\text{Demand}} \times 100\,\% \quad \ldots\ldots\ldots \quad (1\text{-}3\text{-}1)$$

The target of capability margin ratio is to be determined by the target value of power supply reliability.

1-3-2 Power Requirement to be Developed

In order to keep monthly balance between demand and supply, after considering the power decrease due to the annual periodical inspection of thermal power plants and also the power variation due to streamflow change for hydraulic power plants, let the shortage of power supply be the required amount to be developed in the year.

This relation is shown in Formula (1-3-2) and Fig. 1-3-1

$$\sum_{i=1}^{12} Z_i = \sum_{i=1}^{12} L_i + \sum_{i=1}^{12} Y_i + \sum_{i=1}^{12} M_i - \sum_{i=1}^{12} S_i \quad \ldots\ldots\ldots\ldots\ldots \quad (1\text{-}3\text{-}2)$$

Here,

$$\sum_{i=1}^{12} Zi$$ .... Amount to be developed

$$\sum_{i=1}^{12} Li$$ .... Demand

$$\sum_{i=1}^{12} Yi$$ .... Capability margin

$$\sum_{i=1}^{12} Mi$$ .... Amount to be in maintenance

$$\sum_{i=1}^{12} Si$$ .... Existing capability

(a) Li represents average of the 3 days maximum output (MW) at sendingout of power station in i-month and the value of which depends on the demand estimation separately performed.

(b) Yi represents the required capability margin in i-month and the value of which can be calculated by Formula (1-3-3) with Li and α, α being the target value of capability margin ratio.

$$Yi = \alpha \times Li \qquad \text{(1-3-3)}$$

(c) Mi represents the sum of the outputs of the thermal power units which are expected in maintenance in i-month, and can be caloulated by Formula (1-3-4) with P and D; P being the sum of the outputs of the thermal power units which are expected in maintenance in the fiscal year concerned. D being the required equivalent number of months for annual maintenance.

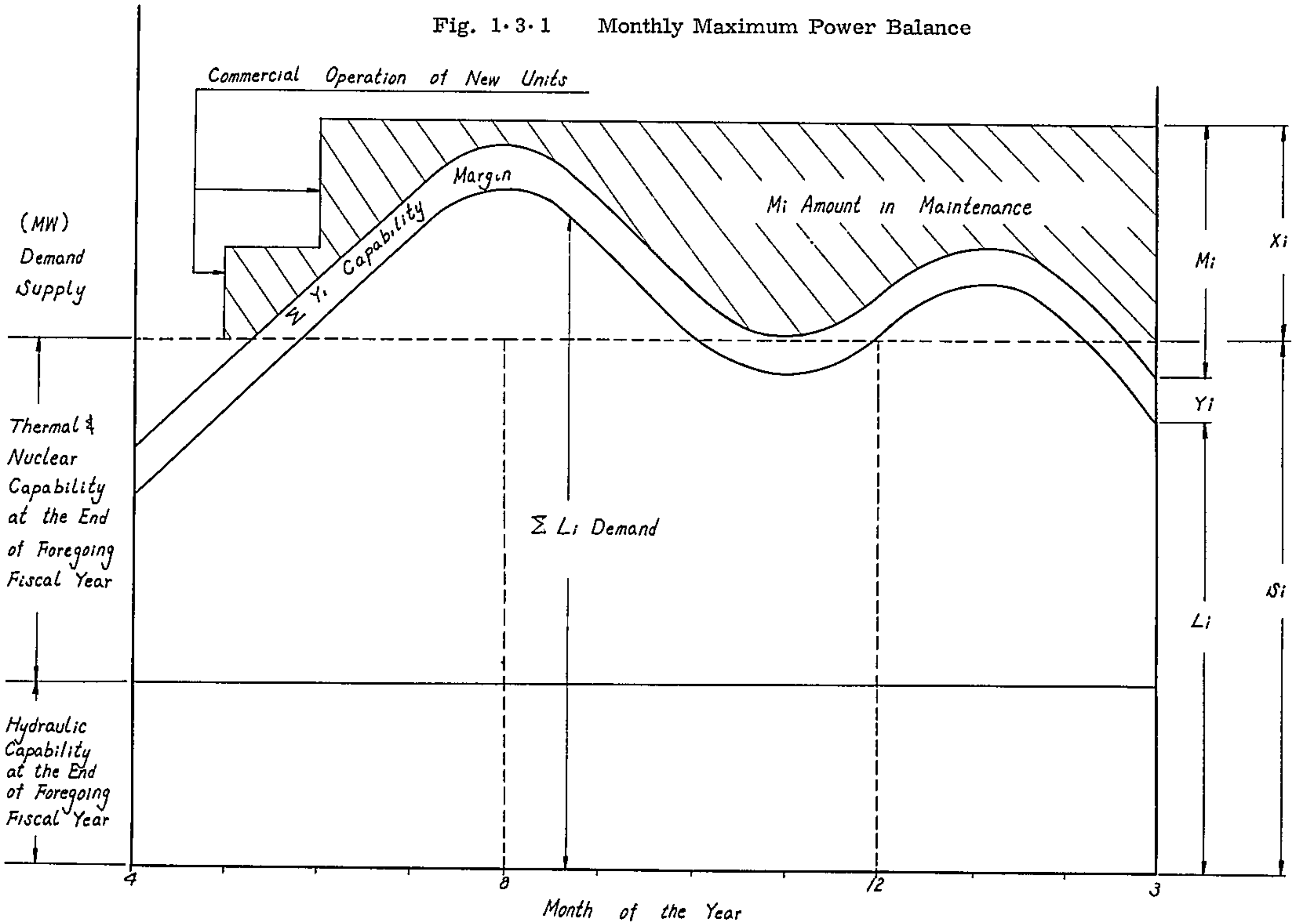
$$\sum_{i=1}^{12} Mi = \sum_{j=1}^{n} (P \cdot Dj) \qquad \text{(1-3-4)}$$

P: Output of j-unit at sendingout of power plant

Dj: Required equivalent number of months of j-unit for annual maintenance

$\sum_{i=1}^{12} Mi$: Amount of power in annual maintenance

Fig. 1·3·1 Monthly Maximum Power Balance



i: number of months

j: number of units

n: number of units in maintenance

(d) Si represents possible existing supply power in i-month, for hydraulic power, supply power (L5), for thermal power, output at sendingout of power station. This concerns the units at the beginning of the fiscal year which have already been brought into operation.

1-3-3 Determination of the Most Adequate Plant

(1) Sequence of procedures in selecting the most adequate plan

In order to the select the most adequate plan of development planning, the following items should be taken into consideration.

(a) Combination of hydraulic, thermal and nuclear power sources.

(b) Locations of individual power sources.

After drawing up two or more plans involving the above-mentioned considerations, the plan that proved to be the least expensive from the long-range viewpoint of the total power systems concerned, shall be the most adequate plan.

(i) Adequancy of capability of the power systems and maintenance of power supply reliability that will meet the ever growing demands for electric service.

(ii) Securing fossil as well as nuclear fuel for electric power generation.

- Diversification of fuels.
- Adequate amount of fuel storage.
- Extended utilization of fission energy.

(iii) Keeping pace with the most advanced technology.

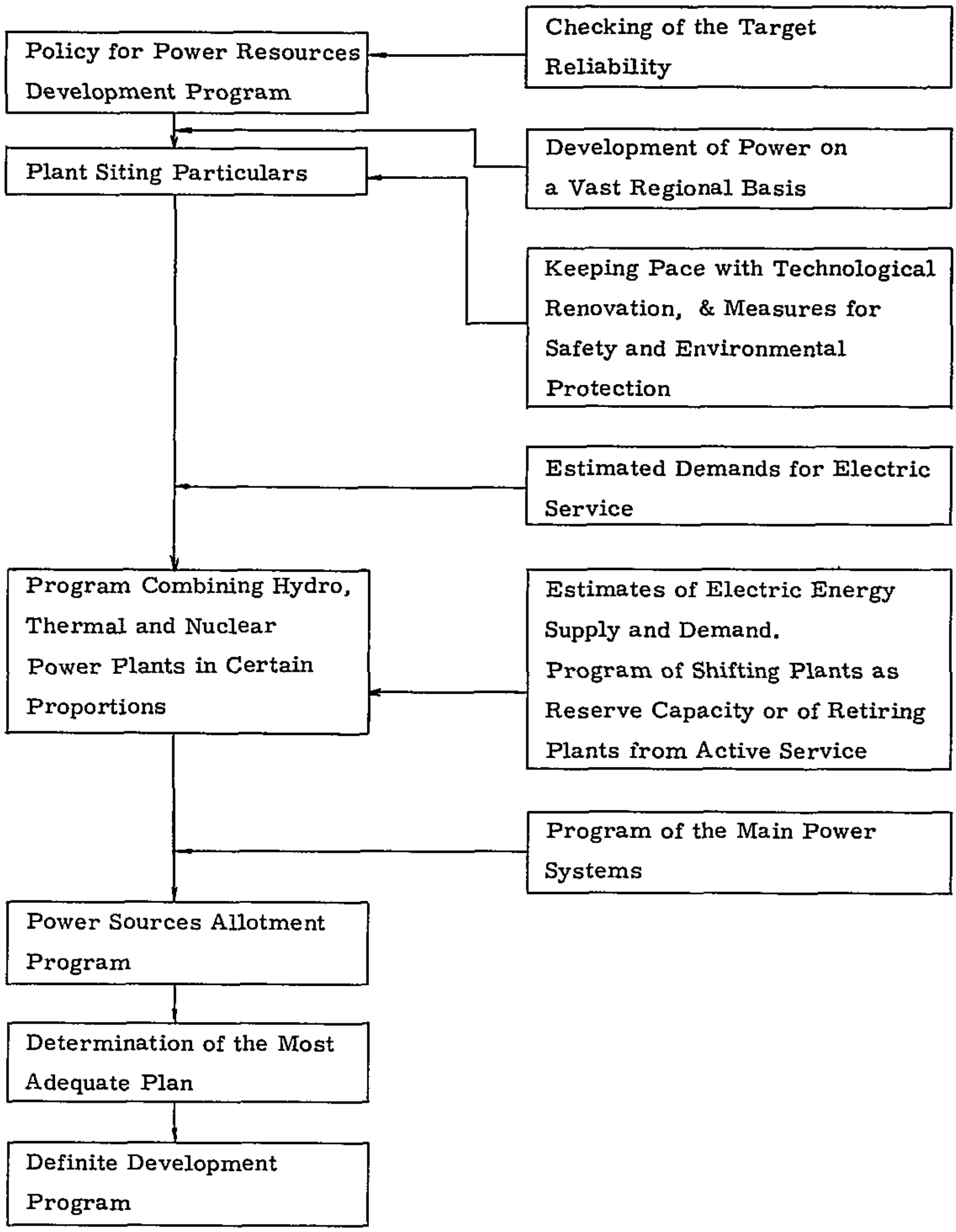
(iv) Measured for safety of employees and for environmental quality control.

(v) Pursuit of efficiency.

(vi) Program of shifting plants as reserve capacity or of retiring plants from active service.

The foregoing summary procedures for the most adequate plan may be illustrated in Fig. 1·3·2 that follows:

Fig. 1·3·2 Sequence of Procedure for the Most Adequate Plan



(2) Assessment of power plant economy

When a power plant site is selected, utilities should exactly calculate the future operating status of the power systems under their direct control for a period as long as 10 to 20 years, account being taken of the future load growth in the area served by the utilities, the trend of regional demands for more electric service, the operating and economical characteristics of all power sources.

Utilities should also take into consideration the program of holding older, less efficient units as reserve or retiring capacity and also the recent predominant trend of power plant development. In this case the assessment of power plant economy shall be made in the following manner.

a. Hydraulic power plants

In cases where a hydraulic power plant is built, two or more plants shall be drawn up on the basis of varied conditions regarding the scale of the plant, reservoir capacity and the time when the plant is put into commercial operation.

Then, the annual expenditures (c) shall be worked out of each of the plants, when put into operation.

Next, supposing that such a hydraulic power plant would not have been built, utilities should calculate the annual expenditures (V) of a thermal power plant to be constructed in place of the hydraulic power plant.

Then, utilities should take such a plan having the largest remainder of $V - C$, or a plan having the smallest quotient of C/V.

b. Thermal power plant

In cases where a fossil fuel-fired plant is built, several plans shall be drawn up on the basis of varied conditions regarding the scale of the plant, the method of power transmission and sorts of fuel to be burnt. Then the annual expenditures shall be worked out on given operating conditions. Utilities should take such a plan with the least annual expenditures.

c. Nuclear power plant

Assessment shall be made in the same way as above.

d. Units to be held as reserve or retiring capacity

In cases where a small hydraulic units with higher operating and maintenance costs or older and less efficient thermal units have come under scrutiny as to whether they shall be used with regularity or be held as reserve or retiring capacity, utilities should calculate the a annual expenditures on the basis of times for removal from the active service to reserve or retiring capacity, account being taken of the associated expenditures for construction of transmission and sub-formation facility, and an automation program.

Utilities should take such a plan with the least annual expenditures.

In cases where fossil fuel plants are reconstructed, particular attention should be given to the natural environmental protection at the site.

1-3-4 Coordination of Hydraulic, Thermal and Nuclear Power System Operations

(1) Basic principle

To meet yearly growing demands for electric power most efficiently and economically, electric utilities shall draw up a capability of their systems suitable to meet a variety of load shape.

This capability shall be made up by arranging hydraulic, thermal and nuclear power plants having different economic and operational characteristics in proper proportions so as to meet a variety of load shape and to maximize the efficiency of their facilities on a collective basis.

(2) Program of combining hydro, thermal and nuclear power plants in proper proportions

Since power plants, when developed, will stand many years service, it is imperative for electric utilities to develop hydraulic, thermal and nuclear power plants, each having different economic and operational characteristics, in an appropriate proportion so that the all-round expenses of the plants developed would be minimized not at any short period but for a comparatively long time.

To assess the economic aspect of the development, it is essential to know the changes in operation that new and older power plants would undergo, future trend of power demands and advancement of technological renovation.

In assessment of the plant economics, firstly, the combination of plants is reviewed in the broad sense, then various other aspects are further studied on the basis of an indication of the conclusion thus arrived at and finally list the plants in the definite expansion program.

1-3-5 Power Sources Allotment Program

In proportion to the expansion of power systems as a result of the growing need for more power, assurance of the system safety and establishment of most economical electric generating facilities are called for.

This principle, however, shall be carried out in cooperation with the utilities programs of main systems. In laying out their plan, the utilities shall divide their systems in a certain number of blocks in comformity with the regional distribution of demands for service and within each block the utilities shall take their respective economics into consideration and maintain an adequate balance between the demand and supply as well as balance among hydraulic, thermal and nuclear capacities.

Based upon the aforementioned thinking, the utilities shall choose plant sites by years and by regions thus drawing up their programs of expansion in a less abstract form.

The utilities then shall use every endeavour to acquire the sites thus selected on paper and shall determine the number of units to be installed therein, dependant upon the size of the site.

2. METHOD OF SELECTING THERMAL POWER PLANT SITES

2. METHOD OF SELECTING THERMAL POWER PLANT SITES

2-1 Importance of Securing the Thermal Power Plant Sites

When developing the thermal power generation, it is most important to have secured the plant sites always at hand, necessary for the thermal power development.

For this purpose, in totally considering the trend of demand in future, combination of the various kinds of power generation and influences to the area and residents, the necessary annual power required for the thermal power generation will be estimated.

It is important to have good preparation for the sites, after surveying and selecting the sites corresponding to the above thermal power development.

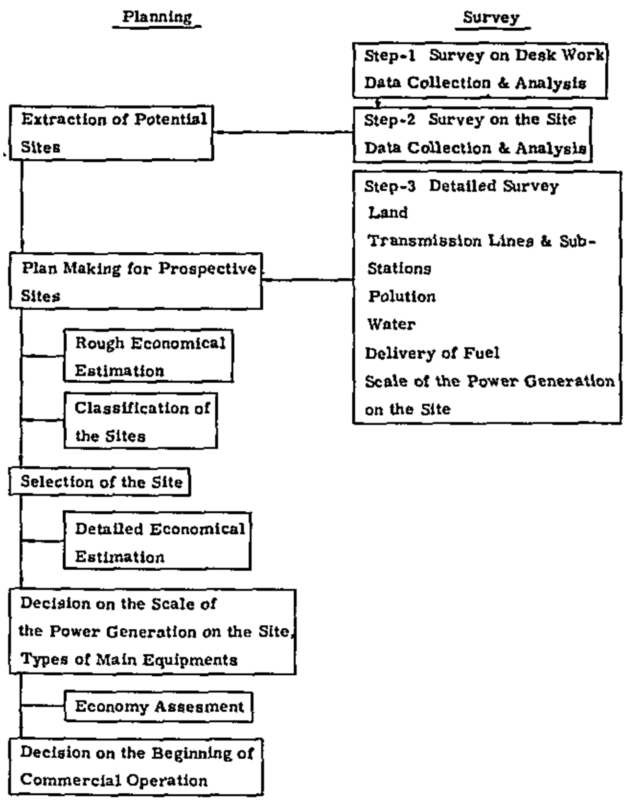
Needless to say, the required period from the construction beginning on the site until the commercial operation of the plant will be about 3 - 4 years.

Therefore, taking the time schedule into thorough consideration, the choise of the sites should desirably be done earlier.

2-2 Outline Procedure for Thermal Power Development Planning

The outline procedure in performing the thermal power plant development planning is shown in Fig. 2·2·1. This item concerns only the survey method of the thermal power plant sites for performing the development planning.

Fig. 2.2.1 Outline Procedure for Thermal Power Development Planning



2-3 Survey Method Prior to Selection of Thermal Power Plant Sites

2-3-1 Basic Care for Survey

It is the survey of the site that is most fundamental in selecting the thermal power plant sites. The development planning of the thermal power generation will be greatly influenced by the result of this site survey, which is ill performed or well performed.

If the survey method is inadequate, or is performed in a consequently the great disadvantage arises, while implementing this plan.

Therefore, this site survey must be very deliverately and quite often repeatedly performed, when needed. The survey reports must be well arranged and kept in good order to be prepared for the later reference and reconsiderations, when necessary.

In the survey and planning department, it is very important to keep the necessary data, drawings and books prepared for occasional use.

2-3-2 Outline Procedure for Survey of Thermal Power Plant Sites

This procedure can be devided into the following three steps.

(a) Step - 1 Survey on desk work

(b) Step - 2 Outline survey on the site

(c) Step - 3 Detailed survey

(a) The survey of step - 1 is the check beforehand the potential thermal power plant sites on maps and is usually carried out in the headquater.

(b) The site survey of step - 2 is to inspect actually the sites, picked up on the desk work survey of step - 1, whether they are adequate or not.

(c) The detailed survey of step - 3 is to make the through research of the sites which passed the step - 1, 2 and to accomplish the final survey.

2-3-3 Survey Method of Thermal Power Plant Sites

(1) Survey on desk work

Taking the main future transmission and transformation system planning into consideration, the survey on desk work will be performed according to Table 2·3·1, "Requirements and Criteria Established by Utilities as Guidelines for Thermal Power Plant Siting".

In this survey, the adequate sites will be sought refering to the land maps and sea charts. And further all the necessary data, such as the meteorology on land and sea, and the other existing data will be collected for the research work.

During the survey on desk work, 2 - 3 potential sites should desirably be found for one power plant in preparation for the future site survey.

In order to better grasp the sites, the serial photos might preferably be taken around the potential sites.

Table 2·3·1 Requirements and Criteria Established by Utilities as Guidelines for Thermal Power Plant Siting

Requirements or Criteria	Particulars	Purposes
Location	Address of the area, Topography. The status of urbanisation around the site.	For building a power plant
Land	Space and shape of the area, Land prices and Indemnity problems	

Requirements or Criteria	Particulars	Purposes
Geology	Location of hard stratum, Ground bearing force and Grade of hardness of excavation	
Site Preparation	Reclamation work, Bank revetment, Industrial zone development program	
Land and Marine Transportation	Roads, Railroads conditions, plan of establishment of harbor combines	For delivery of fuels and construction materials
Boiler Feed Water	Programs of city service water and Industrial water, Underground water	For securing water
Condenser Cooling Water	Plan of taking-in cooling water, Conditions of environment, Temperature of cooling water	
Transmission Line	Housing congestion around the area, Relationship of transmission lines placed in service and expected to be operational	For construction of outgoing transmission line
Wind and Tide	Direction and velocity of wind, Make an inquiry into the presence of inverse layer and tide difference	Countermeasure for safety and environmental protection
Existing Pollution	Air and water pollution, noise nuisance other environmental disruption	

(2) Outline survey on the sites

This survey should be performed, based on the above survey on desk work. Also according to Table 2·3·2· "Items Requiring Research for plant siting", as in the case of (1), real conditions should be confirmed by physical eyes, supplementing the wants of the survey on desk work. It may also be in this survey necessary to hear about the actual meteorology on land and sea from the nearby residents. But in the case when this survey should not be known to the public, care must be taken. In order not to let the sleeping dogs arise, such as the escalation of land price, objection due to pollution and so on, this survey should in general preferably be performed without letting people know.

Table 2.3.2 Items Requiring Research for Plant Siting

Requirements or Criteria	Sub-items	Particulars	Purposes
Location	Location character	Address of the area Local demands for service For promotion of vast area development Supply of power to combines	For building a power plant
	Status of environs around the site	Status of topography, factories, railroads, roads, service water and sewer systems, the condition of the residents, national parks (as to whether they are designated as National Parks)	
	Future program of the environs	Industrial area, harbor construction, reclamation, industrial water, enterprises coming into the area, cooperative power plants, designated area for industrial power installations	
Land	Shape of the area	Shape, space, bank revetment, elevation	For securing a plant site
	Ownership	State, prefectural government, municipality, private ownership	
	Land price		
	Classification of Land	Rice field, farmland, forest, sand beach	
	Object requiring indemnities	Removal of houses, fishing right, mining right, right on river bed	

Requirements or Criteria	Sub-items	Particulars	Purposes
Geology	Geology	Stratum ground bearing force, location of hard layer, hardness of excavation, sinking of ground (Refer to Volume IV Appendix 1-1)	Same as above
Site Preparation	Site preparation	Dredging, tearing down a hill, dumping of ash, reclamation, ground levelling, whether there is any industrial area development program	Same as above
	Past record of disasters	Typhoon, high tide, air & water pollution, damage due to salt, earthquake	
Land & Marine Transportation	Roads	Routes for bringing in constructional plant, width of a road, conditions of pavement works, locations where bridges are built, permissible weight, volume of land traffic	For delivery of fuels and construction materials
	Railroad	The nearest railroad station distance to plant site	
	Harbor	Scale of the harbor, freight handled at harbor volume of sea traffic	
	Receipt of Oil Delivery	Oil unloading capacity at harbor, is there necessity of dredging, capacity of refineries located in the neighborhood, capacity of pipe lines for forwarding	
Boiler Water	Industrial Water	Source of river, volume of water, present amount of consumption, present route of pipeline	For securing water

Requirements or Criteria	Sub-items	Particulars	Purposes
	City service	Quality of water, capacity of receiving service water	
	Underground water	Status of utilization, quality of water, limitation placed on use of underground water	
Condenser Cooling Water	Sea water and River water	Quality of water, temperature and amount of water, dirt in water, amount of water taken in and discharged by adjacent factories, growth of shell, growth of jelly fish	Same as above
Transmission Line		Transmission and transformation facility installed in the neighborhood, difficulty in installing outgoing overhead or underground transmission lines	For construction of outgoing transmission lines
Meteorology on Land and Sea	Wind	Direction and velocity of wind, inverse layer, typhoon, damage caused by salt and dust	Measures for environmental protection
	Tide	Frequency of high tide, high waves, level of high tide, depth of water	
	Surface of sea water	Littoral drift (Refer to Volume IV Appendix 1-2, 1-3)	
Existing Pollution	Flue gas	Status of existent pollutant, source of pollutant	Same as above
	Waste water	Environment protection measures taken in the area, sentiment in local town	
	Noise nuisance		

Requirements or Criteria	Sub-items	Particulars	Purposes
	Restriction placed on high structures	Airport, distance from communication facilities, other matters to be taken into consideration in determining site poten-siality, scale and term of construction.	

(3) Detailed survey

The detailed survey will become necessary, when the prospective sites converge itself, according to the above survey (1) & (2).

Therefore this survey should be performed according to the required items of Table 2·3·2 and the survey reports should be made. In the meanwhile meteorological observation and model test will be done, when necessary, such as test boring, wind tunnel test, wave simulation test etc.

On this mater, the method of investigation and making report will be plactically shown in Volume III. Here it has been explained only in general.

2-4 Survey System for Thermal Power Plant Sites

The most important matter for the sites survey is to prepare data, which contribute to the right and total judgement for the site selection.

For this purpose the cooperation of electrical, mechanical, civil, architectural and chemical engineers is necessary.

And the bringing up of thermal power engineer is also necessary, who have the ability for totally judging and coordinating the technique of thermal power plants.

2-5 Conclusion

Though briefly, the survey method of thermal power plant sites has been explained, and repeatedly it would like to point out that the site survey is the key for implementing the thermal power development planning.

From our past experiences the shortage of plant sites has sometimes agonized us, when the power demand increased rapidly. Therefore it is also in Indonesia for the supply of power very important to make the right site survey earlier and to secure the land beforehand.

3. METHOD OF THERMAL POWER STATION OUTLINE PLANNING

3. METHOD OF THERMAL POWER STATION OUTLINE PLANNING

3-1 Purpose

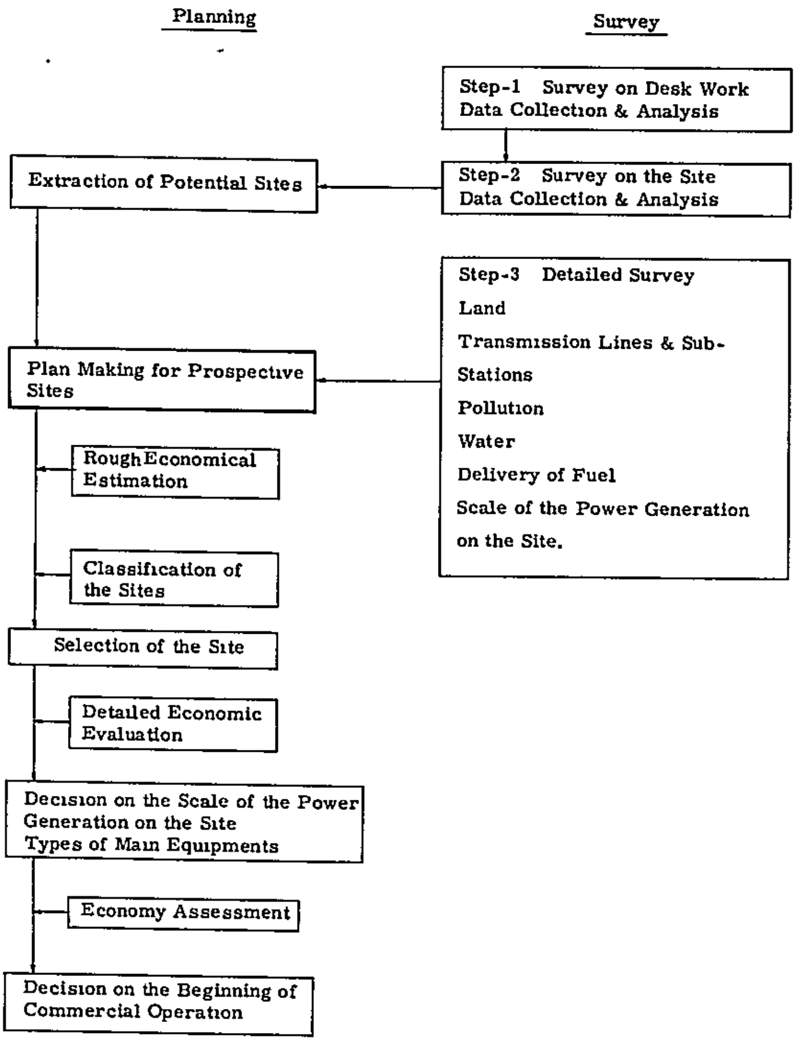
The purpose of outline planning is to make the siting particulars based upon the detailed survey of sites. This siting particulars will become the fundamental data for the economic study of sites and also for the selection of sites. Refer to Fig. 3-1-1.

This outline planning consists of the following items.

(1) Selection of unit size and its steam conditions
(2) Determination of power plant scale
(3) Plot Plan
(4) Planning of general arrangement
(5) Intake and discharge method of condenser cooling water
(6) Delivery and storage of fuel
(7) Security of house service water including boiler water
(8) Main building and its foundation
(9) Measures for environmental protection
(10) Switchyard planning
(11) Determination of ground level
(12) Delivery method of construction materials
(13) Land Reclamation

It will be explained here about oil-firing power generating units. This outline planning of oil-firing power generating units can also be applied to gas and coal firing power generating units, gas turbine units, and diesel units.

Fig. 3.1.1 Outline Procedure for the Thermal Power Development Planning



3-2 Detailed Description

3-2-1 Selection of Unit Size and its Steam Conditions

The price of main equipments of thermal power station, such as boiler, turbine and generator amounts to be about 70 - 80% of the total construction cost. Not only that, these main equipments give much influence upon the operation cost after the end of construction. Therefore, much precaution should be paid for the determination of unit size, steam conditions, etc.

Generally speaking, economy of a thermal power plant can be enhanced by making unit size larger and selecting the higher steam conditions.

However, in reality, the unit type of the thermal power station will be determined by the total economy, considering the scale and capability margin of the power system, operating characteristics of the unit, technical level of manufacturing and operation, and reliability of equipments.

The outline procedure for selecting the unit size will be shown below. Refer to Fig. 3·2·1.

(1) Selection of unit size

a. As shown in Fig. 3·2·1, first of all taking into account the restriction from the system and the manufacturing limit, choose the several alternatives for unit size and then find out the appropriate types of boiler and turbine.

The following items shall also be considered at the same time.

- Records of manufacturing and operation
- Development of the concerned technology
- History of the tendency of the unit size selection and prospect of making unit size larger

b. The restriction from the power system means the following. If unit size is enlarged excessively, excessive cycle drop and voltage fluctuation will come out in the unit trip.

Therefore, in order to secure required reliability, reliability margin must be increased, resulting additional investment. In other words, it is important to such select the unit size that will require the least additional investment cost to the capability margin, restricting the cycle and voltage fluctuation in the case of unit trip within the allowable service level.

In our company, the largest unit size corresponds to 3 - 6% of the maximum supply power of the power system, in order to match the required service level. Refer to Fig. 3·2·2.

c. As for restriction of the design and manufacturing, there are a development of the larger blade length of the last stage of steam turbine and the cooling method of the generator. 1, 000 MW turbine generator is already developed among machines for 50 Hz.. There may be no restriction for the unit size in Indonesia from the technical level of designing and manufacturing.

Fig. 3·2·1 Conditions for the Selection of Most Appropriate Unit Size

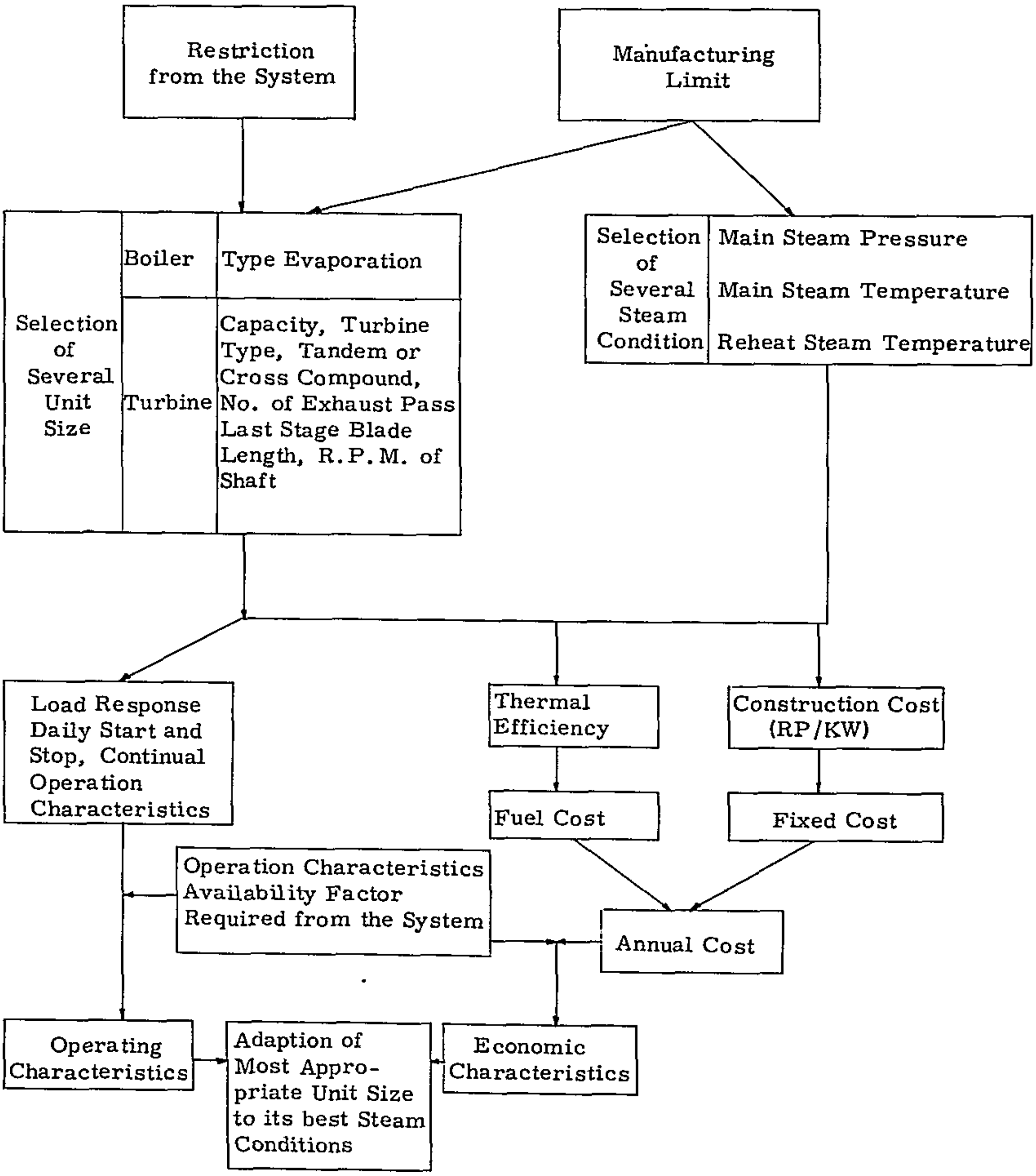
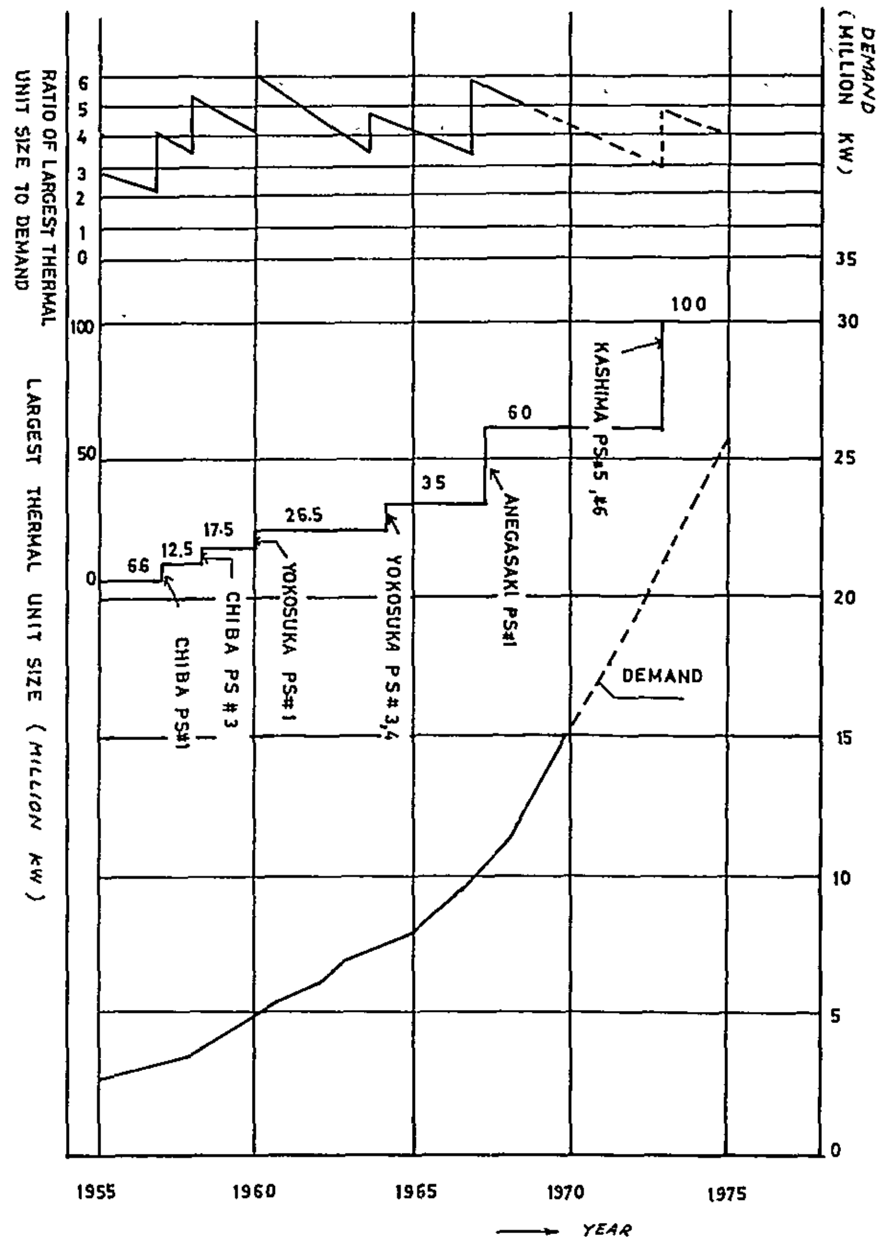


Fig. 3·2·2 Annual Demand & Historical Largest Thermal Unit Size of Tokyo Electric Power Co., Inc.



(2) Selection of steam conditions

Judging from the manufacturing level, several alternatives of practical steam conditions shall be selected in connection with the unit size and then study shall be performed concerning construction cost per KW, thermal efficiency and operating characteristics.

In short, steam conditions give much effects to thermal efficiency and the price of machines.

So the steam conditions shall be determined in balance of decreasing fuel cost for the higher thermal efficiency and the increase of construction cost and maintenance. Steam conditions in connection with unit size in Japan shall be shown in general in Table 3·2·1.

Table 3·2·1- (1) Record of Unit Size & Steam Conditions in Japan

Pressure(kg/cm^2g)	83		102		127		169				190	246		
Temperature (C°)	510		538/538		538/538		566/538				538/538	538/538	538/538/566	538/566
Unit Size (MW) \ Frequency (Hz)	50	60	50	60	50	60	60	60	50	50	50	60	60	50
66	x	x												
75			x	x										
125					x	x								
156							x	x						
175									x		x			
220							x	x						
250								x	x	x				
265										x				
325								x						
350										x				
375								x						
450													x	
500												x		
600													x	x
1000														x

Table 3·2·1-(2) Unit Size & Steam Conditions

STEAM CONDITIONS				ADAPTABLE RANGE
kg/cm^2g	°C	psig	°F	MW
102	538/538	(1 450)	(1000/1000)	60~ 125
127	538/538	(1 800)	(1000/1000)	75~ 150
169	538/538	(2 400)	(1050/1000)	150~ 600
169	566/538	(2 400)	(1050/1000)	150~ 600
169	566/566	(2 400)	(1000/1050)	250~ 600
246	538/538	(3 500)	(1000/1000)	400~1000
246	538/566	(3 500)	(1000/1050)	400~1000
246	538/552/566	(3 500)	(1025/1050)	400~1000

The trend of fuel cost shall also be considered in the above-mentioned study. In Fig 3·2·3 the relation between turbine type and heat rate, in Fig 3·2·4 the trend of construction cost are shown.

(3) Estimation of annual cost and comparison of operating characteristics

a. Annual cost shall be calculated, taking into account the operating characteristics required by the power system and the trend of availability factor during service life from the viewpoint of combination of power sources.

b. On the other hand, study shall be made, which combination of unit size and steam conditions matches to the operating characteristics, such as load response required by the power system, start and stop characteristics and continuous operating characteristics.

(4) Selection of most adequate unit size and its steam conditions

Considering the above-stated study result as a whole, such an alternative shall be selected that has the least annual cost and the combination of unit size and steam conditions matching the operating characteristics required by the power system.

(5) Others

a. The method of the determination of the rating capacity for the main equipments is shown in Volume IV Appendix 2·5.

b. The influence to the boiler equipments using high sulphur residual oil is shown in Volume IV Appendix 2·6.

Fig. 3·2·3-(1) One Example of Turbine Heat Rate Change

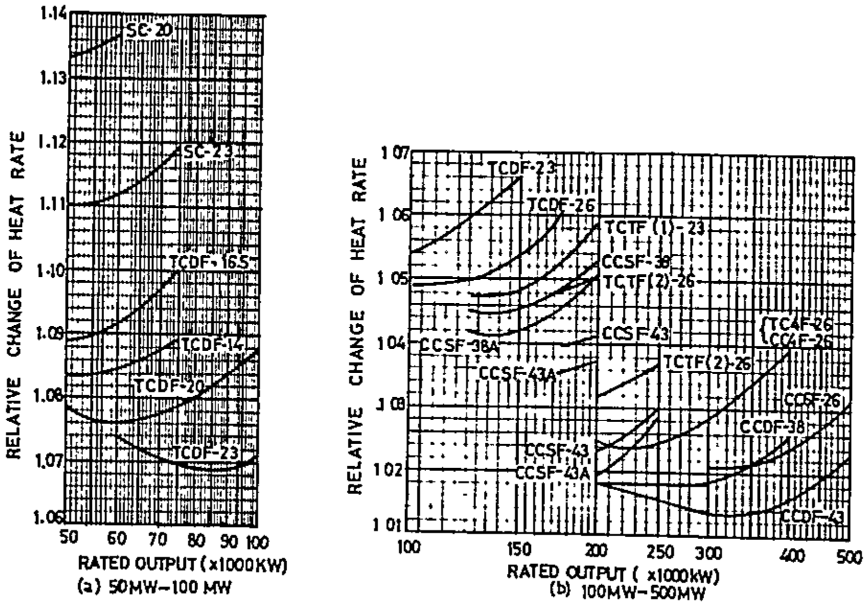


Fig. 3·2·3-(2) Steam Conditions & Heat Rate

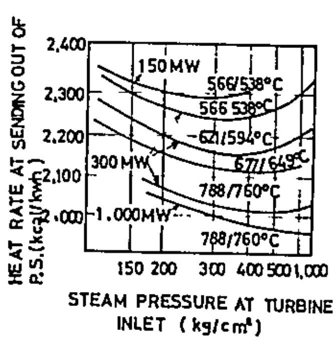
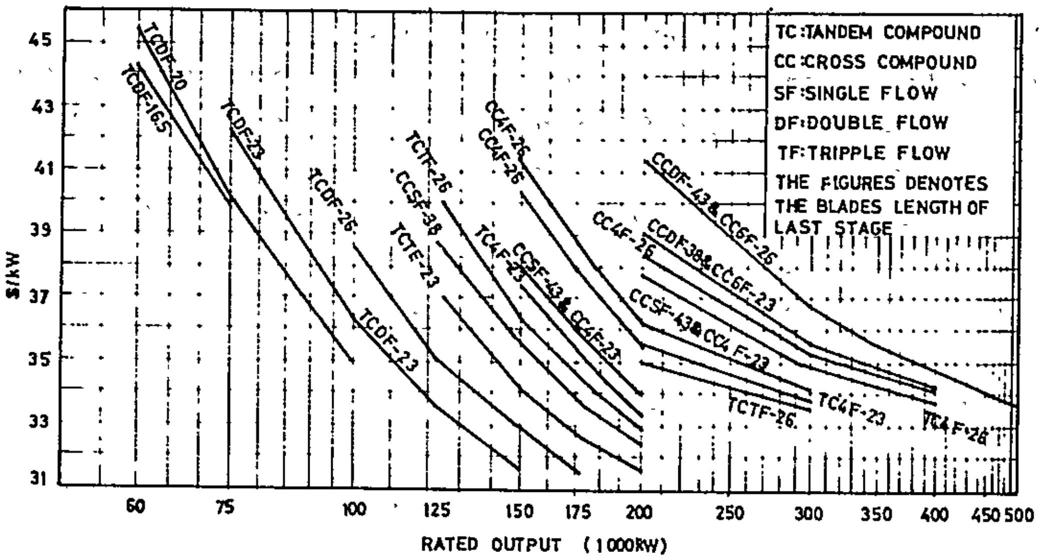


Fig. 3·2·4-(1) One Example of Relation Between Turbine Type & Price



STEAM CONDITIONS

50 ~ 100 X 10^3 kW	102 km/cm²,	538°C / 538°C
100~200 "	127 "	538°C / 538°C
200~500 "	169 "	538°C / 538°C

Fig. 3·2·4-(2) Relation of Unit Size Increase & Construction Cost Increase in Large Scale P. S.

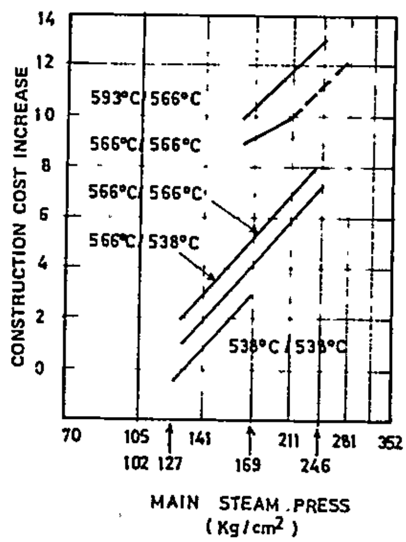
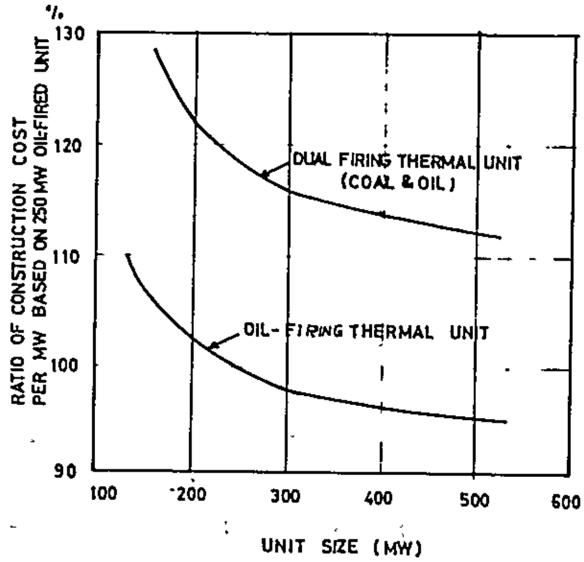


Fig. 3·2·4-(3) Unit Size & Construction Cost



3-2-2 Determination of Power Plant Scale

It is necessary to have a prospect over the final scale of power station to make an investigation of plot plan and economic study of the site.

(1) Advantage of large scale power station development

The land for power station, port for fuel delivery, sea berth, oil pipeline and cooling water intake facility for the power station require large amount of construction cost, but this amount does not change very much dependant upon the power station scale. Therefore, the construction cost per KW will decrease in the case of larger development. Besides, area of the site per KW and architectural structures can also be spared.

In this sense, the construction cost per KW can be decreased by making the final scale of the power station larger. But, there are some restricting factors for the large scale development.

(2) Restricting factors of development scale

In determining the scale, there is an upper limit from the problems of power system and siting conditions.

a. Restricting factors from the power system

If the scale of the power station becomes excessively large, the drop of cycle and voltage of the system will occur in the worst cases such as the black-out of the power station and the simultaneous outage of the transmission line, and may develop to the trip of other power sources and collapse of the system, which will give much influence upon the power system stability.

In order to avoid this, the scale of the power station shall not be too large in connection with the power system, taking into account the system configuration and the scale of the system.

b. Restricting factors from the siting

There are following restricting factors.

(a) The limit of siting area including the area for fuel storage.

(b) The limit of condenser cooling intake water temperature caused by water recirculation.

(c) The limit of the capacity of fuel delivery into the site, either by ship or pipe line on the land.

(d) The limit of the air pollution.

3-2-3 Plot Plan

Based upon the site survey result, determine the dimension of the main equipments, making the image of the final power station.

Then make the plot plan of the power station considering the economy of the power station and the effective utilization of the land. This will serve to make the rough estimation of the construction cost.

(1) Fundamental arrangement of main equipments.

In making plot plan, arrange main equipments in energy flow principle. This arrangement will make the maintenance and operation easier and safer, and prove to be logical.

Namely the sequence of procedure is as follows.

- (a) Pier (Unloading facility of fuel)
- (b) Fuel storage tanks
- (c) Main building of the power station and relevant equipments such as stack
- (d) Cooling water channel
- (e) Substation or switchyard

Standard arrangement and rough dimension of main building are shown in Fig. 3.2.5 and Table 3.2.2 respectively.

(2) Fundamentals for planning

Based upon the fundamental arrangement aforementioned, make the actual plot plan, noting the following points. The size of drawing is preferably in the scale of 1/1000.

a. Coordination with siting conditions

- (a) Most economical arrangement coming from the shape and the shore line of the site
- (b) Arrangement due to equipments safety

  In relation with the kinds of adjacent factories and relative location of the site, avoid the damage that might result from the factories.

b. Considerations for future extension

Plot plan shall be made from the very beginning not to give any limitation to the future extension. Namely, it is desirable to make the space adjacent to the existing units free from equipments in order that any extension plan can be realized later.

Fig. 3·2·5 Standard Plot Plan

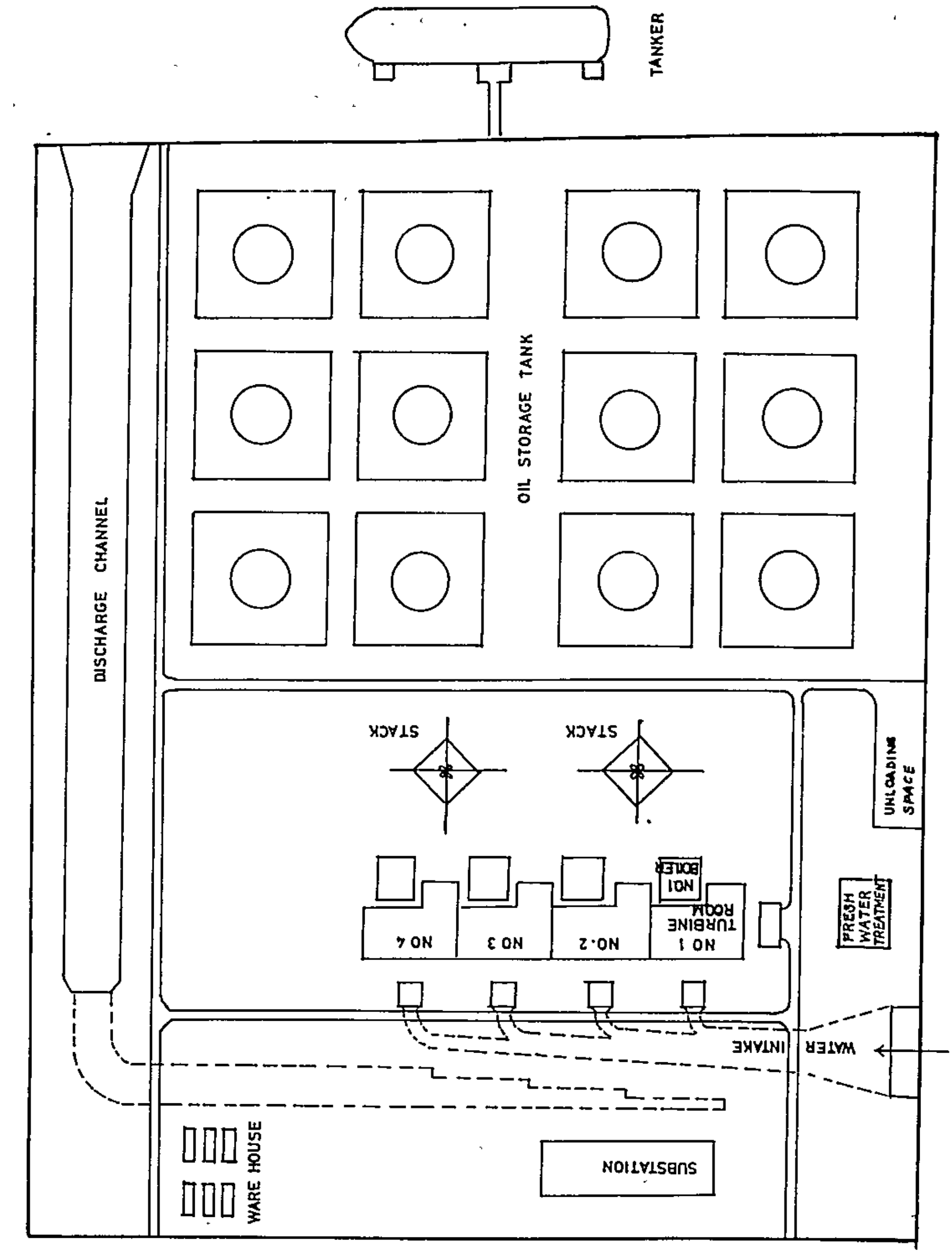
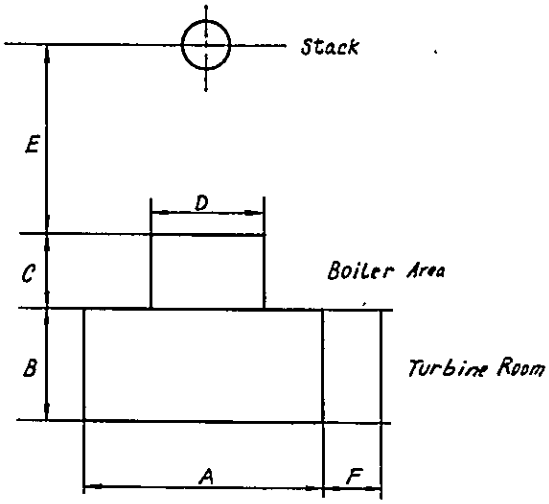


Table 3·2·2 Rough Dimension concerning Main Building & Stack

(Unit: M)

MW	75	125	156	175	250
A	40	45	50	53	60
B	25	25	28	28	34
C	23	25	28	33	39
D	13	27	27	27	32
E	17	40	40	40	45
F	7	8	8	11	18



(3) Consideration for construction work

a. In plot plan, space for construction material and space for boiler fabrication must be considered. In general, future extension space can be used for these purposes.

b. In arranging the equipments, interference of construction work shall not occur, taking into account the construction method and construction schedule.

For instance, excavating zone, method of preservation for machines during construction period.shall be taken into account.

(4) Considerations for safety

Special care must be given to the arrangement of fuel storage tanks for the security of safety in case fire breaks out.

In Japan there is fire regulation, in which regulation is given concerning the arrangement and structure of tanks, and fire-fighting equipment.

Regulation concerning heavy oil tanks will be explained underneath.

a. Required distance between tanks and other structures

Refer to Table 3·2·3.

Table 3·2·3 Required Open Space

Tank Capacity	Open Space (Distance from Tank Surface)
2,000 - 4,000 Kl	$>$ 9 m
4,000 - 6,000 Kl	$>$ 12 m
6,000 - 8,000 Kl	$>$ 15 m
$>$ 8,000 Kl	$>$ Diameter of Tank

b. Required distance between tanks

Refer to Table 3·2·4.

Table 3·2·4 Required Distance

Tank Capacity	Min. Distance between Tanks
$<$ 4,000 Kl	$>$ 3 m
4,000 - 6,000 Kl	$>$ 4 m
6,000 - 8,000 Kl	$>$ 5 m
$>$ 8,000 Kl	$>$ One Third of Dia.

c. Determination of Dike Capacity

(a) In case there is one tank in one dike

Dike Capacity = 0.5 x Tank Capacity

(b) In case there are many tanks in one dike

Dike Capacity = 0.5 x Max. Tank Capacity
+ 0.1 x Total of Other Tank Capacity

But, the height of dike is limited lower than 1.5 m for the convenience of fire-fighting activities.

3-2-4 Planning of General Arrangements

In making the plot plan, general arrangement must be studied concerning major equipments.

(1) Fundamentals for general arrangement

In determining the general arrangement for location of major and auxiliary equipment, firstly major equipment and then auxiliaries should be considered. As arrangement of equipments will give much influence upon the construction cost and the effectiveness of the operation of the power station such as the daily inspection and maintenance, and the convenience of operation in the trouble, the decision shall be made deliberately.

For the arrengement of equipment, following points are the fundamentals.

a. Simplicity shall be preferred to the operation.

b. Equipments should be arranged according to the principle of energy flow as much as possible.

c. Arrangement shall be planned such that length of steam pipes, feed water pipes, electric wires and cables may become as short as possible, together with the shorter distance of fuel delivery.

d. Operation measure shall be taken easily in case of trouble and outage, and spreading of the failure must be prevented.

e. Consideration for extension of units.

(2) Arrangement of major equipment

Arrangement is slightly different with the unit system (one turbine to one boiler) and the system of one turbine with multi boilers.

Unit system is mostly adopted in these days, because the boiler reliability improved itself sharply by the manufacturing technique of boilers.

a. Arrangement of turbine-generators and boilers

The arrangement of turbine-generator and boiler of unit system shall be classified as in the following. This is shown in Fig. 3·2·6.

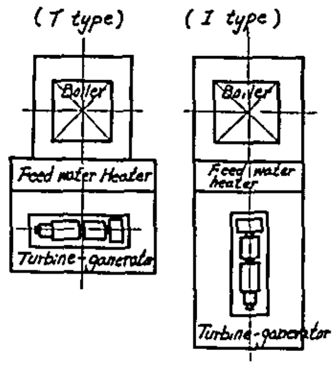
(a) T-Type arrangement having the axis line of the turbine-generator shaft in paralled with the front wall of the boiler.

(b) I-Type arrangement having the axis line of turbine generator shaft at right angle to the boiler front wall.

The selection of this arrangement is not easy to be judged without considering the special conditions of each case.

But in general, as unit size becomes larger, total length of turbine generator gets longer. Then, in the case of I Type arrangement, turbine crane span increases tremendously and economic merit disappears. In our country, T-Type arrangement is used exclusively for the unit size larger than 125 MW.

Fig. 3·2·6
The Arrengement of Turbine-generator and Boiler



b. Selection of indoor or outdoor type
Outdoor type is called for the installation, in which major equipments lie outside, while indoor type installation generally accommodates inside the main building.

Besides these, there is another way, namely turbine generator in building and boiler of outdoor type. It will be decided by siting particulars, operating pattern, and economic studies, which type should be selected.

In Japan, mostly boiler is of outdoor type and turbine-generator is of indoor type. Merits and demerits of outdoor installation will be mentioned briefly here.

(a) Construction cost for the housing can be saved.
(b) Period for construction can be shortened.
(c) Insulation work including waterproof becomes necessary to main machines and pipings.
(d) For machines operated at the spot, local control room may become necessary.
(e) Some measures are necessary for the overhaul and inspection of machines during rain fall.

(3) Arrangement for auxiliaries
After the major equipment such as boiler, turbine and generator are fixed, these accessaries should be arranged.
This arrangement should of course obey the energy flow principle.
From the viewpoint of economic design useless space should be avoided, namely feed water heaters, pulverizers and electric equipments must be installed properly, in case required length for turbine and boiler rooms differs very much each other. In addition, considerations should be paid for the delivery route of heavy parts or blocks and the space for overhauling, thus enabling the most efficient operation and the economic pursuit of arrangement.

(4) An example of general arrangement

As typical 175 MW unit arrangement, No. 4 unit of Yokohama Thermal Power Station, Tokyo Electric Power Co., Inc. is shown in Fig. 3·2·7.

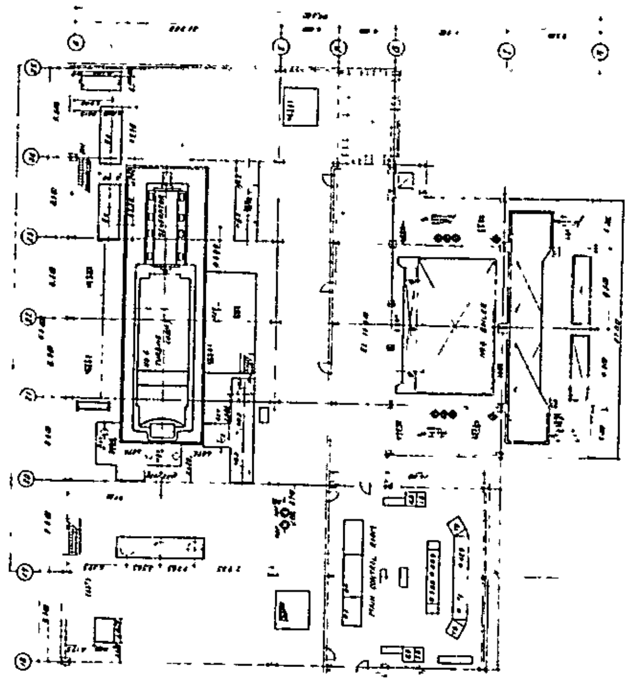


Fig. 3·2·7-(2) 175MW Unit Arrangement
3rd. Floor Arrangement

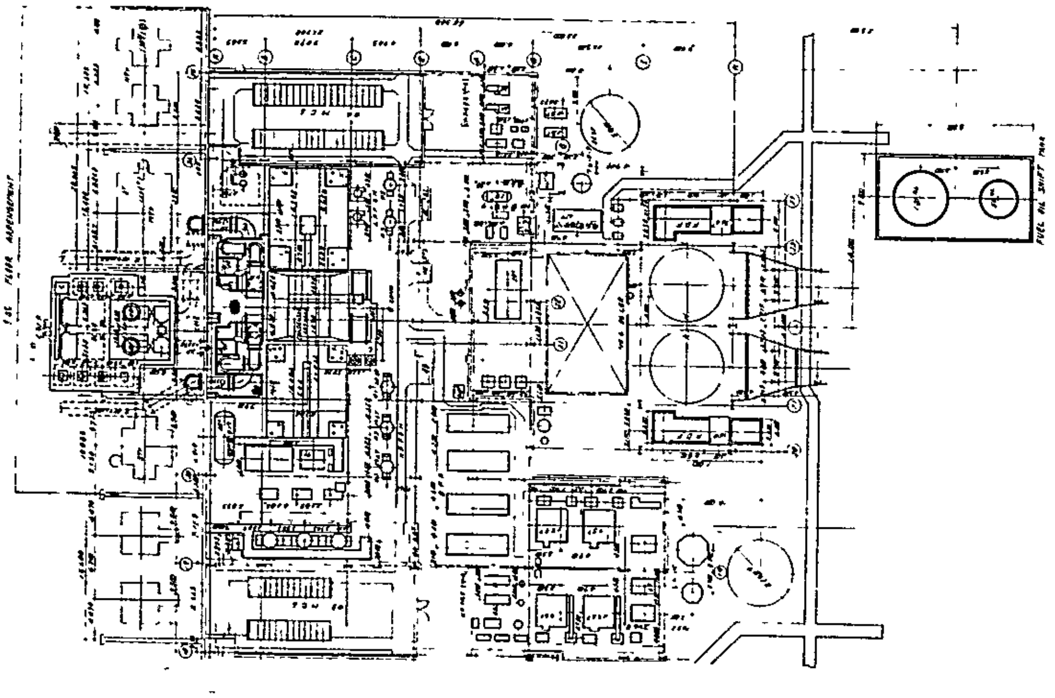
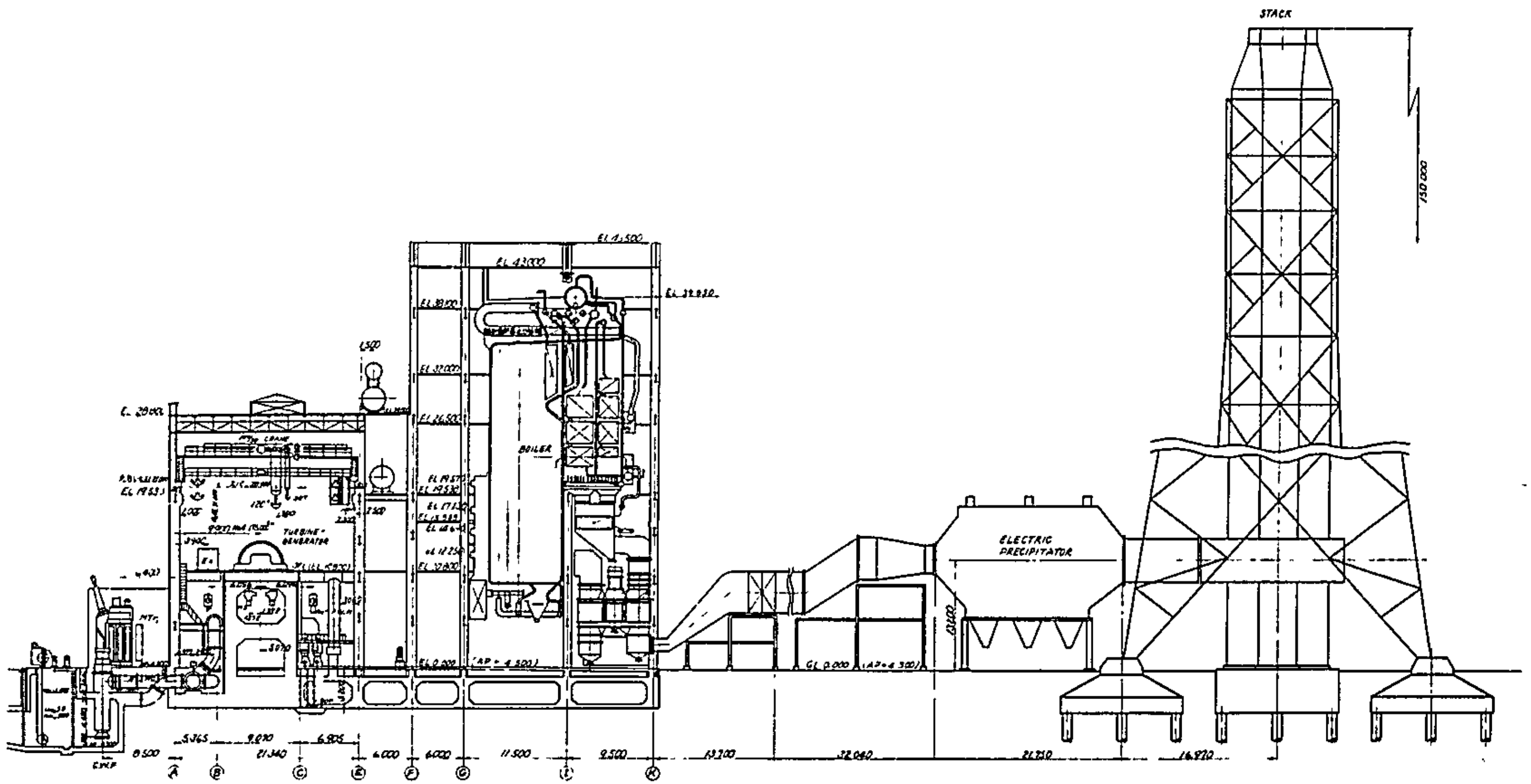


Fig. 3·2·7-(1) 175MW Unit Arrangement
1st. Floor Arrangement

Fig. 3 2 7-(3) 175MW Unit Arrangement Section View



3-2-5 Intake and Discharge of Condenser Cooling Water

Conceptual design shall be made concerning condenser cooling water equipments such as intake and discharge channels, and intake and discharge places. This shall be used as basic data for making plot plan and construction cost.

(1) Fundamentals for the intake of cooling water

In making conceptual design for condenser cooling water equipments, the following basical matters shall be taken into account.

a. Security of low temperature cooling water

Cooling water temperature for condenser will directly affect the unit operating efficiency. Therefore in planning the intake of cooling water, it is desirable to get cooling water temperature as low as possible. Special considerations shall be paid to select the points of intake and discharge in order to prevent the recirculation of discharge water and also to take the cooler cooling water from the deep point of the sea, in case the water temperature is lower in the deeper point. Cooling water temperature is an important figure for the design of condenser and shall be investigated thoroughly during the time of site survey. As far as we could know, the sea water temperature in Indonesia is 28 - 32°C all through the year.

b. Security of required amount of cooling water

The required amount of cooling water for the condenser is different for unit size, steam conditions, water temperature and scale of power station. The required amount of cooling water for the condenser in Indonesia can roughly be calculated as shown in Table 3·2·5 in relation with the unit size, so that the application can be made for a power station by multiplying number of units.

Table 3·2·5 Rough Required Quantity of Condenser Cooling Water

Unit Size	Rough Estimation of Condenser Cooling Water
25 MW	4,100 T/H
50 MW	10,800 T/H
75 MW	16,200 T/H
100 MW	21,600 T/H
150 MW	32,400 T/H

c. Security of high quality cooling water

As cooling water, both sea and fresh water can be available. But in Indonesia, sea water shall be used most of the time from the geographical conditions.

In any of the cases, such clean cooling water is preferable that will not contain impurities causing the plugging and corrosion of condenser tubes. Caution should be paid to the following points.

(a) Acid materials contained in the waste water of the factory

(b) Hydro-sulphite and sulphur ion

(c) Dust, sand and mud

In case when factories are existing near the site, or there are considerable impurities in cooling water, it is necessary to select the appropriate intake point and also equipments. Moreover, the problem using the sea-water as cooling water is shown in Volume IV Appendix 2·7.

(2) Outline design

The detail description for the design of intake and discharge facilities is shown in Volume IV Appendix 2·3. But the outline is shown in the following.

a. Water intake place

There is some difference for water intake method, in case when the site is adjacent to ocean or open bay, or when the site is adjacent to inner bay.

But in any case, following points are necessary to be considered for the water intake place.

(a) To have structures that will allow the carry over of the sand and mud as less as possible and hinders the accumulation of sand and mud.

(b) To have intake structures and also equipments that will not allow the dirty water to come into the cooling water channel during the time of extension work.

(c) To select the intake place such that the recirculation of discharge water may not occur, even when the tide level and the direction of tidal current changes.

(d) If there is temperature difference in the depth of the intake, the intake structure shall be such that the water can be taken from the deeper point from the surface.

Especially in case the water is taken from the ocean or open bay, there are more problem than in the case of inner bay, affected by littoral drift and wave height. In such a case there is a method of jetty enclosure and a suction pipe method.

In any case, in order to prevent the carry over of dust, sand and mud, the cross section of the water intake structure shall be such that the velocity at this section be around 0.2 - 0.4 m/sec. The fluctuation of wave can be determined by the circulating water pump characteristics.

b. Discharge place

(a) It is desirable to have enough distance between discharge and intake places, so that the recirculation of discharge water may not occur, taking into account the tidal current in connection with the arrangements between discharge and intake places.

According to our experience, it is desirable to have more distance than shown in the following Formula (3-2-1). Actually the tidal current and discharge quantity give influence.

$$L = 20Q \qquad (3\text{-}2\text{-}1)$$

Here L : distance between intake and discharge point (m)

Q : total quantity of cooling water (m^3/sec)

(b) Then, discharge velocity and direction are often disputed.

Careful considerations are necessary to the fishermen and ships going in front of the discharge place.

Discharge velocity is different for the occupation of sea in front of discharge place and the occupation of the ship's passage, but the discharge velocity is about 0.3 - 1.0 m/sec.

c. Intake and discharge channels in the site

For the structure of intake and discharge channels in the site, there are three kinds, open channel, box culvert and pipes using cast iron pipe or steel pipe.

As to the selection of the method, it is necessary to consider the following points as a whole.

- Economy of structures of waterways
- Availability of the area above waterways
- Siting conditions
- Plot plan

(a) Intake channel

Concerning the velocity of intake channel,

i For box culvert, 10 cm thickness of margin shall be taken for the accumulation of shells at the inner surface and the velocity of about 1.0 - 1.5 m/sec shall be maintained.

ii For open channel, the velocity shall be about 1.0 m/sec.

iii For pipes, the velocity is around 2.0 m/sec.

(b) Discharge channel

Concerning discharge channel, the velocity shall be about 2.0 m/sec for open channel, box culvert and pipes.

3-2-6 Delivery and Storage of Fuel

Method of fuel delivery into the site, capacity and number of storage tanks in the site shall be determined and plot plan shall be made.

(1) Estimation of fuel consumption

In order to determine the equipments for fuel delivery or storage capacity, it is first of all necessary to estimate the fuel consumption for the expected final scale of the power station.

Fuel consumption per day or per annum can be estimated in terms of unit thermal efficiency, scale of the power station, available factor and calorific value of fuel.

The result of the calculation is shown in Table 3·2·6 as an example.

Table 3·2·6 Estimation Example of Fuel Consumption

Unit Size	Steam Conditions	Turbine Type	Thermal Effi-ciency	Max. Fuel Con-sumption per day	Average Fuel Con-sumption per day	Annual Average Fuel Con-sumption
66MW	88 Kg/Cm^2 510°C	TC	32.2	430 kt	310 kt	114000 kt
75MW	102 Kg/Cm^2 538-538°C	TC	34.8	470	340	124000
125MW	127 Kg/Cm^2 538-538°C	TC	36.8	710	520	189000
175MW	169 Kg/Cm^2 566-538°C	TC	38.5	950	700	252000
250MW	169 Kg/Cm^2 566-538°C	TC	38.8	1350	990	359000

Assumption

Heavy oil	10,000 Kcal/Kg (9900 Kcal/1)
Availability factor	70 %
Correction factor for thermal efficiency caused by availability factor	0.96
Turbine exhaust pressure	700 mmHg

(2) Delivery method of fuel

As delivery methods, there are following ones

(i) Tanker comes to the berth of power station and unload the fuel.

(ii) First receive the oil in the sea by seaberth and deliver the oil by pipeline to the power station

(iii) First unload the oil at refinery, oil terminal or harbour far away and then transport to the power station by pipeline. Detailed description for the harbour is shown in Volume IV Appendix 2·2.

a. Determination of the scale of unloading facilities

In the case of unloading by ship, the average frequency of ship's arrival per annum shall be calculated from the most probable types of ships which have been well surveyed in advance and the annual fuel consumption which has been obtained in the former section.

Then the numbers of unloading facility shall be determined. Further, the scale of the berth facility shall be determined, i.e. the length, numbers and depth, from the maximum daily fuel consumption and the expected maximum ship's type. Standard dimension of the various types of ships and the necessary data for berth are shown in Table 3·2·7.

Table 3.2.7 Standard Tanker Size & Standard Berth Capacity

Size of Ship (DWT)	Length (m)	Width (m)	Full Load Draft (m)	Pump Capacity (Kl/Hr)	Berth Capacity Length (m)	Berth Capacity Depth (m)	Particulars
350 - 500	35	7	3.5	350 - 500	50	4.0	
500 - 800	46	7	4	600	60	4.5	
500 - 1000	46	7	4	350	60	4.5	
1000 - 1500	57	7	4.5	500	71	5.0	
1500 - 2000	65	9	5	500	83	5.5	
2000 - 2500	73	12	5.4	650	97	6.4	
2500 - 3000	84	13	5.5	700	110	6.5	
3000 - 4500	96	14	6.3	700	124	7.3	
30,000 class	183	28	10	1100 x 3	239	12	Draft Margin of Depth
40,000 "	197	30.4	12.2	1250 x 3	258	15	Until 5m 0.5m
50,000 "	217	32	12.5	1250 x 3	281	15	" 7m 1.0m
60,000 "	224	35.4	13.4	1500 x 3	295	1C	" 9m 1.5m " 12m 2.0m
70,000 "	230	34	13.5	1500 x 3	298	16	Over 12m 2.5m
80,000 "	242	37.2	14.6	2000 x 4	316	17	Two third of the length of wave and swell must be added
90,000 "	253	38	14.2	2000 x 4	329	17	
100,000 "	274	41	14.6	2000 x 4	356	17	
130,000 "	276	43	16.5	1640 x 4	362	19	
200,000 "	342	49.8	17.33	3000 x 4		20	
300,000 "	350	55	22.55	3500 x 4		25	

b. Determination of pipeline size

In using pipeline for delivering fuel, it is necessary to determine the size. Pipeline size shall be determined by operating pressure, quantity of delivery fuel and length of pipeline. Velocity in the pipe is usually lower than 2m/sec. Calculation Formula is shown in the following.

(a) Pressure drop calculation of pipeline

Formula for heavy oil, crude oil and light oil

$$h = f.\frac{\ell}{d}.\frac{V^2}{2g} \quad \ldots\ldots \text{(Empirical Formula of Blasius)}$$

h = Head loss (m)

ℓ = Equivalent straight pipe length (m)

V = Velocity (m/s)

d = Inside diameter of pipe (m)

f = Coefficient of friction in pipe

For laminar flow ($Re \leqq 2000$)

$$f = \frac{64}{Re}$$

For turbulent flow ($Re > 2000$)

$$F = 0.316Re^{-0.25}$$

$$Re = \frac{V \cdot d}{v}$$

Re = Leynolds number

v = Coefficient of dynamic viscosity (m^2/s)

(b) Formula for gas flow in pipe

$$Q = K\, d^{8/3}\sqrt{\frac{P_1{}^2 - P_2{}^2}{SL}} \quad \ldots\ldots \text{(Weymouth Formula)}$$

Q = Gas flow (m^3/h, at 1 atm, 15.6°C)

d = Inside diameter of pipe (mm)

P = Initial Pressure (g/cm^2, abs)

P_2 = End pressure (g/cm^2, abs)

$K = 0.386 \times 10^{-2}$

L = Equivalent straight pipe length (Km)

S = Dencity ratio of gas to air (=0.6)

(3) Determination of oil storage in the power station

Oil storage quantity in the power station depends upon the stability of fuel supply. Namely, in an emergency case of the failure of fuel supply, appropriate fuel storage shall be determined from the viewpoint to secure stable supply of power.

In Indonesia, own standard for fuel storage shall be determined, taking into account the feature of oil producing country.

For calculating the number of tanks, the following Formula shall be used.

$$\text{Number of tanks} = \frac{\text{(fuel storage in days) x (daily fuel consumption)}}{\text{0.8 x (capacity of one tank)}}$$

The number of tanks shall be in no case less than two, considering the maintenance and the probable trouble of the tank.

Standard dimension of tank is shown in Table 3·2·8.

Table 3·2·8 Capacity and Dimension of Fuel Tank

(Unit: Kl)

Tank Diameter (m)	Effective Depth (m)							
	7620	9140	10660	12180	13700	15220	16740	18260
19.38	2240	2690	3140	3590	4040	4480	4930	5380
21.30	2710	3250	3790	4340	4880	5420	5960	6500
23.24	3230	3870	4520	5160	5800	6450	7100	7740
25.18		4550	5300	6060	6820	7570	8330	9090
27.12		5270	6150	7030	7900	8790	9660	10540
29.06		6060	7070	8070	9080	10090	11100	12110
30.99		6890	8040	9180	10330	11480	12620	13770
32.93			9070	10370	11660	12960	14250	15550
34.87			10180	11630	13080	14530	15980	17430
36.81			11340	12960	14570	16190	17800	19430
38.74			12560	14350	16140	17940	19730	21520
40.68			13850	15830	17800	19780	21750	23730
42.62			15200	17370	19540	21710	23880	26050
44.55			16610	18980	21350	23720	26090	28460
46.49			18090	20670	23250	25830	28410	30990
48.42			19620	22420	25220	28020	30820	33620
50.36			21230	24260	27280	30310	33340	36370
53.30			22900	26160	29430	32690	35960	39220

3-2-7 Security of House Service Water Including Boiler Water

Capacity and number of fresh water storage tanks for boiler water and house service water shall be planned as well as the pure water treatment.

(1) Water source

Fresh water used for power station shall be taken from city water, industrial water, river water or underground water. If there lacks any of these sources, sea water desalting plant shall be installed for the security of fresh water requirement.

(2) Water quality

Quality standard for fresh water in power station use shall be aimed as in the following. For boiler water, an example is shown in Table 3·2·9.

(a) Raw water for boiler use

SS	10 ppm
PH	6 - 8
Total solids	200 ppm
Free chlorine	0.5 ppm
COD	5 ppm

(b) Bearing cooling water

Almost as raw water for boiler, but additionally

Total hardness	$>$ 50 ppm
Iron	$<$ 0.5 ppm

(c) Insulator cleaning water

In case insulators in the substation is washed in the hot-line, the water quality as of raw water for boiler water shall be used. But additionally

Specific resistance $>$ 5000 Ω - cm

(3) Quantity for house service water

This quantity differs with unit size, steam conditions, scale of power station, frequency of start up and shut down. In the stage of conceptual design, fresh water consumption in power station is estimated for about 2 - 3T/MW a day. The actual records in some power station are shown in Table 3·2·10.

Table 3·2·9 Quality Standard of Boiler Water

Water Classification	Quality Item	Steam Pressure at Boiler Outlet 30-50 Kg/cm²	65 Kg/cm²	100 Kg/cm²	130 Kg/cm²	170 Kg/cm² (Drum Boilers)		246Kg/cm² (Including once-through boiler)	Remarks
For demineralizer water	SS ppm C/2 ppm	1 0.00	1 0.00	1 0.00	1 0.00	1 0.00	1 0.00		
After demineralizing water tank	μ℧/cm Ca CO_3 ppm SiO_2 ppm	<5 0 <0.1	<5 0 <0.1	<5 0 <0.05	<5 0 <0.05	<5 0 <0.015	<5 0 <0.015	<0.015	
For economiser inlet water	PH μ℧/cm Cl ppm O_2 PPb F PPb Cu PPb N_2H_4 PPb SiO_2 ppm	8.0-9.0 - <0.2 <10 - - - -	8.6-9.0 - < 0.2 < 7 - - 10-30 -	8.6-9.0 - < 0.2 < 7 < 20 < 15 10-30 -	8.6-9.0 - < 0.2 < 7 < 15 < 10 10-30 -	8.6-9.0 - <0.2 < 7 < 10 < 5 10-30 -	8.6-9.0 - < 0.2 < 7 < 10 < 5 10-30 -	9.0-9.5 < 0.3 - < 7 < 10 < 3 10-30 0.020	1. For steel tube feed water heaters PH 9.0-9.5 2. In the feed water after passing cation ion exchanger 3. Feed water to dearator
For boiler water after boiler feed water pump	PH μ℧/cm OH ppm Cl ppm SO_3 ppm PO_4 ppm SiO_2ppm	10.5-11.0 <1000 - - 5-20 10-40 < 25	10.0-10.5 - - < 3 - 4-15 < 5	10.0-10.5 - < 3 < 2 - 4-15 < 2	9.0-10.0 - < 1 < 1 - 0.3-3 < 1	9.0-10.0 - < 0.5 < 1 - 0.3-3 < 0.3	8.3-9.0 - 0 < 1 - - <0.2	- - - - - - -	
For boiler steam	μ℧/cm S_iO_2 ppm	< 4 < 0.05	< 4 < 0.02	< 4 < 0.02	< 4 < 0.02	< 4 < 0.02	< 4 < 0.02	< 4 < 0.02	4. Lower than 0.3 after passing cation ion exchanger
					Low phosphate treatment	Volatile chemicals treatment	Volatile chemicals treatment		

Table 3·2·10 Example of Fresh Water Consumption in Some Power Stations

Output of Power Station	Fresh Water In Total			Demineralized Water In Total		
	T/P.S. day	T/Unit day	T/MW. day	T/P.S. day	T/Unit day	T/MW. day
375 MW	630	209	1.7	218	73	0.6
480 MW	1,525	253	3.2	495	82	1.0
600 MW	2,015	503	3.4	348	87	0.6
1050 MW	1,858	371	2.0	331	66	0.4

(4) Conceptual design of raw water equipment

An example for fresh water flow diagram is shown in Fig. 3.·2·8.

a. Water filtrating equipment

In case industrial, underground or raw water is used, this equipment is necessary for the rough filtration. The capacity shall be 3 - 6T/MW-day and equipment shall consist more than two systems separately.

b. Raw water tanks

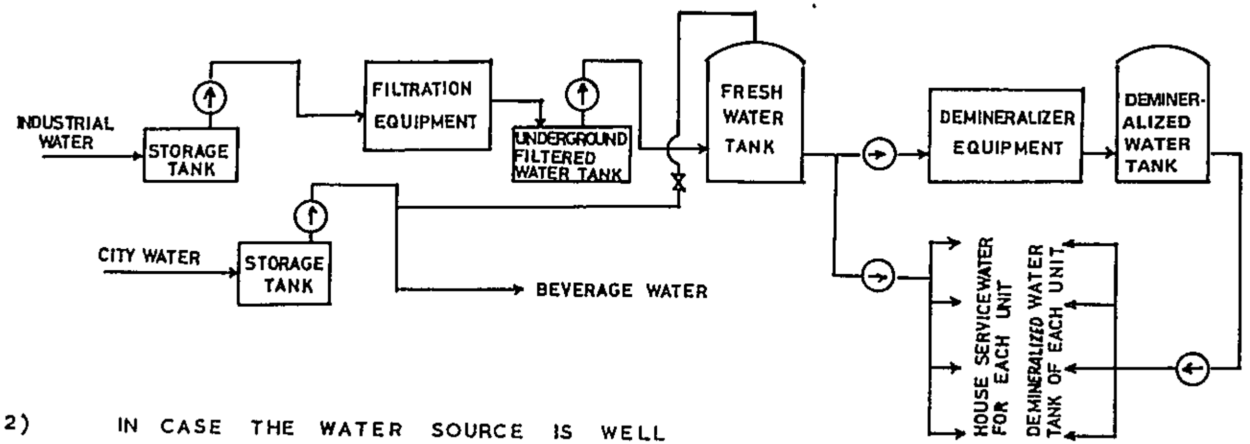
The storage capacity depends upon the reliability of the supply sources, but in general the capacity shall be 3 days storage of the normal operation (6 - 9 T/MW). The installed number of tanks also depends upon the reliability of the tank, but is preferable for two, instead of one.

c. Pure water tank

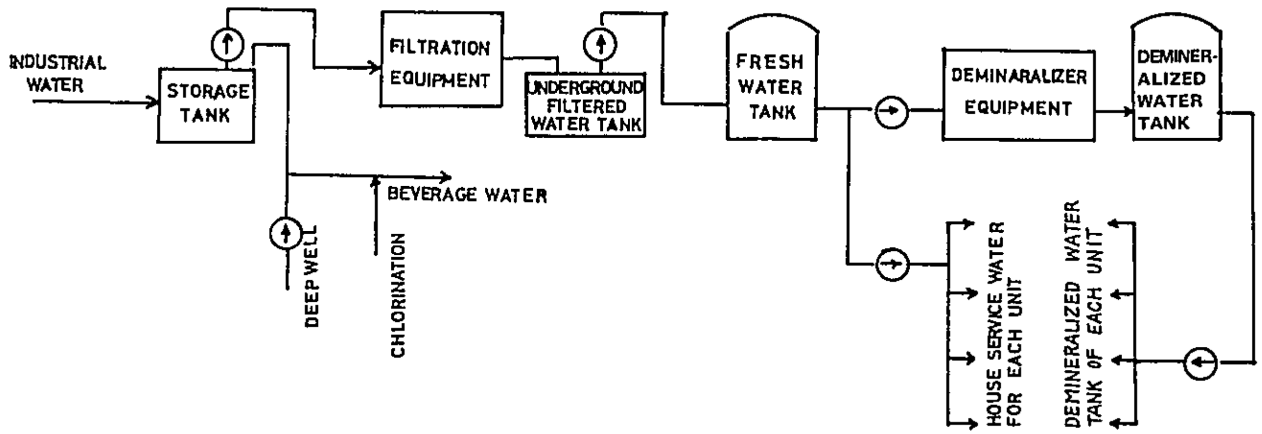
Storage capacity of pure water differs with the number of units, but is in general 2 - 3T/MW.

Fig. 3·2·8 Fresh Water Flow Diagram

(1) IN CASE THE WATER SOURCE IS CITY WATER OR INDUSTRIAL WATER



(2) IN CASE THE WATER SOURCE IS WELL



3-2-8 Main Building and its Foundation

First, obtain the climatic condition and geological data around the site of the power station, and then make conceptual design for the main building and its foundation, through which the construction cost can be estimated.

(1) Main building

a. The scale of the main building.

The scale of the main building is different with unit size and arrangement of various kinds of the auxiliary machines. The scale of the main building for each unit size in Japan will be shown in Table 3·2·11.

Table 3·2·11 Main Building Volume and Floor Space

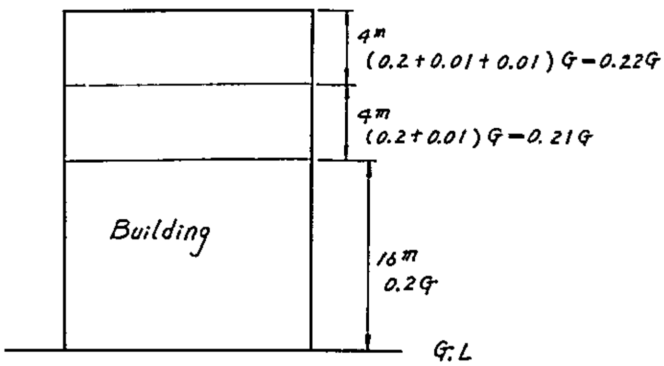
	Building Volume (m^3)	Floor Space (m^2)
125 MW	48, 360	2, 070
175 MW	70, 000	2, 730
265 MW	76, 000	3, 930
350 MW	85, 000	4, 260

b. The weight of the steel structure

In designing steel structure for the main building, the earthquake and wind load must be taken into account in addition to ordinary equipment loads.

In Japan the earthquake load is considered as in Fig. 3·2·9 and the larger value either of the earthquake load or wind load is adopted as the design load.

Fig. 3· 2· 9 Earthquake Load for Building in Japan



Note: Until building height is 16m, the earthquake force is 0. 2G. For each 4m height increase above 16m, 0. 01G shall be added to as coefficient of earthquake.

The effect of considering the earthquake load is apparent in the weight of columns and beams, which figure will amounts to several per cent of the total weight of structure steel.
In Table 3·2·12, the weight of the steel structure for the main building is shown.

Table 3·2·12 Main Building Structure Steel Weight

	In Turbine Room	In Boiler Area
125 MW	750 ton	830 ton
175 MW	1570	910
265 MW	1570	1020
350 MW	1710	1130

In Indonesia, the earthquake load and wind load are supposed to be smaller than that of Japan from the data shown in Volume IV Appendix 3·2, and so in detailed design stage, steel structure will be determined considering the aforementioned point.

(2) Selection of foundation work method of main building

a. Bearing force of the ground

In order to support the main structures safely and surely, it is preferable that the bearing force of the stratum shall be larger than $40T/m^2$. This corresponds 50 of N value, i.e., the result of standard peratration test. Investigate in what depth the abovementioned stratum exists by making use of geological data of site survey. It is desirable to have such stratum as has enough bearing force to support the structures of the power station facilities within 30 m from the ground surface.

b. Selection of foundation work method

There are various foundation work method corresponding to the depth of stratum. Mostly they shall be shown in Table 3·2·13.
Even in the most peculiar case, the depth of the stratum is 70 m at its limit.

Table 3·2·13 Foundation Practice

Method	Limit	Remarks
Mat foundation	Bearing stratum must exist within GL -7 m	
Pile driving foundation		
1) Precast concrete pile	15m	Use the largest single pile, because pile connection has less reliability.
2) P.C.pile	60m	
3) Cast in-place concrete pile	25 - 30m	Limit differs with soil conditions
4) Steel piling	60 - 70m	
Cason Method	Bearing stratum must exist within GL -40 m	Allowable pressure for working is about 3.5 atg. This corresponds to 36 m water gage. Supposing underground water level GL - 4m 1 = 36 + 4 = 40m

3-2-9 Measures for Environmental Protection

Make outline planning for anti-pollution facilities of the power staion and this shall be used for making plot plan and estimation of construction cost.

(1) Kinds of countermeasures for anti-pollution

It shall be classified into three countermeasures.

(a) Anti-air pollution

(b) Anti-water pollution

(c) Anti-noise

(2) Countermeasure for anti-air pollution

This has the main purpose of dispersing SO_X and decreasing dust discharge from stack of the boiler.

Recently it is often discussed about the NOx pollution in the air, but the effective countermeasure has not yet been established. So in Japan the countermeasure is employed mainly for the improvement of combustion system.

Concerning the flue gas desulphurizing equipment, it is in the stage of technology development in the practical scale for various kinds of systems.

Therefore, the study in the stage of conceptual design shall be mainly for the determination of stack height and the necessity of installing electric precipitator.

a. Determination of stack height

(a) Taking into account the following elements into consideration, so aiming the dispersion and dilution of flue gas through effective height of stack that the density on the ground level shall conform to the value matching the actual condition of the region, calculate by the formula shown in Volume IV Appendix 2・8.

(i) Fuel quantity used and sulphur content in the fuel

(ii) Fuel gas quantity from boiler

(iii) Exit stack velocity and temperature of flue gas from stack

(iv) Climatic conditions of the area

In Indonesia there exists no industrial pollution and also no environmental quality standard for SO_X. As reference, an example in Japan shall be shown in Table 3・2・14.

In Indonesia, there must be many plants which are not known as to what kind of effects they suffer from SO_X. Also, as reference, effects of SO_X to some plants are shown in Table 3・2・15 which is quoted from Air Pollution Handbook published by McGrow Hill.

Table. 3・2・14 Environmental Quality Standard Concerning Sulfur Oxides in Japan

Unit Time	Density of Sulfur Oxides	Hours & Days	Percentages
(1) One hour value	Under 0.2 ppm	8760 hrs(One year)	Above 99%
(2) One hour value	Under 0.1 ppm	8760 hrs(One year)	Above 88%
(3) Average value of one day	Under 0.05 ppm	365 days(One year)	Above 70%
(4) Average value of one year	Under 0.05 ppm	Average value of 8760 hrs(One year)	-
(5) Emergency value	0.2 ppm x 3 hrs 0.3 ppm x 2 hrs 0.5 ppm x 1 hr Average value of 48 hrs is above 0.15 ppm	Contaminated days of 365 days(One year)	Under 3% (11 days) and not continue 3 days
Each condition from (1) to (3) must be satisfied			

Table 3.2.15 Relative Sensitivity of Cultivated and Native Plants to Injury by Sulfur Dioxide

(Determined by O'Gara)

Sensitive		Intermediate		Resistant	
Cultivated Plants					
Alfalfa	1.0[a]	Cauliflower	1.6[a]	Gladiolus (1.1–4.0)[b]	2.6[a]
Barley	1.0	Parsley	1.6	Horse-radish	2.6
Endive	1.0	Sugar beet	1.6	Sweet cherry	2.6
Cotton	1.0	Sweet William	1.6	Canna	2.6
Four o'clock	1.1	Aster	1.6	Rose	2.8–4.3
Cosmos	1.1	Tomato (1.3–1.7)[b]	1.7	Potato (Irish)	3.0
Rhubarb	1.1	Eggplant	1.7	Castor bean	3.2
Sweet pea	1.1	Parsnip	1.7	Maple	3.3
Radish	1.2	Apple	1.8	Boxelder	3.3
Verbena	1.2	Catalpa	1.9	Wisteria	3.3
Lettuce	1.2	Cabbage	2.0	Mock orange	3.5
Sweet potato	1.2	Hollyhock	2.1	Honeysuckle	3.5
Spinach	1.2	Peas	2.1	Hibiscus	3.7
Bean	1.1–1.5	Gooseberry	2.1	Virginia creeper	3.8
Broccoli	1.3	Zinnia (1.2)[b]	2.1	Onion	3.8
Brussels sprouts	1.3	Marigold	2.1	Lilac	4.0
Pumpkin	1.3	Hydrangea	2.2	Corn	4.0
Table beet	1.3	Leek	2.2	Cucumber	4.2
Oats	1.3	Begonia	2.2	Gourd	5.2
Bachelor's-button	1.4	Rye (1.0)[b]	2.3	Chrysanthemum	5.3–7.3
Clover	1.4	Grape	2.2–3.0	Snowball	5.8
Squash (1.1–1.4)[b]	1.4	Linden	2.3	Celery	6.4
Carrot	1.5	Peach	2.3	Citrus	6.5–6.9
Swiss chard	1.5	Apricot	2.3	Cantaloupe (muskmelon)	7.7
Turnip	1.5	Kale	2.3	Arborvitae	7.8
Wheat	1.5	Nasturtium	2.3	Currant blossom	12.0
		Elm	2.4	Live oak	14.0
		Birch	2.4	Privet	15.0
		Iris	2.4	Corn silks and tassels	21.0
		Plum	2.5	Apple blossoms	25.0
		Poplar	2.5	Apple buds	87.0
Native Plants					
Gaura (1.0)[b]		Dandelion	1.6	Purslane	2.6
Tobacco tree (*N. glauca*)	1.0	Orchard grass	1.6	Sumac	2.8
June grass (*B tectorum*)	1.0	Rough pigweed (redroot)	1.7	Shepherd's purse	3.0
Prickly lettuce	1.0	Black mustard	1.7	Milkweed	4.6
Mallow	1.1	Smartweed	1.8	Salt grass	4.6+
Ragweed	1.1–1.2	Lamb's-quarters	1.8	Pine[c]	7–15.0
Curly dock	1.2	Sweet clover	1.9		
Buckwheat	1.2–1.3	Nightshade	2.0		
Bouncing bet	1.3	Hedge mustard	2.1		
Plantain	1.3	Cocklebur	2.3		
Sunflower	1.3–1.4	Tumbling mustard	2.4		
Rye grass	1.4				

[a] Factors of relative resistance compared with alfalfa as unity.
[b] More probable factors based on later experience.
[c] Data for pine represent October fumigations in Palo Alto, Calif., of Monterey, white, Allepo, and Coulter varieties. O'Gara factors calculated from the data of Katz and McCallum (Effect of Sulfur Dioxide on Vegetation, *Nat. Research Council Can., Pub.* 815, 1939) are as follows: larch in May, 1.5; Douglas fir in May, 2.3; yellow pine (year-old) seedlings in May, 1.6, in August, 2.4 to 4.7.

(b) Check the stack height which is obtained in the abovementioned formula, whether it matches the restriction given by the airport in the vicinity. Aviation law, or international law and regulation give the restriction of height of structures in the vicinity of airport according to the grades of airports.

(c) In case there exists micro wave passage for communication in the vicinity of the site, check whether the height and position of the stack will not interfere with the micro wave passage.

(d) Check whether the effective height of the stack obtained above is higher than the height of the inversion layer that usually occurs in the region.

(e) If it is necessary to check the dispersion of flue gas in the strong wind, following points shall be checked.

  (i) Whether the stack height is by 2.5 times higher than the buildings nearby, so that down wash phenomenon may not occur.

  (ii) Whether the exit stack velocity is by 2 times larger than the wind velocity, so that down wash phenomenon may not occur.

The detail description of the influence caused by the climatic condition is shown in Volume IV Appendix 2・8.

b. Determination of the installation of electric precipitator

When the quantity of dust soot and acid smud in the boiler flue gas does not match the requirement of the region, electric precipitator shall be installed in order to reduce the dust quantity emitted from the stack.

In Indonesia there is no environmental quality standard concerning dust and no damage or trouble has ever occured. As an example, environmental quality standard in Japan is shown in Table 3・2・16.

As type of precipitator, electric precipitator shall preferably be adopted, because flue gas quantity is large and dust size is comparatively small. Refer to Table 3・2・17.

In this case, the use of ammonia gas injection will neutralize SO_3 and dry the dust, making the separation of the dust more effective.

Table 3·2·16 Environmental Quality Standard Concerning Dust in Japan

Sorts of Facilities		Sizes of Facilities (Emission Gas Qy/hr)		General Emission Standard (g/Nm^3)	Special Emission Standard	
					Value(g/Nm^3)	Applied Districts
Boiler	Exclusive firing of liquid fuel such as heavy oil	Above 200×10^3 Nm^3 (About 60 MW)		0.10	0.05	Tokyo Yokohama Kawasaki Yokosuka
		40 - 200×10^3 Nm^3		0.20	0.05	
		Under 40×10^3 Nm^3		0.30	0.20	
	Coal firing (Above 5, 000Kcal/kg)	-		0.40	0.20	
	Others except above	-		0.80	0.20	
Waste Incinerator		Continuous furnace	Above 200t/day	0.20	0.10	
			Under 200t/day	0.70	0.20	
		Except Above		0.70	0.40	

For each facility, emission gas limit is applied above values to one M^3 gas converted at 0°C and one Atm.

Table 3·2·17 Practical Performance of Various Dust Collectors

Principle	Name	Dust Grain Size [μ]	Press Drop ΔP (mmAq)	Efficiency (%)	Contruction Cost	Operating Cost
Gravity	Sedimentation Room	1000 - 50	10 - 15	40 - 60	Low	Low
Inertia		100 - 10	30 - 70	50 - 70	Low	Low
Centrifugal	Cyclone	100 - 3	50 - 150	85 - 95	Middle	Medium
Washing	Venturi Scrabber	100 - 0.1	300 - 380	80 - 95	Middle	High
Sound Wave		100 - 0.1	60 - 100	80 - 95	More than middle	Medium
Filter	Bag. Filter	20 - 0.1	100 - 200	90 - 99	More than middle	More than medium
Electricity		20 - 0.05	10 - 20	80 - 99.9	High	Small medium

(3) Countermeasures for water pollution

In the power station, waste water comes out less in comparison with other industries. But, if waste water from the power station does not match the regional requirement, such equipment of neutralization, sedimentation and filtration including oil shall be installed. An example will be shown in Fig. 3·2·10.

Quality standard for waste water in Japan is differently determined in a law from region to region and there is no common regulating figure for every region.

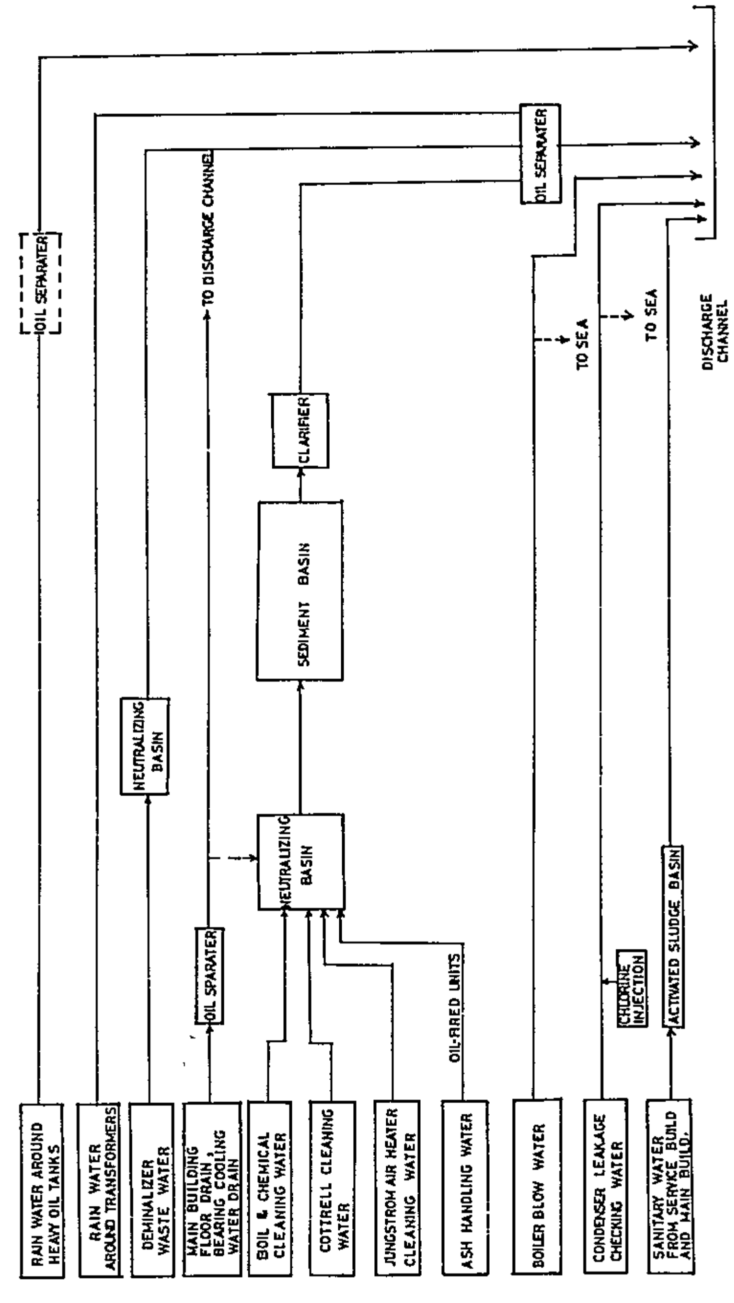


Fig. 3·2·10 Waste Water Flow Diagram of Thermal P. S.

(4) Measures for noise control

In Indonesia, it is generally possible to construct the power station far from the residential area and it is only in the rare case, when it becomes necessary to pay special attention to the noise. But for those power stations which require noise control, such measures shall be adopted as indoor arrangement of machines, low-noise design and installation of silencer to safety valves and fans.

In Japan there is noise abatement law and the restrict noize level is determined at the boundary of the site. This shall be shown in Table 3·2·18.

Table 3·2·18 Restricted Noise Level by Noise Abatement Law at the Boundary of the Site

(Unit Phon)

	In the Daytime	Morning & Evening	At Night
Class 1 District Needed to keep specially quiet	45 - 50	40 - 45	40 - 45
Class 2 District Needed to keep quiet	50 - 60	45 - 50	40 - 50
Class 3 District Needed to prevent noise	60 - 65	60 - 65	50 - 55
Class 4 District Needed to prevent remarkable noise	65 - 70	60 - 70	55 - 65

3-2-10 Switchyard Planning

Switchyard size shall be determined, considering the relationship of transmission systems and the future scale of power station.

(1) Planning of one line diagram

Following items shall be determined beforehand.

(a) Transmission line voltage

In local power stations, low voltage shall preferably be adopted because of the less transmission and transformation system losses.

(b) Number of out-going transmission lines

- Unit transmission line system, or bus system

- Final number of out-going transmission lines

(c) Bus system of the switchyard

- Double bus system or single bus system

(d) Number of transmission lines for the unit start up supplying power

(e) Type of the transmission line

- Overhead transmission line or underground cable

(f) Installation of substation for local load

(g) Calculation of the interrupting capacity of the system

(2) Determination of switchyard scale

Outline design of the switchyard shall be made, based upon the aforementioned one line diagram and dimension and area shall be determined.

At the same time, adoption of indoor substation shall be studied for the prevention of salt-pollution in case transmission line voltage becomes higher and for the effective utilization of the area. An example of 150 KV one line diagram and switchyard shall be shown in Fig. 3·2·11.

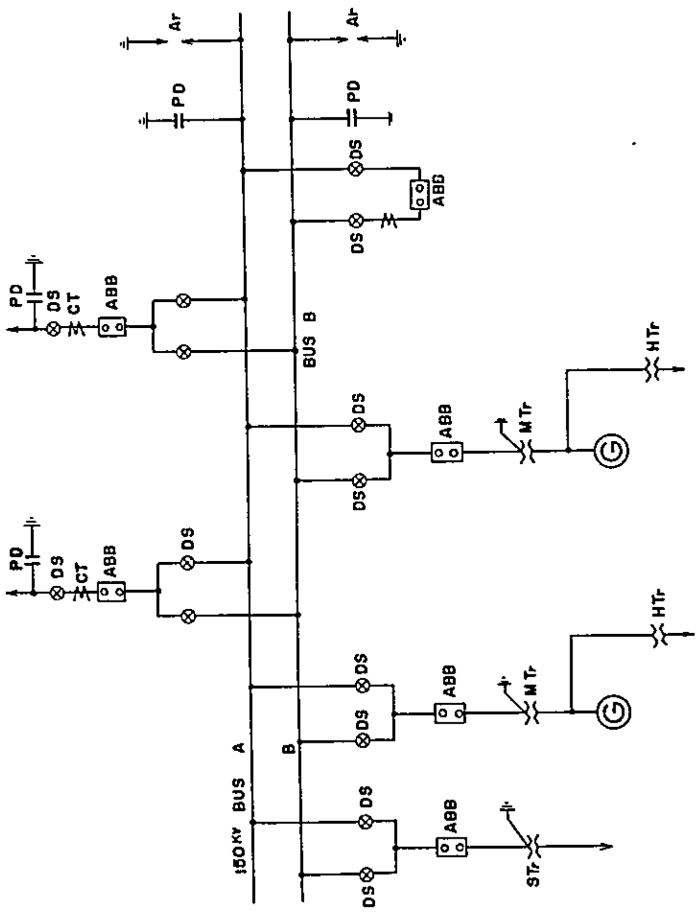


Fig. 3·2·11-(1) One Line Diagram

Fig. 3·2·11-(2) 150KV Outdoor Type Switchyard

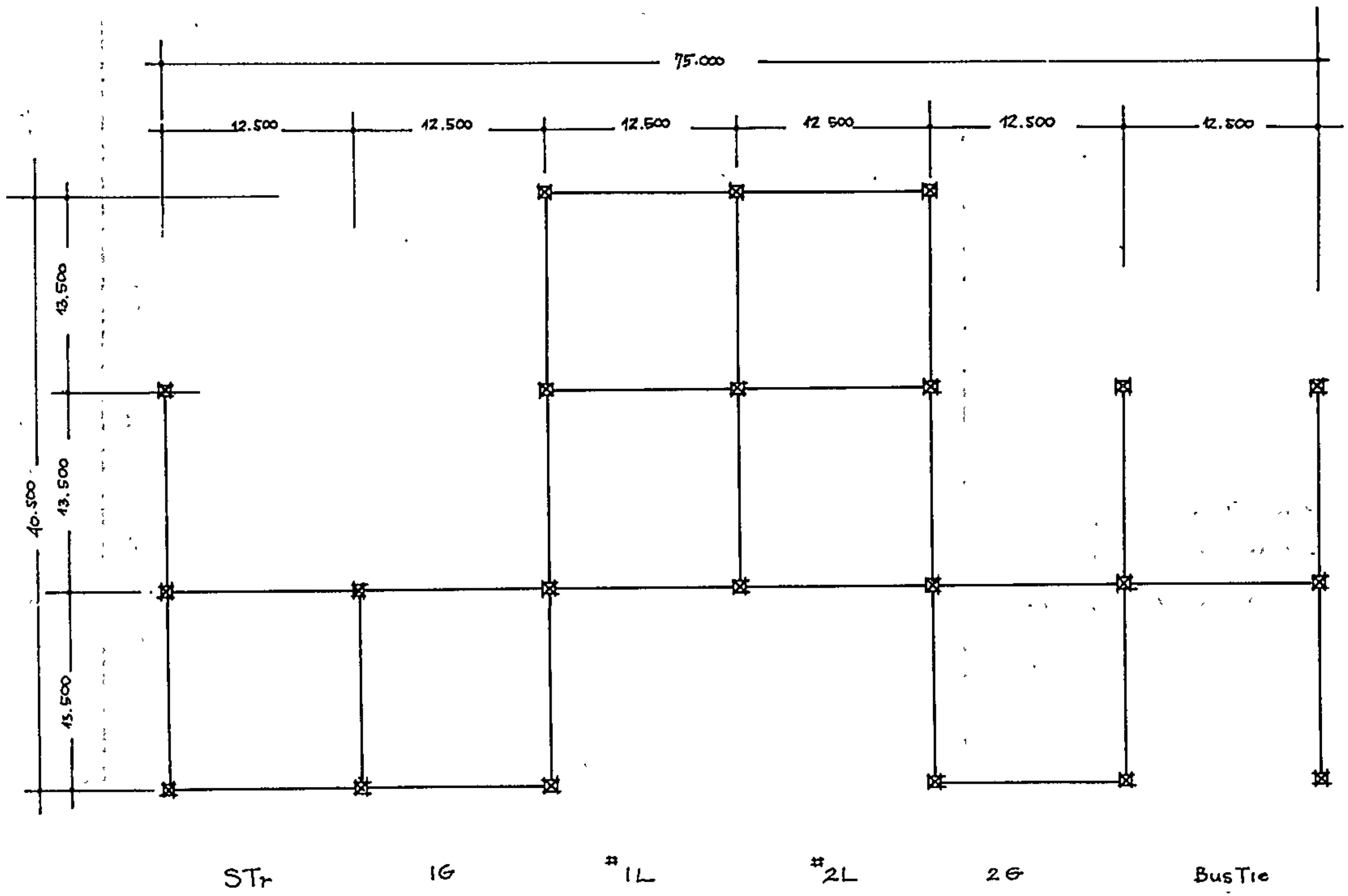
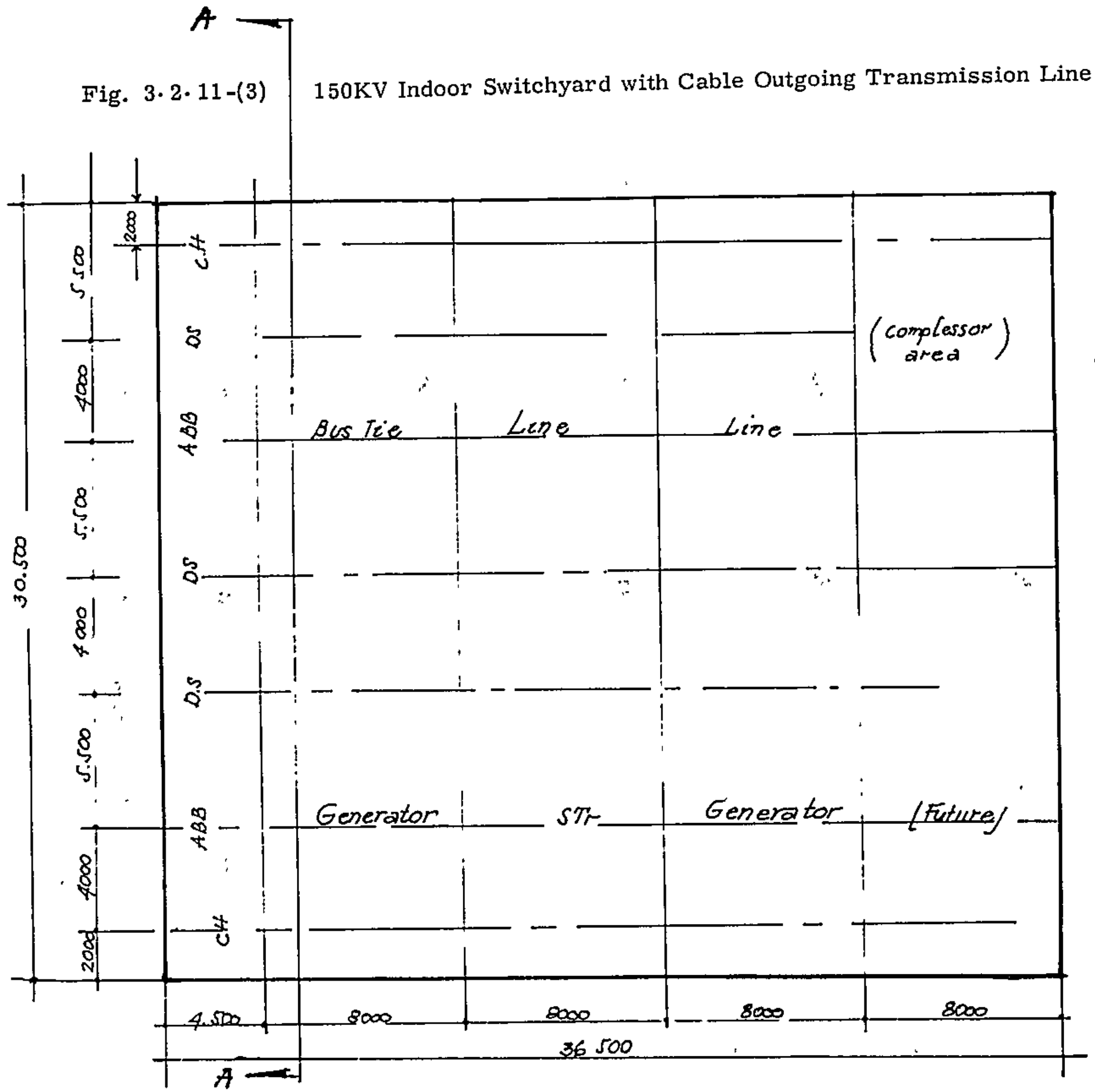


Fig. 3·2·11-(3) 150KV Indoor Switchyard with Cable Outgoing Transmission Line



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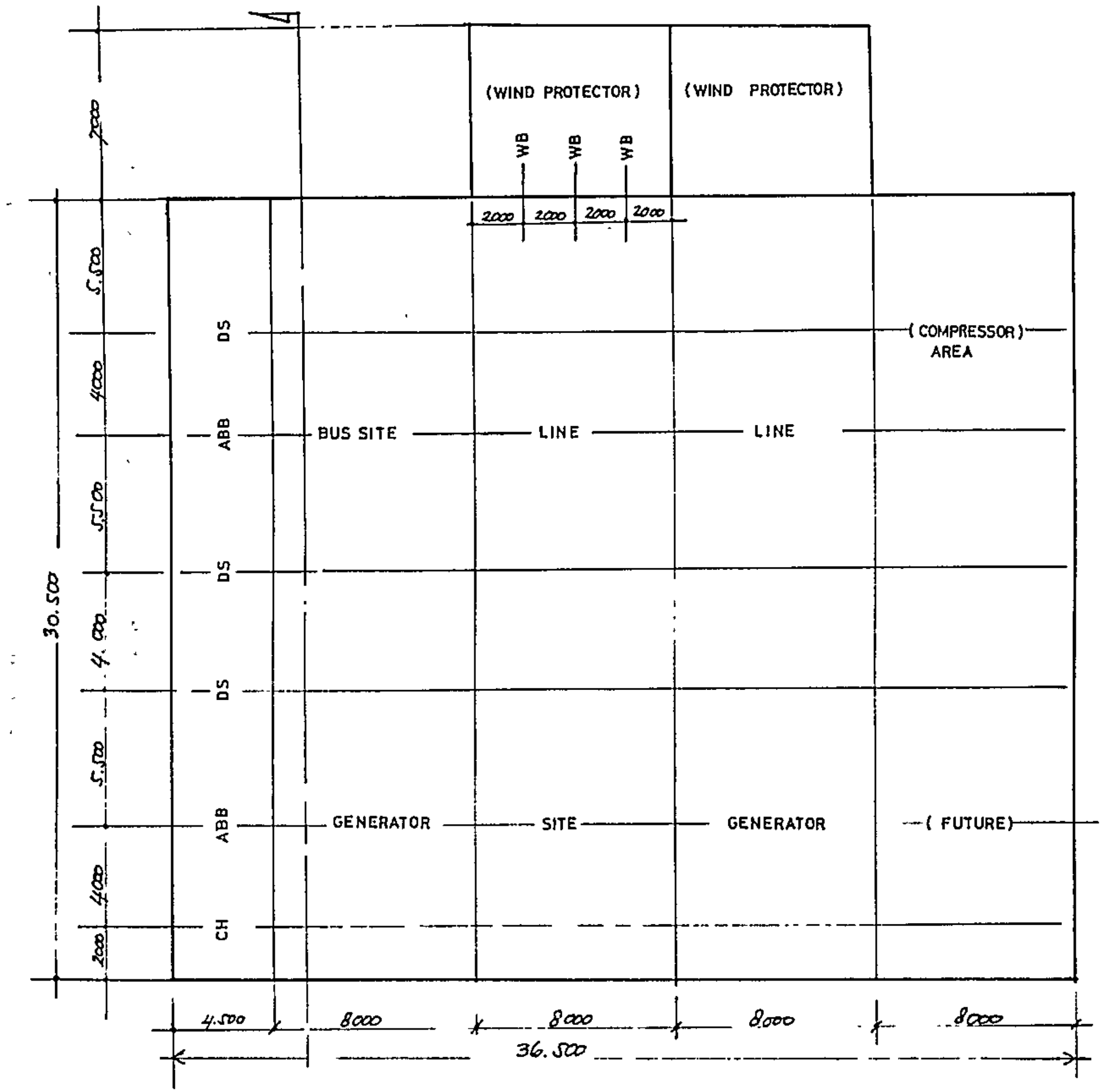
CH . Cable Head

ABB: Circuit breaker

D.S : Disconnecting switch

STr : Starting Transformer

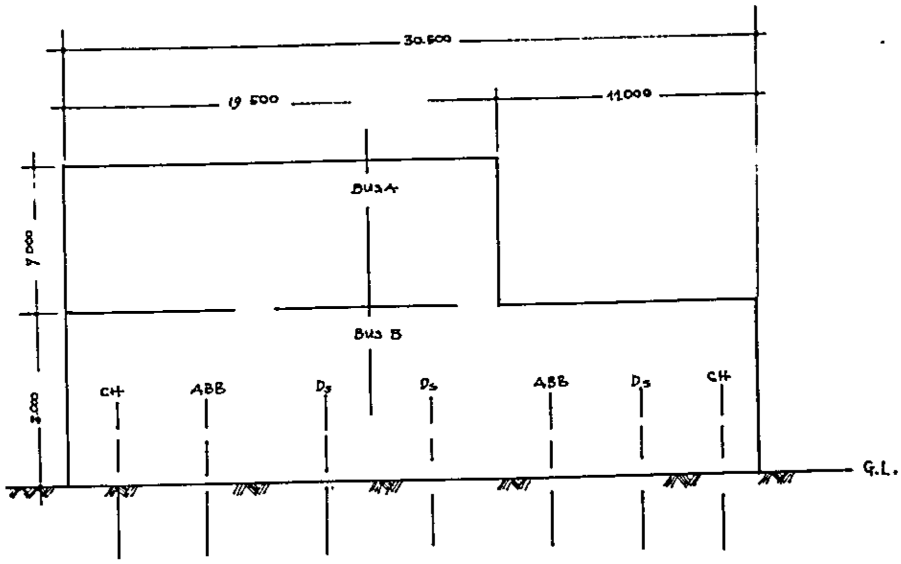
Fig. 3·2·11-(4)   150KV Indoor Switchyard with Overhead Outgoing Transmission Line



INDEX

CH CABLE HEAD
ABB CIRCUIT BREAKER
DS DISCONNECTING SWITCH
WB WALL BUSHING
STR STARTING TRANSFORMER

Fig. 3·2·11-(5)   150KV Indoor Switchyard



A — A SECTION

3-2-11 Determination of Ground Level

After determining the ground level of the power station site, site preparation cost can be calculated for covering the ground level difference between the present one and the prepared one.

Ground level shall be generally determined considering the following points.

(a) The ground level shall not be covered with water, even in the highest tide such as typhoon and monsoon.

(b) The ground level in such that the condenser cooling water can be taken economically.

(c) The ground shall be high enough for the future possible land subsidence.

In general ground level shall be determined by the following Formula.

Site Ground Level

= Mean monthly highest water level + maximum tidal level deviation in the past + Surplus

3-2-12 Delivery Method of Construction Materials

This shall be studied in order to be considered in the plot plan and in the estimation of the construction cost.

(1) Investigation of dimension and weight of the heaviest parts

The key factors when bringing the construction materials into the site are the heaviest and the largest blocks.

As there are different with the unit size and steam conditions, it is necessary to make investigation right after the determination of unit size. The weight and dimention of the heaviest and largest parts in our experience is shown in Table 3·2·19.

Table 3·2·19. Weight and Dimension of Heaviest and Largest Materials for Transportation

Unit Size	Item	Weight in Ton	Dimension in Meter (L x W x H)
125 MW TC-DF	Boiler drum	80	12.5 x 2.3 x 2.9
	Turbine lower casing	49	9.2 x 5.9 x 3.0
	Generator stator	142	7.5 x 4.3 x 4.0
	Main transformer	130	6.5 x 6.4 x 6.0
175 MW TC-3F	Boiler drum	160	18.4 x 2.5 x 2.5
	Turbine lower casing	50	7.4 x 5.1 x 2.0
	Generator stator	180	7.1 x 4.0 x 4.0
	Main transformer	200	7.0 x 3.0 x 6.8
265 MW CC-4F	Boiler drum	200	19.0 x 2.5 x 2.5
	Turbine lower casing	50	7.9 x 5.1 x 2.1
	Generator stator	150	6.1 x 3.8 x 3.8
	Main transformer	220	7.2 x 4.0 x 7.0
350 MW CC-4F	Boiler drum	230	20.0 x 2.5 x 2.5
	Turbine lower casing	60	9.3 x 5.6 x 3.8
	Generator stator	180	8.3 x 4.6 x 4.8
	Main transformer	270	7.5 x 4.8 x 7.3

(2) Determination of delivery method

a. Transportation on the sea

Study first, whether the materials can be delivered by ship directly to power station, because in the case of thermal power station there are many heavy and large materials, and also much in quantity. The scale of the pier for sea transportation shall preferably be:

Depth 4 - 5 m

Type of ship 800 - 1000 ton class

Moreover the design method is shown in Volume IV Appendix 2·2.

b. Transportation on the land

When there is no other way, study such land transportation as road and railway. In this case, there are limitations of dimension and weight for road and railway. Therefore it is necessary to make detailed investigation for every possible delivery route.

If as a result this limitation of delivery cannot be fulfilled, it is necessary to check whether the standard design change for such main equipments as turbine, generator and boiler can make it possible to come within this limitation. In this case, increase of manpower for assembly in the field will naturally become necessary and the cost for installation will increase.

Concerning road and railway it may become necessary partly to make reinforcement or improvement.

3-2-13 Land Reclamation

In case the existing land cannot be used for the power station site or land reclamation is economically advantageous, land reclamation can be applied.

(1) The site being easily reclaimed

By our experience, the site having the following condition can be reclaimed easily.

(a) Having a shoal
(b) Getting enough and economic filling material (mud and sand)
(c) Having a good sea condition (less wind and wave)
(d) Having the harbor construction plan

(2) The method of the reclamation

There are three methods for the land reclamation.

(a) Reclaiming method using earth, shaving the higher part of the land
(b) Reclaiming method using dredged mud and sand
(c) Combining method (a) and (b)

The reclaiming method must be selected in accordance with overall economy. The reclaiming method using dredged earth of which there is no experience in Indonesia, is shown detail in Volume IV Appendix 2·1.

(3) Judgement of the advantage of the land reclamation

For making the decision, whether existing land can be better used or new land shall be reclaimed, following points shall be taken into account for the overall judgement.

(a) Does the site satisfy aforementioned condition of item (1)?

(b) How much construction cost is necessary to get clean and enough condenser cooling water?

(c) How much construction cost is required to deliver the fuel and condenser cooling water?

(d) How much is the existing land?

4. ECONOMIC EVALUATION METHOD OF THERMAL POWER STATION

4. ECONOMIC EVALUATION METHOD OF THERMAL POWER STATION

4-1 Economic Evaluation

4-1-1 Basic Idea of Economic Evaluation

In planning power sources or transmission and transformation facilities, the guideline shall be to minimize the cost for the total power system in the long term. It is necessary not to make a mistake for the long period economy.

As a practical method of economic evaluation annual cost comparison method shall be used. In this case it is necessary totake into account accurately such influencing factors to each alternative plan as operating plan during service life when making the economic evaluation, and then the comparison of totalized annual cost in the long term in the present worth or comparison of equalized annual cost shall be made.

In the initial phase of rough evaluation, if there is no difference in the conditions to study between each alternative plan, a simplified comparison can be made by KWH cost or construction cost per KW.

4-1-2 Procedures for Development Planning of Power Sources and Economic Evaluation

In coping with the ever increasing demand most economically, it is necessary to compose supply power matching with the characteristics of the load.

It is necessary to combine corresponding to the load shapes of demand the hydraulic, thermal and nuclear power sources, having different characteristics of economy and operation, and then make the most economical and logical development planning, waging the ability of each equipment to full extent.

(1) Procedures for development planning of power sources

Based upon prospected sites of power sources, several alternative plans consisting of various combinations of hydraulic, thermal and nuclear power sources, and of locations shall be made. Considering the following items and evaluating as a whole, the most adequate plan shall be selected which proves to be the least overall cost of the power system, from the long term viewpoint.

(a) Security of power supply and preservance of supply reliability corresponding to the demand increase.

(b) Stable aquisition of energy for electric power.

(c) Adoption of technical innovation.

(d) Environmental considerations.

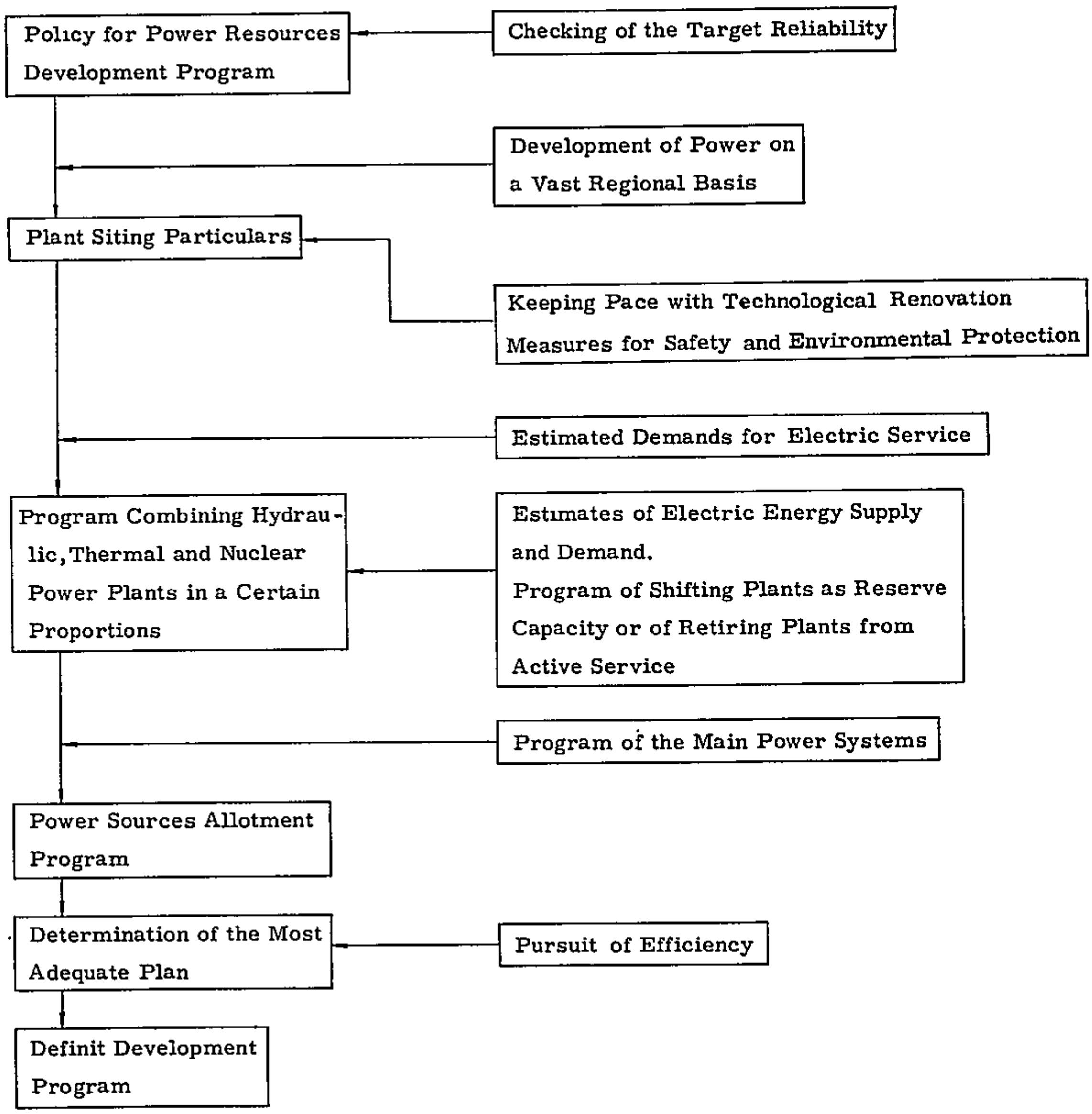
(e) Pursuit of efficiency.

(f) Furtherance of power development together with other enterprises.

(g) Program of shifting plants as reserve capacity or of retiring plants from active service.

Procedure of finding the most adequate program is shown in Fig. 4·1·1.

Fig. 4·1·1 Procedure of Finding the Most Adequate Program



(2) Economic Evaluation

After knowing accurately future operation of power sources for the long period of ten to twenty years, considering the future load curve, trend of regional demand, operating and economic characteristics of various power sources, search the development guidelines of hydraulic, thermal and nuclear power sources. Along this line, determine the individual site for hydraulic, thermal and nuclear as scheduled to be put into development program. In this case, economic evaluation shall be done as in the following manner.

a. Hydraulic power

First, make several alternative plans, concerning development sites, letting development scale, reservoir capacity and time of commercial operation be as variables. After studying the adaptability to load curve, find the annual cost "C" and "V". An alternative shall be chosen, such that (V-C) becomes maximum or C/V becomes minimum.

Here,

"C" is the annual cost of the hydro power concerned.

"V" is the annual cost of the substituted thermal power, when hydraulic power shall not be developed.

b. Thermal power

First, make several alternative plans concerning development sites, letting development scale, expected transmission line and fuel be as variables.

After studying future operating pattern choose an alternative plan which proved to be minimized totalized present worth of annual cost.

In this case, the output and generating KWH between each alternative plan shall be the same as much as possible, so that the comparison may be done fairly.

c. Nuclear power

Same as thermal power.

4-1-3 Procedures for Thermal Power Development Planning and Economic Evaluation

(1) Procedures for thermal power development planning

In order to fit the development ratio of the thermal power resources, it is necessary to make a thermal power development plan coordinating with relevant transmission and transformation development plan in adequate timing and capacity of development. The plan must be of minimized the overall system cost and have appropriate operation characteristics to the expected load curve, such as thermal power unit for base or middle load, and gas turbine unit for peak load.

In making individual thermal power development, pursue economical improvement by positively reflecting the result of technical renovation. At the same time, considerations should be given to acquisition of prospected thermal power plant site, security of energy sources and environmental protection. Outline procedure for thermal power development planning is shown in Fig. 4・1・2.

(2) Economic evaluation

Annual cost comparison method shall be used for the economic evaluation concerning the decision of site, unit size, development scale and development timing.

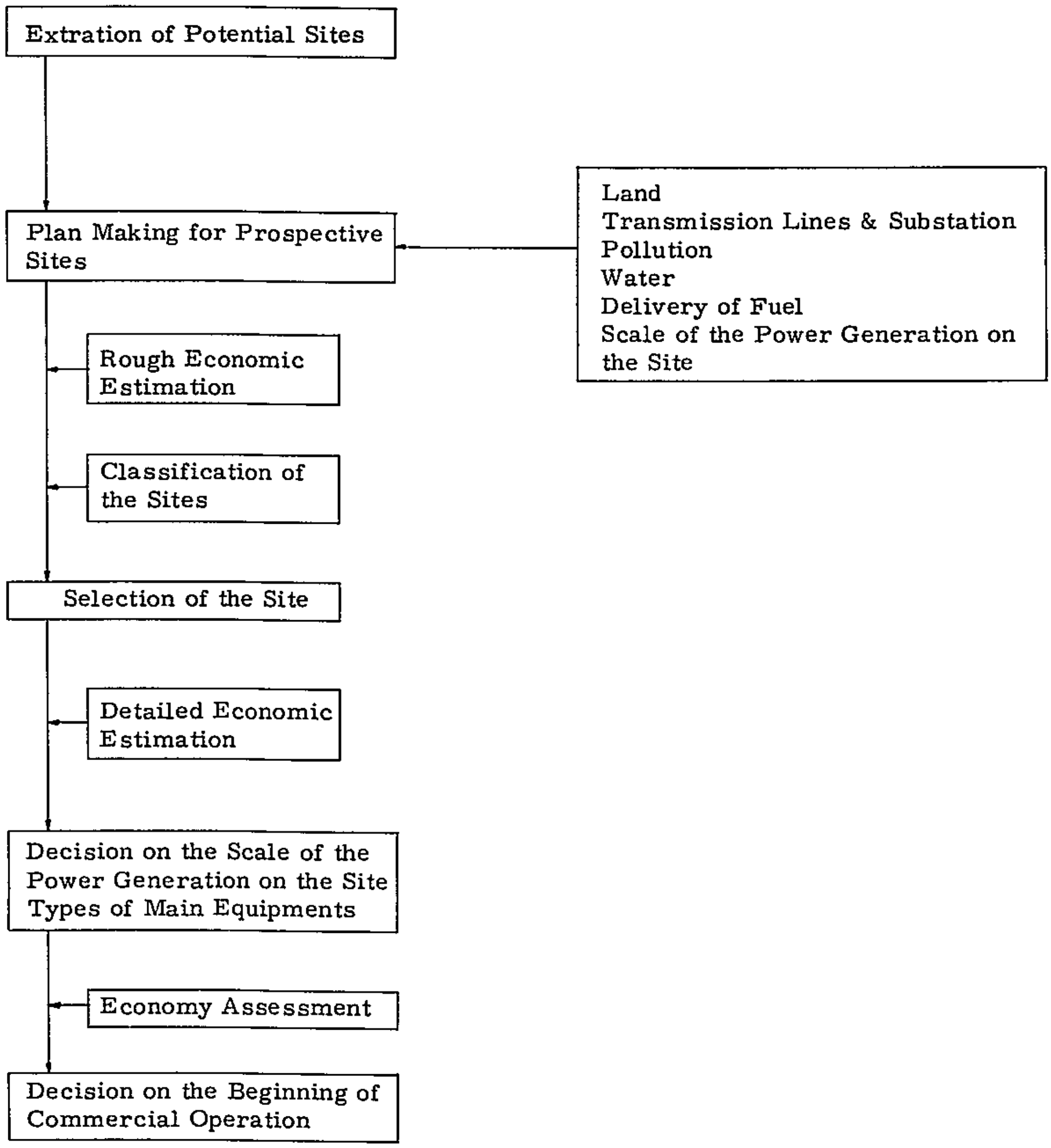
In this case, following items shall be accurately taken into account for the economic evaluation.

- Operation plan during service life
- Change of fuel situation
- Present condition of site, pollution, harbor, transmission and transformation systems.

Then economic evaluation shall be done by comparison of totalized present worth annual cost in long period or of equalized annual cost of equivalent model of the plan with the equalized annual cost of the other models, such as standard thermal power development plan.

But in the case when availability factor, fuel cost and transmission line cost can be regarded almost same for all the alternatives, a simplified method of comparing KWH cost and construction cost per KW can be used.

Fig. 4·1·2 Procedures of Development Planning and Economic Evaluation



4-2 Practical Methods for Economic Evaluation

4-2-1 Annual Cost Comparison Method

Development planning for thermal power facilities should be performed aiming at the cost minimum over the long term. It is of importance not to make misjudgement over the long range economy regardless of study period and the characters of the alternative plans.

For this sake, it is necessary to understand cost variables over the study period between ten to fifteen years equivalent of the long range view. Annual cost comparison method is suited.

(1) Economic comparison method

As economic comparison methods, there are two. One is the comparison of totalized present worth annual cost in long term. The other is the comparison of equalized annual cost with that of the standard model.

Both methods will be explained underneath.

a. A method of totalized present worth annual cost in long term

There are two alternatives, namely Plan "B" is an alternative plan of Plan "A".

Economic evaluation shall be done by comparing the result of Formula (4-2-1) & (4-2-2) which have been calculated for the totalized present worth of equalized annual cost through the service life by taking account of ten to fifteen years as calculated period (n).

If $A < B$, plan "A" is more profitable.

If $A > B$, plan "B" is more profitable.

(a) Totalized present worth of annual cost of the Plan "A."

$$A = \sum_{j=1}^{n} [C_{jTA} + C_{jTSA} + F_{jTA} + S_{ja}] \times P_j \qquad \cdots\cdots\cdots\cdots (4\text{-}2\text{-}1)$$

Here, about plan "A".

C_{jT} : Fixed cost of the thermal power station in j th year

C_{jTS} : Fixed cost and losses of relevant transmission and transformation systems in j th year

F_{jT} : Fuel cost of the thermal power station in j th year

S_j : Compensation of the annual cost become from system in j th year

P_j : Present worth factor in j th year

(b) Totalized present worth of annual cost of the substitution plan "B".

$$B = \sum_{j=1}^{n} [C_{jTB} + C_{jTSB} + F_{jTB}] \times P_j \qquad \cdots\cdots\cdots\cdots (4\text{-}2\text{-}2)$$

Here, symbolts mean the same of Formula (4-2-1)

b. The method of comparing the equalized annual cost with that of the standard model.

If a plan is easily to be modified to a model, comparison shall be made between equalized annual cost of a equivalent model and equalized annual cost of standard model i. e., standard thermal unit. And if equalized annual cost of the equivalent model is less, this plan can be adopted.

c. Some remarks when employing annual cost comparison method

(a) When comparing the plans for thermal power units having different ratio of forced outage, unit size and maintenance period, necessary facilities shall be compensated in order to equalize the supply reliability.

(b) When comparing the plans for thermal power units having different availability factor, deviation of the fuel cost of the power system shall be compensated, considering the effect of new power sources to the total fuel cost of existing thermal power units.
But, if this effect is very small, this can be neglected.

(c) When comparing the plans for thermal power units having different relevant transmission and transformation systems until consumer end, annual cost and losses for relevant transmission and transformation systems shall be included in the comparison.

(2) Calculation method of annual cost

Annual cost for thermal power facilities shall be calculated in the following way.

a. Calculation of annual fixed cost

Fixed cost consists of interest and depreciation, personnel expenses, repairing expenses, miscellaneous expenses, administrative expenses and the calculation method of each expenses is shown underneath. Principally each of these shall be calculated separately and added as a whole. But in order to spare the time, if the average ratio of these cost to construction cost is prepared, it has the convenience of getting the fixed cost directly from construction cost. This ratio is called a fixed cost ratio and used for the convenience. This is 16.3 % in our company in 1973.

(a) Interest and depreciation

Equalized value (α) of interest and depreciation through service line can be obtained by Formula (4-2-3)

$$\alpha = \frac{i\,(1+i)^n}{(1+i)^n - 1} \times (1 - \beta) + i\ \beta \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4\text{-}2\text{-}3)$$

i : Interest rate per year

n : Service life (in terms of year)

β : Rate of residual value

(b) Taxes

They are fixed asset tax, incorporate tax and can be calculated by the taxiable rate.

(c) Personnel expenses

This shall be calculated actually, but if it is very hard, this can be obtained by multipling average personal expenses of one power station employes per year by standard number of employees.

(d) Repairing expenses

This shall be calculated, considering the passed years of service and availability factor of the facilities. Actual cost experienced shall also be referred to.

(e) Miscellaneous cost

This means necessary lubricating oil for the power station and waste and supply accounting and these shall be obtained by the past experience.

(f) Administrative expenses

This means administrative expenses in head and branch offices and additional administrative expenses must be estimated for the operation of the new power station.

b. Calculation of annual fuel cost

Variable cost for thermal power facilities is mainly fuel cost and can be calculated by Formula (4-2-4).

Annual fuel cost

$$= \text{Output (KW)} \times 8760\,\text{(Hours)} \times \text{Availability Factor}$$

$$\times \frac{0.86(10^3\text{Kcal/KWH})}{\text{Operation Efficiency}} \times \text{Fuel Cost per } 10^3 \text{ Kcal} \quad \ldots\ldots \quad (4\text{-}2\text{-}4)$$

(a) Calculation of availability factor

i. Definition of availability factor

$$\text{Availability Factor} = \frac{\text{Annual Power Generation (KWH)}}{\text{Output(KW)} \times 8760\text{(Hours)}} \quad \ldots\ldots \quad (4\text{-}2\text{-}5)$$

ii. Change of availability factor during service life

In general the idea for thermal power development is that new developed units with higher efficiency shall be used as base-load operation and accordingly existing generating units shall be pushed upward in turn in the load curve diagram.

Let us look at the change of availability factor during service life. Several years after the beginning of commercial operation, a generating unit will operate as base-load power with such high availability factor as 70 - 80 %. But gradually, this unit will be pushed upward and become middle load power supply unit with the availability factor of 40 - 50 %. And then after several years this will shift to peak power supply unit with the availability factor of 20 - 50 %. Finally the unit ends its service life as reserve power, reaching retirement.

Operation pattern of thermal power unit and change of availability factor during service life are shown in Fig. 4·2·1 and in Table 4·2·1 respectively.

At present standard average availability factor is calculated about 70% through service life.

Fig. 4·2·1 Change of Availability Factor During Service Life

$$\text{Availability Factor (\%)} = \frac{a}{b} \times 100$$

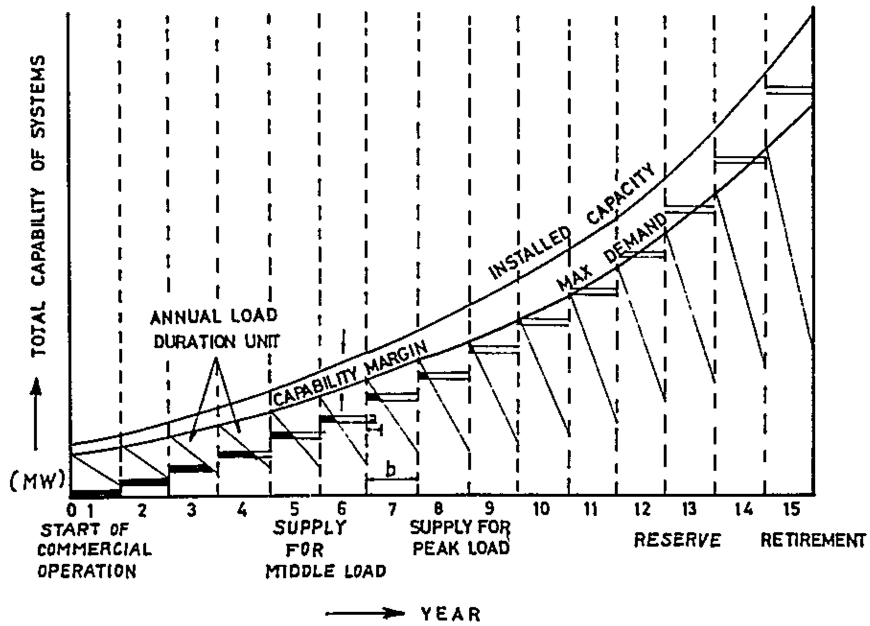


Table 4.2.1 Operation Pattern of Thermal Power Units

Daily Operation Pattern	Week Days		Holidays	Availability Factor
	In the Daytime with Heavy Load	At Night with Light Load		
Base-Load Units	Full Load	Full Load or Partial Load	Same as in Week days	For Base-Load Max. 80 % For Middle Load Smaller For Peak-Load Still Smaller
Middle-Load Units	Full Load	Shut Down	Shorter Operation Hours as Compared with in Week Days	
Peak-Load Units	Full Load or Shut Down	Shut Down		

As this figure will change corresponding to the following items, special attention should be paid in using this figure.

(i) Capacity to be developed exclusively for peak-load supply such as pumped-up hydraulic power and gas turbine, and also for middle-load supply.
The larger this amount is, the higher the availability factor.

(ii) Nuclear capacity to be developed.
The larger this capacity is, the lower the availability factor.

(iii) Capacity of units already in retired or reserved condition.
The larger this amount is, the lower the availability factor.

(iv) Ratio of capability margin
The larger this amount is, the lower the availability factor.

(v) Load curve of the demand
The sharper the peak is, the lower the availability factor.

(vi) Rate of demand increase
The larger the rate is, the lower the availability factor.

(b) Operating thermal efficiency

This efficiency shall be calculated by Formula (4-2-6).

Operating Thermal Efficiency = (Design Thermal Efficiency)
x (Correction Factor)........... (4-2-6)

Here,

i. Design thermal efficiency

Expected efficiency at steam rating under design conditions.

ii. Correction factor

Correction factor due to change of annual operational conditions, such as availability factor, variation of output, startup and shut down, etc. In general, figures in Table 4·2·2 are used as correction factor.

Table 4·2·2 Correction Factor for Operating Thermal Efficiency

Availability Factor (%)	100	90	80	70	60	50
Correction Factor	0.98	0.98	0.97	0.96	0.95	0.94

iii. Operating efficiency of the standard unit with 70 % availability factor is shown in Table 4·2·3.

Table 4·2·3 Thermal Efficiency of the Standard Unit

Unit size (MW)	Fuel	Net thermal efficiency		Power ratio for station use		Driving method of boiler feed water pump	Gross thermal efficiency
		Design thermal efficiency (%)	Operating thermal efficiency (%)	KW base (%)	KWh base (%)		
1000	Heavy and crude oil	40.8	39.2	2.1	2.3	Steam-driven	38.3
	L N G	39.2	38.6	1.9	2.1	"	37.8
600	Heavy and crude oil	40.3	38.7	2.5	2.8	"	37.6
	L N G	38.7	37.6	2.3	2.5	"	36.7
350	Heavy and crude oil	39.8	38.2	3.0	3.3	"	37.0
	L N G	38.2	36.7	2.7	3.0	"	35.6
265	Heavy and crude oil	40.0	38.4	6.0	6.0	Motor-driven	36.0
	Coal	39.8	38.2	7.0	7.0	"	35.5
175	Heavy and crude oil	39.2	37.6	6.0	6.0	"	35.4
	Coal	38.8	37.2	7.0	7.0	"	34.6
125	Coal	37.2	35.7	7.0	7.0	"	33.2
75	Coal	36.0	34.6	7.0	7.0	"	32.2

c. Calculation of total annual cost of thermal power station
This shall be obtained by Formula (4-2-7)

Total Annual Expenses of Thermal Power Facilities
= Annual Fixed Cost + Annual Fuel Cost .... (4-2-7)

4-2-2 Simplified Comparison Method

(1) Comparison method of power generating cost

When the two alternative plans have the almost same availability factor, economic evaluation can be done by comparing power generating cost. Power generating cost can be obtained by Formula (4-2-8).

$$\text{Power Generating Cost} = \frac{[\text{Construction Cost}] \times \begin{bmatrix}\text{Equalized annual cost} \\ \text{ratio through service life}\end{bmatrix} + \begin{bmatrix}\text{Annual variable} \\ \text{cost}\end{bmatrix}}{[\text{Output}] \times [8760] \times [\text{Availability Factor}]} \qquad \text{(4-2-8)}$$

(2) Comparison method of construction cost per KW

When two alternative plans have almost the same thermal efficiency, fuel cost and availability factor, economic evaluation can be roughly done by comparing construction cost per KW.

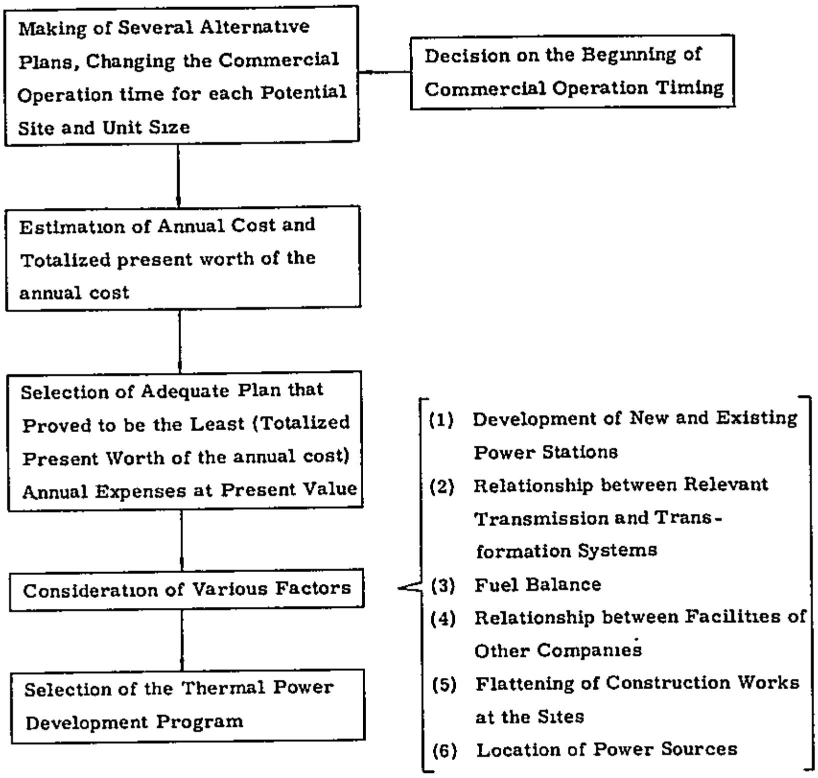
4-2-3 Practical Application Method of Economic Evaluation

Practical method of evaluating a site development plan planning is going to be explained.

(1) Procedures for economic comparison of site development plans

Procedures for economic comparison of site development plans shall be performed in the procedure shown in Fig. 4. 2. 2.

Fig. 4·2·2 Procedures for Economic Comparison of Site Development Plans



(2) Nomenclature

Before explaining the comparison method, symbols for calculation will be defined in Table 4·2·4.

Table 4·2·4 Nomenclature

Symbol	Definition	Explanation
r	Name of Unit	
s	One of Alternative Plans	
a_{rs}	Construction Cost per KW of Unit "r" of Plan "s"	If construction cost changes with the variation of the timing of construction and commercial operation, this shall be taken into account. In general, the construction cost of first unit is higher than that of a extension unit.

Symbol	Definition	Explanation
a_{2rs}	Construction Cost per KW of Transmission and Transformation Systems Relevant to Unit "r" of Plan "s"	Transmission and transformation systems common to all alternative plans shall be excluded. a_{2rs} shall be average construction cost per sending end KW of new, extended or voltage step up transmission and transformation systems in connection with the operation of unit "r".
b_{1r}	Fixed Cost Ratio of Unit "r"	Standard equalized annual cost ratio through the service life shall be used. If there is a deference of the service life in using facilities or a special factor for the unit "r" such as number of employee for operation, the much deviation of the repairing expenses caused by fuel and the type of unit, must be review of the depreciation and interest, personnel expenses and repairing expenses including in standard equalized annual cost ratio.
b_2	Fixed Annual Cost Ratio of New Transmission and Transformation Systems	Standard equalized annual cost through the service life shall be used.
Frsj	Fuel Cost per net KWH of the unit "r" of Plan "s"	Calculate in the following formula $\frac{0.86(10^3 kcal/kwh) x Fuel\ cost(Yen/10^3 kwh)}{Net\ Thermal\ Operation\ Efficiency\ of\ Unit\ "r"\ with\ availability\ factor\ of\ j\ th\ Year}$
Hrsj	Operative Hours of Unit "r" of Plan "s" in the j th Year	This shall be estimated by the allotment of thermal units of total power systems.
i	Interest	
j	Fiscal Year	
lrsj	Loss Factor in KW or KWH of Unit "r" of Plan "s" in the j th Year	Estimation shall be made in connection with the enlargement of transmission and transformation programs.
Drj	Net Output of Unit "r" of Plan "s" of the j th Year	Figures shall be used, enlisted in the demand and supply program.
t_{1rsj}	Month of Commercial Operation of Unit "r" of Plan "s" in the j th Year	This shall be determined by keeping balance between demand and supply.

<table>
<tr><th>Symbol</th><th>Definition</th><th>Explanation</th></tr>
<tr><td>t_{2rsj}</td><td>Month of Operation of Transmission and Transformation Systems Relevant to Unit "r" of Plan "s" in the j th Year</td><td>This is the operation month of transmission and transformation systems in connection with that of the thermal unit and is in general several months prior to the operation of the thermal unit in case of new systems.
The reason is that period of test operation of the thermal unit is long and accordingly the preceding number of months prior to units operation becomes long.
If month of operation of transmission and transformation systems falls to be month of the preceding year, j must be substituted by (j - 1).</td></tr>
<tr><td>U_{1rsj}</td><td>The Deviation Factor of the Fixed Cost and Valiable Cost Caused by Commercial Operation in an Odd Month in j th Year for the Unit "r" of the Plan s.</td><td>In order to estimate the annual cost after the commercial operation month corresponding to t_{1rsj} in the "j" th year.
The deviation factor shall be used.</td></tr>
<tr><td>U_{2rsj}</td><td>The Deviation Factor in j th Year for the Annual Cost of the Relevant Transmission and Transformation System to the Unit "r" of the Plan "A"</td><td>This factor shall be used in order to estimate annual cost for only operating monthes in "j" th year after commercial operation month t_{2rsj}

Here:
If the commercial operation year of unit "r" of the plan "s" is shown in "n",
$j < n$ $U_{2rsj} = 0$
$j = n$ U_{2rsj} is shown is following table.
<table>
<tr><td>t'_{2rsj}</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td>U'_{2rsj}</td><td>1</td><td>0.92</td><td>0.83</td><td>0.75</td><td>0.67</td><td>0.58</td><td>0.50</td></tr>
</table>
<table>
<tr><td>11</td><td>12</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>0.42</td><td>0.33</td><td>0.25</td><td>0.17</td><td>0.08</td></tr>
</table>
$j > n$ $U_{2rsj} = 1$</td></tr>
<tr><td>α_{sj}</td><td>KWH Correction of Existing Thermal Units of Plan "s" in the j th Year (10^6/Year)</td><td></td></tr>
</table>

(3) Development program making

r : Name of unit

Pr : Output

A_{1r} : Construction cost of thermal unit for unit "r"

D_{1r} : Fixed cost ratio of thermal units

Fr : Fuel cost per net KWH or KWH of sending end

j : The probable year of commercial operation

a_{2r} : Construction cost of relevant transmission and transformation facilities

Based upon the above notation, several development program shall be made as Table 4·2·2, keeping the balance between demand and supply.

Table 4·2·5 Summary of Alternative Development Programs

Year of Commercial Operation j	Alternative Program S = 1			Alternarive Program S = 2		
	Unit "r"	Output Prs Construction Cost a_{1rs}	Construction Cost of Relevant Transmission and Transformation Systems	Unit "r"	Output Prs Construction Cost $a_{2}rs$	Construction Cost of Relevant Transmission and Transformation Systems
1	1	P_{11}	a_{211}	1	P_{12}	a_{212}
		a_{111}			a_{112}	
	2	P_{21}		4	P_{42}	
		a_{121}			a_{142}	
2	3	P_{31}	a_{231}	5	P_{52}	
		a_{131}			a_{152}	
	4	P_{41}		3	P_{32}	a_{232}
		a_{141}			a_{132}	
3	5	P_{51}		2	P_{32}	
		a_{151}			a_{122}	
	6	P_{41}	a_{261}	6	P_{42}	
		a_{161}			a_{112}	

(4) Calculation method of annual cost and totalized present worth

Annual cost shall be obtained as in the following way, omitting common cost to all. Refer to Table 4.2.6.

a. Annual cost of unit "r" of plan "S" in the j th Year Wrsj

$$W_{rsj} = \frac{P_{rj}}{1 - l_{rsj}} (a_{1rs} \cdot b_{1r} \cdot U_{1rsj} + a_{2rs} \cdot b_2 \cdot U_{2rsj})$$

$$+ \frac{P_{rj}}{1 - l_{rsj}} \cdot H_{rsj} \cdot F_{rsj} \times 10^{-3}$$

$a_{1rs} \cdot b_{1r} \cdot U_{1rsj}$: Annual fixed cost of thermal power unit

$a_{2rs} \cdot b_{1r}\ U_{1rsj}$: Annual fixed cost of relevant transmission and transformation systems

b. Annual cost of all the units of plan "S" in the j th year Wsj

$$W_{sj} = \sum_{r=1}^{P} W_{rsj} - \alpha_{sj}$$

α_{sj} : Term of KWH correction

P : Numbers of units operating in the j th year

c. Totalized present worth of the annual cost Ws

$$W_s = \sum_{j=1}^{n} W_{sj} \frac{1}{(1+i)^j}$$

n : Study period

Table 4.2.6 Table for Annual Cost Calculation

Year of Commercial Operation / Unit "r"	1	2	3	4		n
1 2 3 4 5 6 : P	W_{111} W_{211}	W_{112} W_{212} W_{312} W_{412}	W_{113} W_{213} W_{313} W_{413} W_{513} W_{613}	W_{114} W_{214} W_{314} W_{414} W_{514} W_{614}	....	W_{11n} W_{21n} W_{21n} W_{41n} W_{51n} W_{61n} W_{p1n}
Correction Factor of KWH	(Base)	α_{12}	α_{13}	α_{14}		α_{1n}
Annual cost of each Year	W_{11}	W_{12}	W_{13}	W_{14}	......	W_{1n}
Present Worth Conversion	$\frac{W_{11}}{(1+i)}$	$\frac{W_{12}}{(1+i)^2}$	$\frac{W_{13}}{(1+i)^3}$	$\frac{W_{14}}{(1+i)^4}$	......	$\frac{W_{1n}}{(1+i)^n}$
Total W_s						

4-3 Rough Calculation Method of Construction Cost

Construction cost shall be roughly calculated by using the result of conceptual design, based upon the siting particulars. This shall be performed item by item as shown in Table 4·3·1.

Construction cost for each of these items shall be estimated by referring to the price lists of many manufacturers, purchase records and trend of prices which have been collected, stored and arranged in the routine work.

Table 4.3.1 - (1) Summary Sheet of Thermal Power Construction Cost

Item \ Unit No.	No. 1	No. 2	Remarks
Land & Compensations			
Civil Engineering Works			
Architectual Works			
Mechanical Works			
Electrical Works			
Furniture & Apparatus			
Office Operation			
Contigency			
Sub-total			
Interest during Construction			
Administration			
Total			

Table 4·3·1-(2) Detail

	Spec.	Q'ty	Unit price	Total price	Remarks
Land & Compensations					
1) Purchase of Station Land		m^2.	Rp/m^2		at Site Survey by Conceptual Design.
2) Purchase of Residence Land		m^2.	Rp/m^2		Operation & Maintenance Personnel.
3) Compensations object on the ground fishing rights.					

	Specification	Quantity	Unit price	Total price	Remarks
Civil Engineering Works					
1) Bank Rivetment					
a) Circumference of	structure				
Site.		m	Rp/m		by Outline Design
b) Unloading Wharf	ship scale				by Unit Size
c) Wharf for Oil	ship scale				by Largest Tanker Size
d) Sub-total					
2) Water Channel					
a) Intake Place	Water Velocity Water Quantity Cross Section				by Required Water Quantity
b) Intake Channel					by Required Water Quantity & Plot-plan
Open Channel	W. Velocity				
	W. Quantity	m	Rp/m		
	Cross Sect.				
Culvert-channel	" "	"	"		
c) Discharge channel					" "
Open-channel	" "	"	"		
Culvert-channel	" "	"	"		
d) Discharge Place					" "
e) Cooling Pipe &					
Foundation	ϕ	"	Rp/m		" "
f) Cooling Pump					
Station					" "
g) Others					Stop log, etc.
h) Sub total					
3) Road					
a) Road in the Site	width,	m	Rp/m		by Plot Plan
b) Access Road	"	"	"		at the Site
c) Others					
d) Sub-total					

	Specification	Quantity	Unit price	Total price	Remarks
4) Land Reclamation					
a) Reclamation	Ground level				by Site Survey
	Reclamation Depth	m^3	Rp/m^3		and Required Level
b) Levelling		m^3	Rp/m^3		
c) Site Preperation					
5) Foundation of Tanks					
a) Oil Tank Foundation & Dike	Diameter Method of Foundation Practice				by Tank Size
b) Misc. Tanks					
6) Investigation & measurements					
7) Deep Well	Depth		Rp/m		
8) Temporary Facility					
a) Temporary Road	Width	m	Rp/m		
b) Temporary Sewerage					
Architectual Works					
1) Main Building					
a) Foundations	Depth Concrete m^3	Pile ton Concrete m^3	Rp/m^3		by Soil Conditions
b) Structural Steel		ton	Rp/ton		by Unit Size
c) Steel Works		ton	Rp/ton		
d) Upper Finishing Works		m^3	Rp/m^3		by Unit Size
e) Foundation of Indoor Equipment					
f) Foundation of Outdoor Equipment					

	Specification	Quantity	Unit price	Total price	Remarks
2) Misc. Buildings					
a) Company House	m^2		Rp/		Operation & Maintenance Personnel
b) Sub-Station Building and Foundations		m^3	Rp/m^3		
c) Water Treatment House		m^3	Rp/m^3		
d) H_2. Storage House		m^3	Rp/m^3		
e) Oil Pump House		m^3	Rp/m^3		by Number and Size of Pumps
f) Service Building					
g) Guardman Shack		m^3	Rp/m^3		by Number of Guardman
h) Storage House					
3) Stack					
a) Stack proper	height				Steel or Concrete
b) Foundation					by Soil Condition
4) Temporary Facility					
a) Construction office	m^2		Rp/m^2		by Number of Personnel
b) Temporary storage House					by Keeping of Materials
Machinery Works					
1) Main Machinery					by Price List, Actual Result, Price-rise
a) Boiler Turbine Generator	MW				F.O.B. Price
b) Transportation					Marine & Land, Transportation
c) Taxes					
d) Installation Works					
e) Insurences					Marine & Installation Insurance

	Specifi-cation	Quantity	Unit price	Total price	Remarks
f) Consultant-Fee					In the Field
2) Tanks					
a) Oil Tanks	Kl				
b) Raw-Water Tanks	Kl				
c) Demineralized Water Tanks	Kl				
3) Misc. Facilities					
a) Dust Collector					
b) Water Treatment					
c) Oil Pump					
d) Oil Flow-Meter	T/H				
e) Oil Unloadings	T/H				
f) Fire Fighting					
g) Waste Water Treatment	T				
h) Overhead Crane	T				
i) Station Boiler	T/H				
j) Emergency Generator					
4) Misc. Works					
a) Raw Water Piping	ϕ	m	Rp/m		
b) Water Piping	ϕ	m	Rp/m		
c) Fuel Oil Piping	ϕ	m	Rp/m		
5) Temporary Facility					
a)					
b)					
Electrical Works					
1) Transformers					
a) Main Trans.	MVA KV/KV		Rp/ MVA		

	Specifi-cation	Quantity	Unit price	Total price	Remarks
b) Start up Transformer	MVA KV/KV		Rp/ MVA		
c) Station Transformer	MVA KV/KV		Rp/ MVA		
2) Other Equipment					
a) Circuit Breaker	KV MVA A				
b) Disconnecting Switch	KV.A				
c) Potential Transformer	KV				
d) Lightning Arrester	KV				
e) Neutral Equipment					
f) Air Compressor					
g) Telecommunication system					
h) Paging Equipment					
i) Cables	Size x m.	m	Rp/m		
OF - Cable					
Power Cable					
Control Cable					
j) Receiver System for Load Dispatching System					
k) Insulation Oil					
3) Misc. Works					
a) Switch Yard Works		Span	Rp/ span		
b) Piping & Wiring Works					
c) Communication Works					
d) Electric Work of Service Building					

	Specification	Quantity	Unit price	Total price	Remarks
e) Lighting Works in Main Building					
f) Lighting Works in Yard					
g) Others					
4) Temporary Facilities					
a) Sub-station for Construction					
b) Distribution wiring for works					
c) Communication equipment for works					
Furniture & Apparatus					for Operation & Maintenance
Office Operation					Personnel Expense Test running Elec. Power for Works etc.
Contingency					Unexpected Factor a few % Construction Cost.
Interest During Construction					
Administration					Allotment Expenditure of Head Office During Construction

5. EXAMPLES OF PLANNING AND SURVEY

5. EXAMPLES OF PLANNING AND SURVEY

5-1 Example of Calculating Survey Cost for Cilacap Site

5-1-1 Assumptions

(1) Final Development Size	125 MW x 4 = 500 KW
(2) Area of Site	140.000 m^2
(3) Place	at left side of Donan Bay
(4) Beginning of Construction	in 1978
(5) Survey Period	in 1974 - 1977 (4 years)
(6) Cost Base	Cost in Japan as of 1972

5-1-2 Preliminary Survey

(1) Preliminary survey is to be made in 1974

(2) Five boring tests are to be made until 40 m depth

(3) Sounding test is to be made once at every 1. 5 m

(4) Sampling test and soil test are to be made once at every 10 m

5-1-3 Feasibility Survey

(1) Fifty boring tests are to be made respectively in 1975 and 1977. Total 100 hole, each 50 bor hole. The depth is just the same with preliminary survey.

(2) Sounding test, sampling test and soil test are to be made just the same as in preliminary survey.

(3) Concerning littoral drift, isotope method is not to be adopted but sea depth measurement be made every year after 1974.

(4) Wind velocity recorder, air pollution meter, salt sticking in the air measurement device and noise measurement apparatus are to be purchased and installed in 1975.

(5) Hydraulic model test is not to be made.

5-1-4 Estimation of the Site Survey Cost

The result is shown in Table 5·1·1.

Table.5・1・1 Summary of Survey Cost

(US$)

By survey stage / By Fiscal Year / Survey items	Preliminary survey	Feasibility survey			Total
	1974	1975	1976	1977	
(1) Location land	(16.040)	(4.000)	(0)	(0)	(20.040)
Purchase of map	20	-	-	-	20
Purchase of sea chart	20	-	-	-	20
Aerial photo	16.000	-	-	-	16.000
Topographical measurement	-	4,000	-	-	4.000
Sea depth measurement		(Performed with littoral drift survey)			
(2) Ground condition	(7.460)	(74.600)	(0)	(114.600)	(196.660)
Boring test	3,200	32.000	-	32.000	67.200
Sounding test	660	6.600	-	6.600	13.860
Sampling	400	4.000	-	4.000	8.400
Soil test	3.200	32.000	-	32.000	67.200
Test piling, Load test	-	-	-	40.000	40.000
(3) Water quality	(1.550)	(1.550)	(25.550)	(1.550)	(30.200)
Fresh water	50	50	50	50	200
Sea water	1.500	1.500	1.500	1.500	6.000
Deep well	-	-	24.000	-	24.000
(4) Meteology	(8.800)	(10.400)	(400)	(10.400)	(30.000)
Wind direction, velocity	1.700	100	100	100	2.000
Inverse layer	-	10.000	-	10.000	20.000
Salt sticking	7.100	300	300	300	8.000
(5) Marine conditions	(8.700)	(46.600)	(5.350)	(17.350)	(78.000)
Wave direction height	-	29.500	250	250	30.000
Tide level	3.700	100	100	100	4.000
Tidal current temp. Bottom material	-	12.000	-	12.000	24.000
Littoral drift	5.000	5.000	5.000	5.000	20.000
(6) Existing Pollution	(50)	(4.050)	(50)	(50)	(4.200)
SO_2 density measurement	-	2.000	-	-	2.000
Waste water analysis	50	50	50	50	200
Noise measurement	-	2.000	-	-	2.000
(7) Model test	(0)	(0)	(0)	(12.000)	(12.000)
Wind tunnel test	-	-	-	12.000	12.000
Hydraulic model test	-	-	-	-	0
(8) Others	(0)	(0)	(0)	(0)	(0)
Total	42.600	141.200	31.350	155.950	371.100

5-2 Example of Outline Planning

5-2-1 Assumptions

After site survey, suppose that following conditions have become clear.

(1) Land

The land is almost rectangular, two sides being surrounded by sea. Enough area can be secured as required.

This site shall be located in the bay and the depth of the sea near coastal line is 5m. There is no mountain or hill and there is no house within the area, from two to three km apart from the site boundary.

The former ground level is G. L. + 1. 5 m.

(2) Soil

The surface is mostly sand and there is bearing stratum of N value 40 at 20 m depth. This stratum is strong enough to support the structures.

(3) Condenser cooling water

Cooling water for condenser can be taken directly from the sorrounding sea. Annual average water temperature is about 21. 1°C.

(4) Boiler water

House service water, including boiler water can be obtained from the city water supply.

(5) Delivery of fuel

As there is no refinery nearby, fuel shall be delivered by ship.

After negotiating with a oil supply company, it became clear that about 300, 000 kl oil at the most can be supplied yearly.

A tanker will be used, having the capacity of 5000 DWT.

(6) Transmission line

There is a primary 150 KV substation, about 5 km apart from the site. There is space for the construction of the overhead transmission line from the site to the substation.

(7) Existing pollution

There is no existing pollution, such as air and water pollution, and noise.

(8) Development scale

The final scale of the power station shall be about 700 MW, consisting of four units.

(9) Unit size and steam conditions

From the overall study in connection with the features of demand and the scale of the system, following conclusion is drawn.

a. Unit output — 175 MW

b. Steam conditions — 169 kg/m^2
566/538°C

5-2-2 Outline Planning

(1) Intake and discharge facilities for condencer cooling water

a. Design condition

(a) Quantity of cooling water per one unit

Average sea water temperature throughout the year 21.1°C

Turbine exhaust pressure at rated output in design conditions 1.5" Hg

Quantity of cooling water 23,400 Ton/Hr (6.5 Ton/Sec)

(b) Velocity of intake point — 0.35 m/Sec.

(c) Velocity of discharge point — 0.4 m/Sec.

(d) Velocity of intake culvert channel — 1.5 m/Sec.

(e) Velocity of discharge open and culvert channel — 2.0 m/Sec.

(f) Thickness of shell accumulation at the inner surface of intake channel. — 10cm

b. Design of intake place

If there is no water temperature difference in the depth direction of the intake, the intake place structure shall be the normal one, so that the water can not be profitably be taken from the deeper point from the water surface. In general the velocity of intake place is 0.35 m/Sec. and bellow in order to avoid sucking sand and wastes.

The area of intake place per unit shall be calculated in the following Formula.

$$A = \frac{Q}{V} = \frac{6.5}{0.35} = 18\ m^2$$

The design of intake place is shown in Fig. 5·2·1 and Fig. 5·2·2.

Fig. 5.2.1 Section of Intake Point

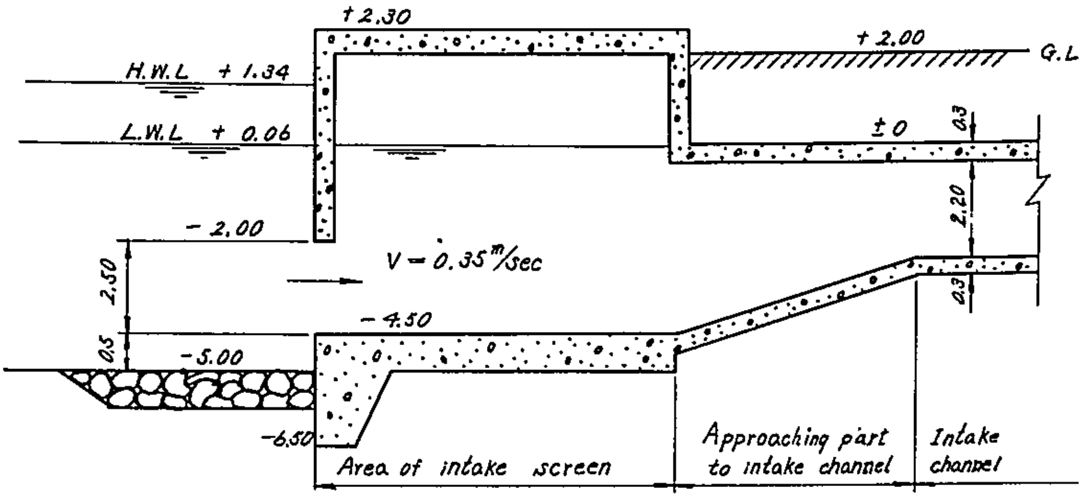
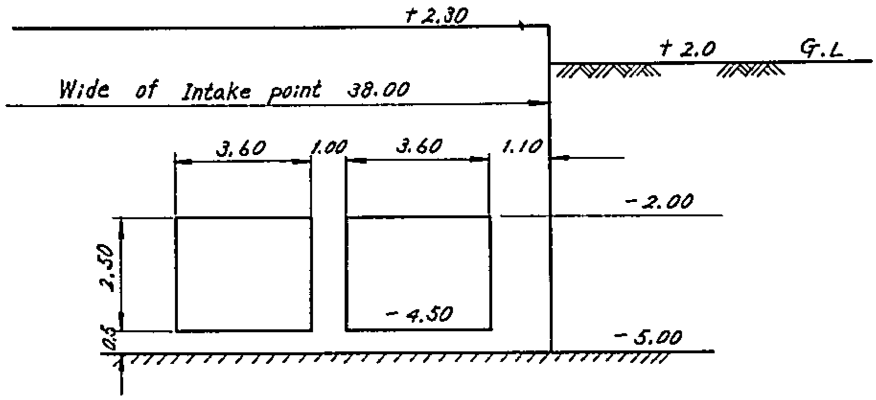


Fig. 5.2.2 Front View of Intake Point



c. Intake channel

(a) Design of intake channel

i. Determination of cross section

Cross section of intake channel must be selected from the various kinds of structure and section in condition of minimized annual cost.

But, in our experience, if the velocity of intake channel be taken 1.5m/sec. in outline design stage, the section area will come into comformity with the theoretical economy.

In this case the culvert channel shall be adopted for the intake channel.

Cross section of intake channel $= \frac{6.5}{1.5} = 2.08^2 \quad m^2$

ii. Determination of the channel depth

The depth of inner channel cieling should be under the hydraulic gradient line from the water surface avoiding destruction of the structure by air hammer, occuring from wave intrusion.

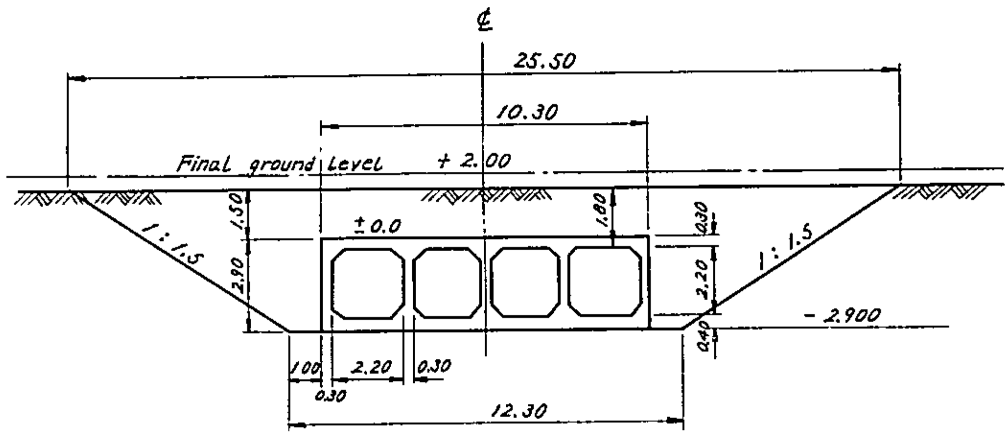
From this reason, the depth shall be adopted by 0.3 m under the hydraulic gradient line.

Since the water flows with the hydraulic gradient line, incurred by pump operation, the slope of channel must be kept about 1/1000 so that the actual work can be easily done.

iii. Determination of standard cross section

From the above mentioned considerations, the standard section shall be determined as shown in Fig. 5·2·3.

Fig. 5.2.3 Standard Section of Intake Water Channel



(b) Study of intake channel foundation

If the soil condition of intake water channel area is medium soil of sandy ground having 30 N value judging from the soil investigation, the bearing power of ground will be estimated about 20 ton/m^2 from Table 5·2·1. The loading of the intake and discharge facilities will be calculated 5 ton/m^2. There is no reason the pile foundation method because the safety factor to the bearing capacity becomes four as a resulty of above calculation.

Table 5.2.1 Long-term Allowable Ground Bearing Force

Ground	(T/M^2)	N value	$Qu(Kg/Cm^2)$
Rock	100	> 100	
Sand Ground	50	> 50	
Hardpan (Mud Stone)	30	> 30	
Gravel Pebb Layer (Solid)	60		
Gravel Pebb Layer (Not Solid)	30		
Sandy Ground (Solid)	30	30 - 50	
" " (Medium Solid)	20	20 - 30	
" " (" ")	10	10 - 20	
" " (Loose)	5	5 - 10	
" " (Extremely Loose)	0	0 - 5	
Clayey Ground (Very Hard)	20	15 - 30	2.5
" " (Hard)	10	8 - 15	1.0 - 2.5
" " (Medium Hardness)	5	4 - 8	0.5 - 1.0
" " (Soft)	2	2 - 4	0.25 - 0.5
" " (Extremely Soft)	0	0 - 2	0.25

d. Discharge channel

(a) Design of discharge channel

i. Determination of the minimum water level at the discharge point. The minimum water level at the discharge point of circulating water pipe to the discharge channel must be determined, no to lose the advantage of siphon effect. Following Formula (5.2.1) will be obtained.

$$P \leqq -H + \Delta H \quad \cdots\cdots\cdots\cdots \quad (5\cdot2\cdot1)$$

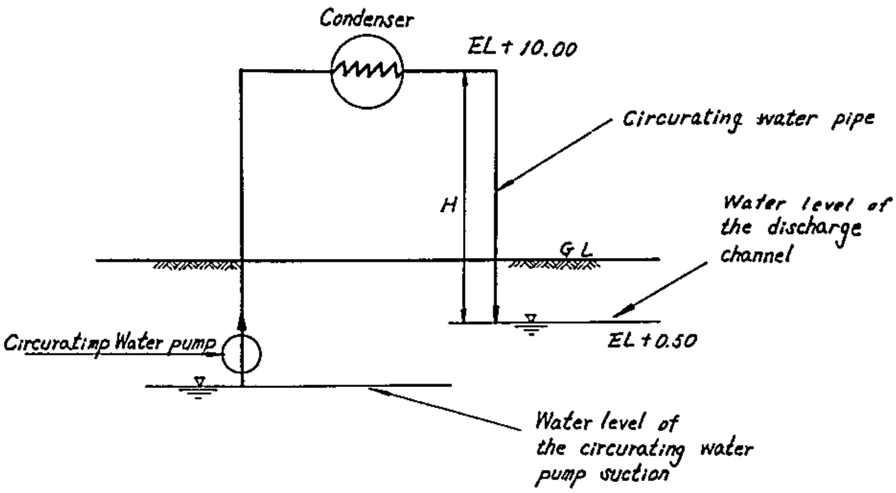
Refer to Fig. 5·2·4

Here, P : Actual siphon effect head (m)

H : Head difference between center level of the condenser and water level at connection point to the discharge channel.

ΔH : Head loss of the circulating water pipe between condenser outlet and the connection point to the discharge channel (m)

Fig. 5.2.4 Conceptual View of Water Level of Discharge Channel



An example of calculation is shown as in the following.

(i) P = EL - 8.0 m

(ii) Condenser top height EL + 10 m

(iii) L. L. W. L. EL ± 0

(iv) Head loss between discharge point of channel and the connection point to the circulating water channel 0.5 m

(v) The water level at the connection point of the circulating water pipe and discharge channel EL + 0.5 m

(vi) H = EL + 2.0 m

Formula (5·2·1) will be calcurated as follow.

$$-H + \Delta H = -(10.0 - 0.50) + 2.0 = -7.5 \text{ m}$$

Since the result of calculation of overall loss is less than 8.0m. The siphon effect will be kept.

ii. Determination of cross section

The calculation of the cross section shall be done same as in take channel.

The most economical design water velocity will be about 2.0m/sec. judging from our experience.

Area of discharge channel = $\frac{6.5}{2} = 1.8^2 m^2$

Taking account of the maintenance work, the standard section of the discharge channel shall be determined as Fig. 5·2·5 for culvert channel and Fig. 5·2·6 for the open channel.

Fig. 5.2.5 · Standard Section of Discharge Culvert Channel

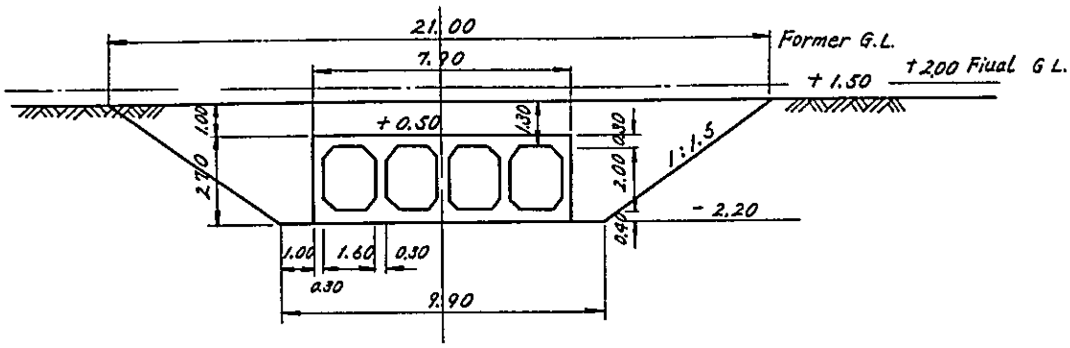
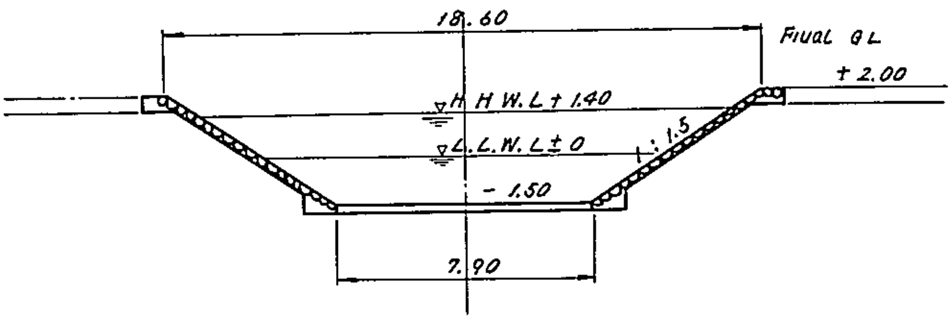


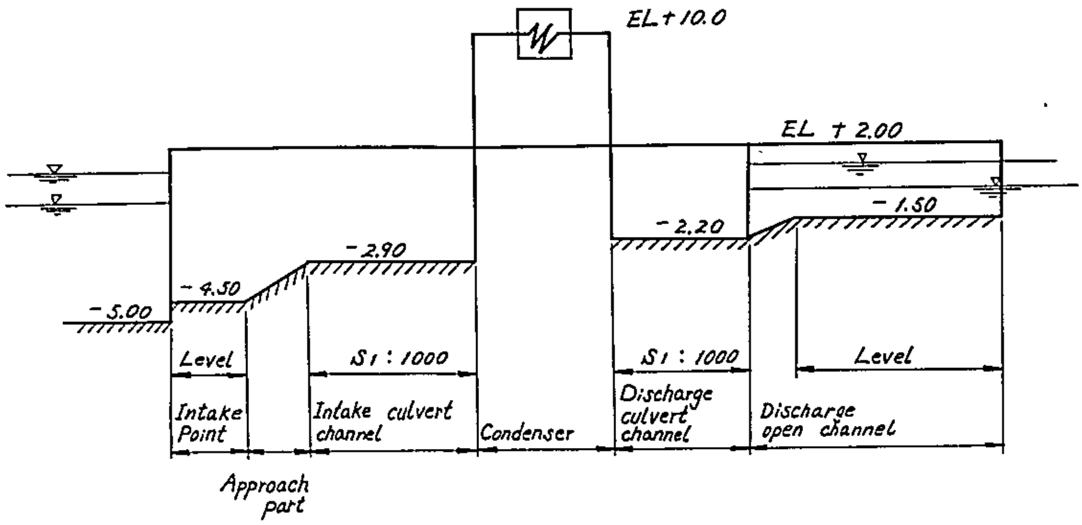
Fig. 5.2.6 Standard Section of Discharge Open Channel



e. The section between intake and discharge point

The drawing of the section between intake and discharge point shall be show in Fig. 5·2·7. The protection facility for the invading wave to discharge channel is not taken into account because the wave is small.

Fig. 5·2·7 Section of Intake and Discharge Facilities



(2) Fuel delivery method and number of fuel storage tanks

a. Fuel consumption

Design gross thermal efficiency	39.2 %
Annual average availability factor	70 %
Calorific value of residual oil	9900 Kcal/Kl
Correction factor of design thermal efficiency against availability factor	0.96

Annual fuel consumption

$$Fc = \frac{8760 \times 175 \times 10^3 \times 0.7 \times 860}{0.392 \times 0.96} = 263,000 \text{ Kl/Year-unit}$$

Max. daily fuel consumption

$$Fc_D = \frac{24 \times 175 \times 10^3 \times 860}{0.392} = 922 \text{ Kl/Day-unit}$$

b. Fuel oil berth

(a) Required fuel oil quantity to be unloaded

For 700 MW power station, having 4 units of 175 MW, required annual fuel oil quantity to be unloaded is;

$$FL = 263,000 \text{ Kl} \times 4 \text{ units} = 1050 \times 10^3 \text{ Kl/Year}$$

(b) Frequency of ship's arrival

5000 DWT class ship is most frequently used after the investigation.

$$\text{Average frequency of ship's arrival} = \frac{1,050 \times 10^{3} \times 0.96}{5,000} = 250$$

Specific gravity of heavy oil is assumed to be 0.96 Kg/l

Availability factor of harbor is 90%/Year after investigation.

$$\text{Unloading Interval} = \frac{365 \times 0.9}{250} = 1.3 \text{ Day/once}$$

Therefore, even after the consideration of availability factor of harbor, unloading becomes necessary only twice in three days and one pier for unloading is enough.

Note:

Specification of mooring facilities

5,000 DWT pier	1 set
Required depth	7.5 m
Length of berth	124 m

c. Storage capacity

Storage capacity of the power station shall be 45 Days.

$$\text{Storage quantity for 45 days} = 1,050 \times 10^{3} \times \frac{45}{365} \doteqdot 130,000 \text{ Kl}$$

If a tank capacity is 30,000 Kl and the effective storage percentage of the tank is 80%,

Number of storage tanks are ;

$$= \frac{130,000}{0.8 \times 30,000} \doteqdot 6$$

Note:

Specification of 30,000 Kl tank

Inside diameter 48.4 m ($\doteqdot$ 49 m)

Effective height 16.7 m ($\doteqdot$ 17 m)

(3) Fresh water for power station use including boiler water

a. House service water

Required daily fresh water quantity for station use when the final unit is in operation

Qw = 175 MW x 4 x 2.5 T/MW-Day

= 1750 T/Day

b. Outline planning of raw water equipment

As city water is available, it will be used as in the Fig. 5·2·8

(a) Raw water tank

Total tank capacity of raw water after four units come into commercial operation

= 1750 T/Day x 3 days storage

= 5250 T

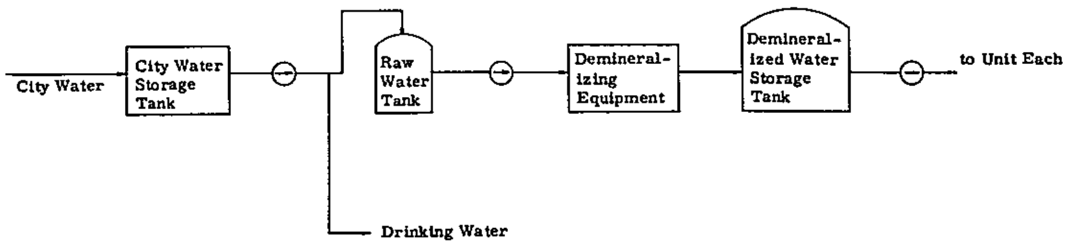
Number of tanks 1000 T x 6 tanks

(b) Demineralized water tank

Total tank capacity of demineralized water

Number of tanks 500 T x 3 tanks

Fig. 5·2·8 Fresh Water Flow Diagram for Station Use



(4) Design of foundation work for main building

a. Soil condition

(a) The result of sounding test shall show the N value of 40 at 20 m depth from the ground surface.

(b) Result of loading test by test piling shows.

Ultimate bearing capacity 450 Ton

Yield strength 370 Ton

b. Static weight

Floor space including boiler mat 2,733 m^2

Static weight including mat 14.5 t/m^2

Total load = 2,733 x 14.5 40,000 ton

c. Selection of foundation work method

Comparing the construction cost per ton of bearing power of ground using the tables for foundation work of the building, economically speaking, small cason method (1,200 Yen/T) and steel pile method (1,320 Yen/T) are preferable. But, this site has no sand and gravel layer and steel pile method requires less construction period, therefore steel pile foundation work method shall be adopted.

d. Long time allowable bearing power of ground

Long time allowable bearing power of ground shall be estimated from the result of testing pile load test to the smaller value of either one third of ultimate bearing capacity or half of yielding load.

Hence

$$Ra = 450 \times \frac{1}{3} = 150 \text{ Ton}$$

$$Ra = 370 \times \frac{1}{2} = 185 \text{ Ton}$$

For reference, this value shall be checked by Meyerhoff's Formula.

$$Ra = \frac{1}{3} (40.N.Ap + \bar{N}.L.\frac{1}{5} \phi)$$

Here

N : N value at the tip of pile

Ap : Cross section area at the tip of pile 0.334 m^2

$\bar{N}$: Average N value at circumferential length of pile

L : Length of pile

ϕ : Circumferential length of pile

If the circumferential friction in the sand be neglected ;

$$Ra = \frac{1}{3} \times 40 \times 40 \times 0.334 = 183 \text{ Ton}$$

Bearing capacity of steel pile section (A = 207 cm^2)

$1.6 \times 207 = 332 > 183$ Ton

Judged from above, long time allowable bearing force shall be

110 ton/one pile

e. Determination of number of piles

$40,000/110 \times 0.85 \doteqdot 430$ piles/unit

430 x 20 m x 0.165 t/m = 1,420 Ton/unit

f. Determination of first floor level of power station

Now that the ground level of power station site is planned to be +2.00m, first floor level shall be +2.20m.

(5) Environmental considerations

Stack height shall be determined from the following calculation.

a. Conditions determining stack height

(a) The maximum average ground-level concentrations value shall be regulated 0.045 ppm by sulphur oxide emission standard.

(b) Sulphur content of using fuel 2.5 %

(c) As calculation formula for the maximum average ground-level concentration value, Japanese Government determined formula shall be used.

(d) Type of stack

One stack for two 175 MW units of tower supported multiple tube stack

(e) Kinds of fuel Heavy oil

b. Calculation of stack height

(a) Calculation of flue gas discharge

Theoretical air requirement

$$Ao = \frac{22.4}{21} \left(\frac{C}{12} + \frac{H}{4} - \frac{0}{32} + \frac{S}{32} \right) = 10.78 \quad Nm^3/Kg$$

Theoretical flue gas volume

$$Go = 0.79Ao + \frac{22.4}{100} \left(\frac{C}{12} + \frac{H}{2} + \frac{S}{32} + \frac{W}{18} \right) = 11.45 \quad Nm^3/Kg$$

Actual flue gas volume

$$Q' = Go + (\lambda - 1)\,Ao = 13.28\ Nm^3/Kg$$

Flue gas discharge at boiler outlet

$$Q = Q' \times F \times \frac{1}{3600} \times \frac{273 + 15}{273} = 156\ m^3/sec.\ \text{at } 15°C\text{ - unit}$$

(on MCR base)

(b) Discharge of sulphur oxide

$$q' = 0.7 \times \frac{S}{100} \times F \times 10^3\ Nm^3/H = 0.7 \times \frac{2.5}{100} \times 40 \times 10^3$$

$$= 700\ Nm^3/H\text{-unit}$$

$$= 739\ m^3/H \text{ at } 15°C\text{-unit}$$

(c) Required stack height

Maximum average ground-level concentration value.

$$c\ max. = 0.045 = 1.72 \times \frac{q'}{He^2}$$

$$He = \sqrt{\frac{q'}{C\ max} \times 1.72} = \sqrt{1.72 \times \frac{1478}{0.045}} = 220\ m$$

Effective height

$$He = Ho + 0.65\ (Hm + Ht)$$

Maximum velocity rise

$$Hm = \frac{0.795\ \sqrt{QV}}{1 + \frac{2.58}{V}} = \frac{0.795\ \sqrt{312 \times 32.5}}{1 + \frac{2.58}{32.5}} = 23.4m$$

Note: Exit gas velocity at stack outlet at ECR 30 m/sec

Gas velocity at stack outlet at MCR 32.5 m/sec

Maximum thermal rise exit

$$Ht = 2.01 \times 10^{-3} \times Q(T-288)(2.3\log_{10} J + \frac{1}{J} - 1)$$

$$J = \frac{1}{\sqrt{QV}}\ (1460 - 296\ \frac{V}{T-288}) + 1$$

$$= \frac{1}{\sqrt{312 \times 32.5}}\ (1460 - 296\ \frac{32.5}{403 - 288}\ ) + 1 = 14.7$$

$$Ht = 2.01 \times 10^{-3} \times 312\ (403 - 288)\ (2.3\log 14.7 + \frac{1}{14.7} - 1) = 127\ m$$

Stack height

$$Ho = He - 0.65\ (\ Hm + Ht\ ) = 220 - 0.65(23.4 + 12.7) = 122m$$

Hence,

Stack height 125 m

Stack exit velocity 30 m/sec.

Stack exit temperature of flue gas 130 °C

(6) Switchyard planning

a. Planning of one line diagram

(a) Transmission line voltage: 150 KV

(b) The number of outgoing transmission lines: finally four(4) circuits

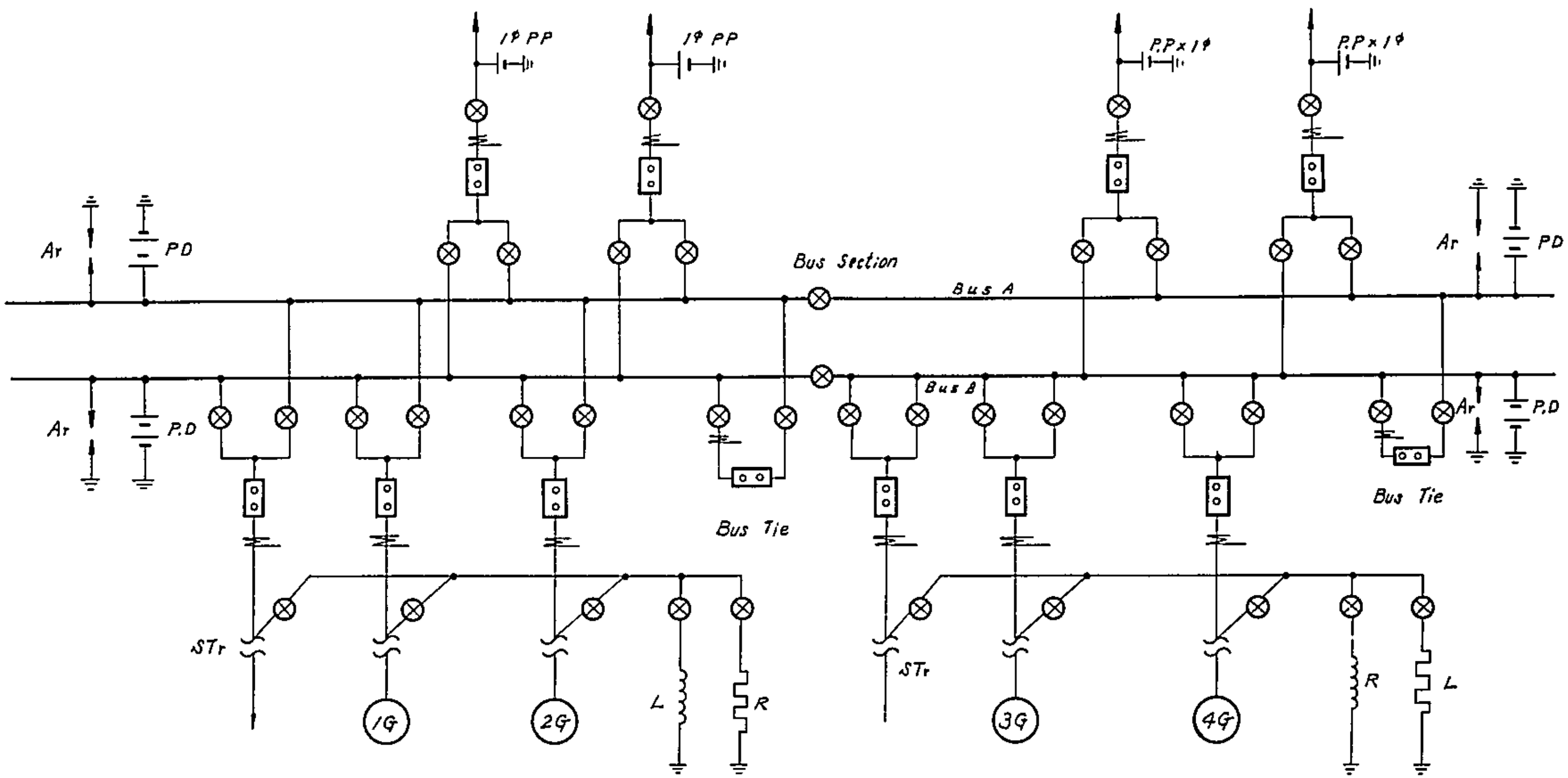
(c) Bus system of switchyard: double bus system

(d) The number of transmission lines for the unit start up supplying power : one (1) circuit for 2 units, total two circuits

(e) ·Transmission method : overhead type

Fulfilling above conditions, one line diagram shall be shown as in Fig. 5·2·9.

Fig. 5·2·9 One Line Diagram



b. Determination of switchyard scale

As the switchyard is located near the sea and the voltage is high, there is possibility for salt damage. Therefore, switchyard shall be of indoor type.

Outline arrangement and dimension of switchyard building is shown in Fig. 5·2·10.

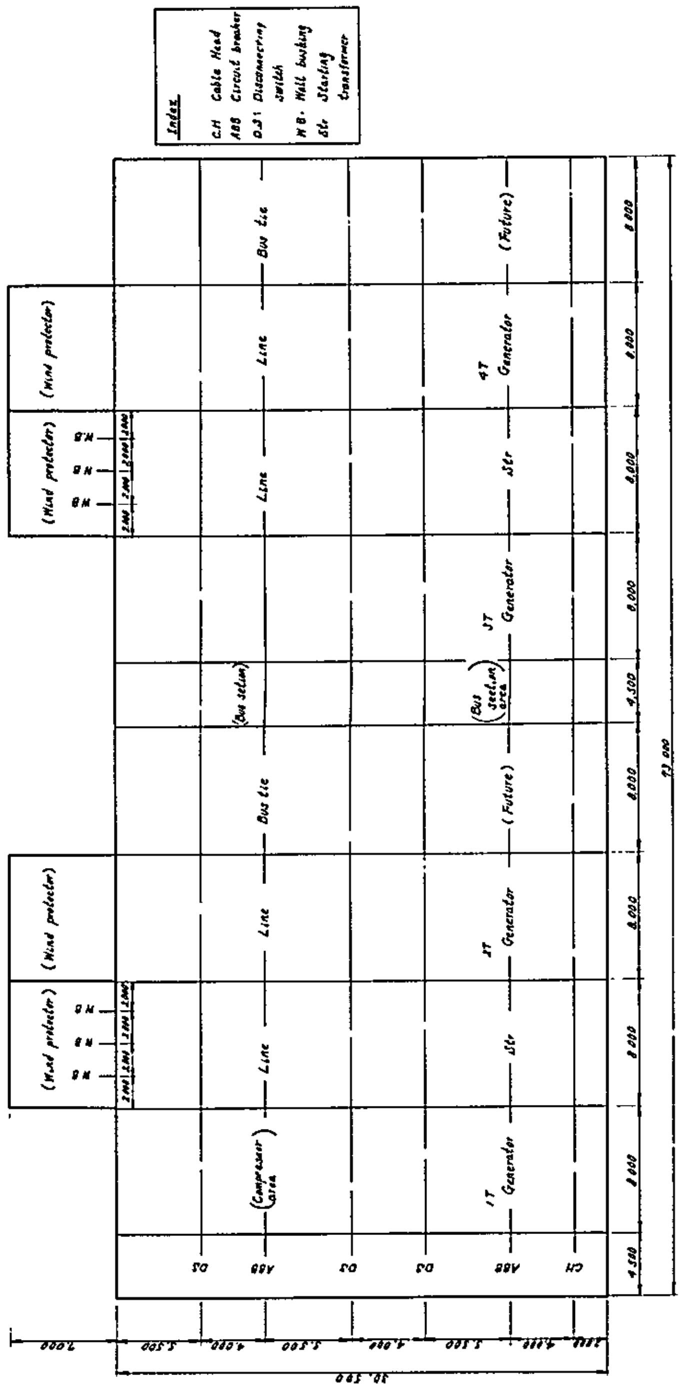
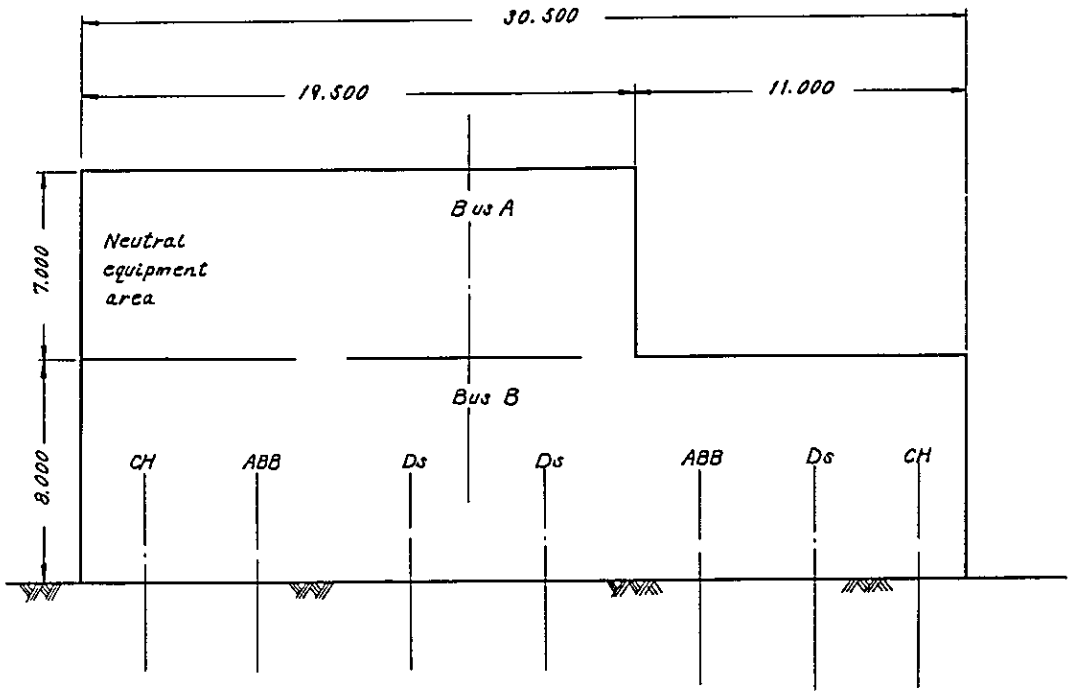


Fig. 5·2·10-(1) Indoor Switchyard with Over Head Outgoing Transmission Line

Fig. 5·2·10-(2) Sectional View of Indoor Switchyard



(7) Ground level

a. Analysis of tide measurements

Monthly average of max. and min. tidal level during these past ten years is shown in the following Table 5・2・2.

5・2・2 Tidal Level

	Max. Tidal Level (H. H. W. L.)	Min. Tidal level (L. L. W. L.)
January	+1.30	+0.10
February	+1.30	+0.10
March	+1.30	+0.10
April	+1.40	± 0
May	+1.40	+0.10
June	+1.40	+0.10
July	+1.40	+0.10
August	+1.30	± 0
September	+1.30	± 0
October	+1.30	+0.10
November	+1.30	+0.10
December	+1.40	± 0
Average	+1.34	+0.06

H. H. W. L. = 1.40   L. L. W. L. = ± 0
H. W. L. = 1.34   L. W. L. = 0.06

b. Determination of design tidal level

There are following three methods for determining the above tidal level.

(1) H. W. L. + Maximum tidal level deviation in the past year

(2) H. H. W. L. + Surplus

(3) H. W. L. + Tidal level difference by model typhoon

As there is no typhoon and no accumulation of data for the tidal level in Indonesia, Method (2) shall be used for an example.

Design High Water Level = 1.40 + 0.3 = + 1.75

Design Low Water Level = L. W. L. = + 0.06

c. Determination of ground level of the power station site

As the power station site shall in no case be covered with the water, the ground level must be higher than design tidal level.

Let surplus be 0.30 m,

G.L. = (+1.70) + (0.30) = +2.00

If the former ground level is +1.50m, 0.5m land raising shall be necessary.

(8) Delivery of construction materials

a. Dimension and weight of materials in transit

Heavy and large materials in transit for a standard unit of 175 MW are shown Table 5·2·3.

Table 5·2·3 Dimension and Weight for 175 MW unit

Names of Material	Weight in Ton	Dimension in Meter (Length x Width x Height)
Boiler Drum	150	18.4 x 2.5 x 2.5
LP Turbine Lower Casing	50	7.4 x 5.1 x 2.0
Generator Stator	180	7.1 x 4.0 x 4.0
Main Transformer	200	7.0 x 3.0 x 6.8

b. Delivery method

As the site is located inside of the bay and the sea depth is front of the site is 5m, sea transportation can be considered mainly.

The unloading space shall be the following scale.

(a) Berth capacity 1000 ton ship

(b) Unloading space 40 m x 20 m

The berth is of upright revetment construction type.

(9) Plot plan

Based upon the conceptual design finished, a plot plan shall be made.

a. Dike capacity of oil tanks

Each tank shall have its own dike.

Dike capacity = 0.5 x 30,000 kl = 15,000 kl

If the dike height is 1.5 m, dike area is;

$$\frac{15,000}{1.5} = 10,000 \text{ m}^2$$

b. Tank arrangement

(a) Distance between tank and other structures

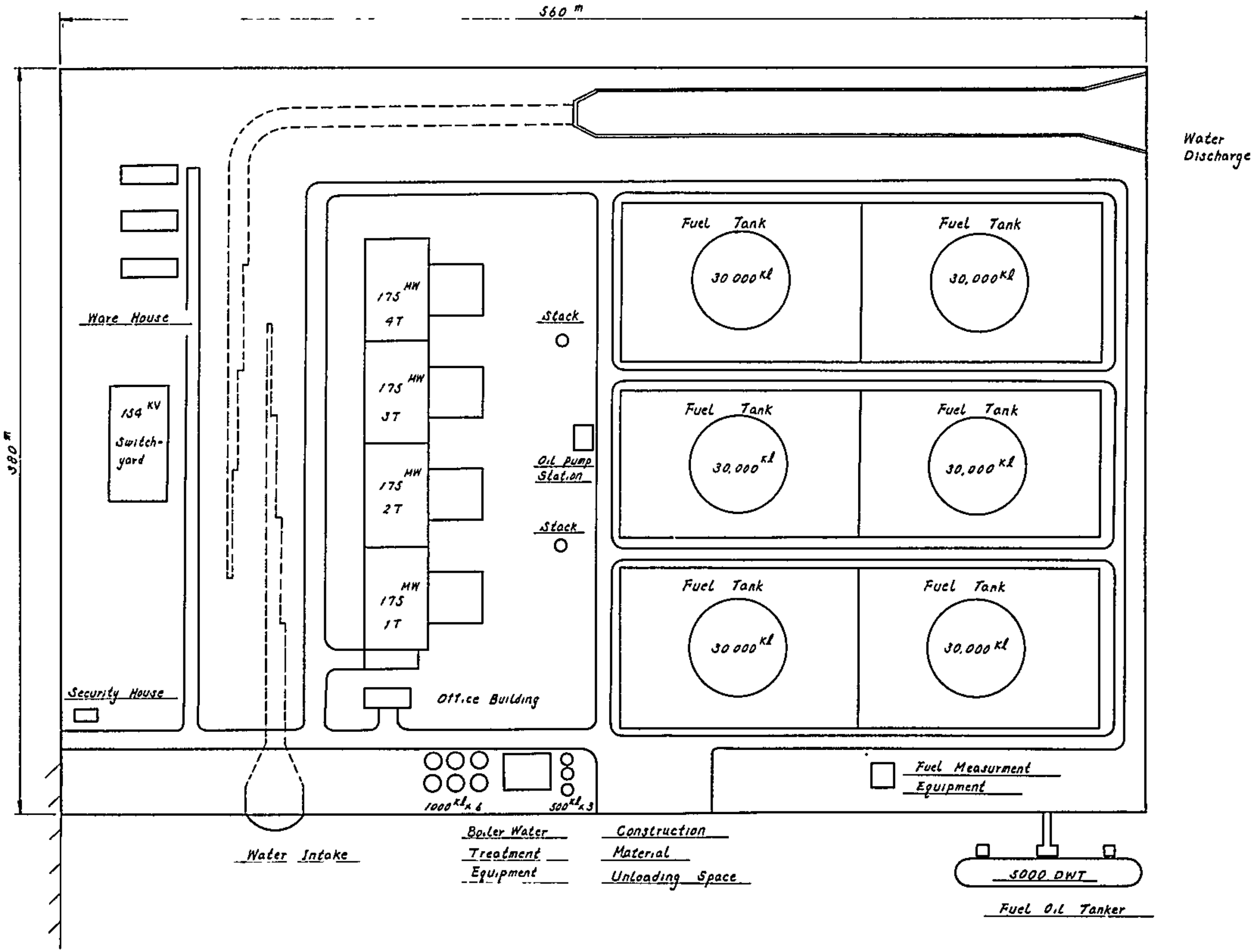
As tank capacity is 30,000kl, there must be a distance of tank diamiter ie. 49m between the tank and other structures.

(b) Distance between tanks shall not be less than one third of the tank diameter, ie. 16.5m

c. Plot plan

Refer to the attached drawing. Fig. 5·2·11

Fig. 5·2·11 Plot Plan 175MW x 4 Units



(10) Survey cost

a. Boring location

Refer to Fig. 5.2.12 for the location of boring test

Boring	160 points
Sounding	4,266 points
Testing	640 points
Soil sampling	640 point

b. Other items of survey

Following items of survey shall be performed as in the case of 5-1 Example of Calculating Survey Cost in this volume.

(i) Purchase of Maps, Aerial Photo, topographical surveying

(ii) Water Analysis including one sample of a deep well

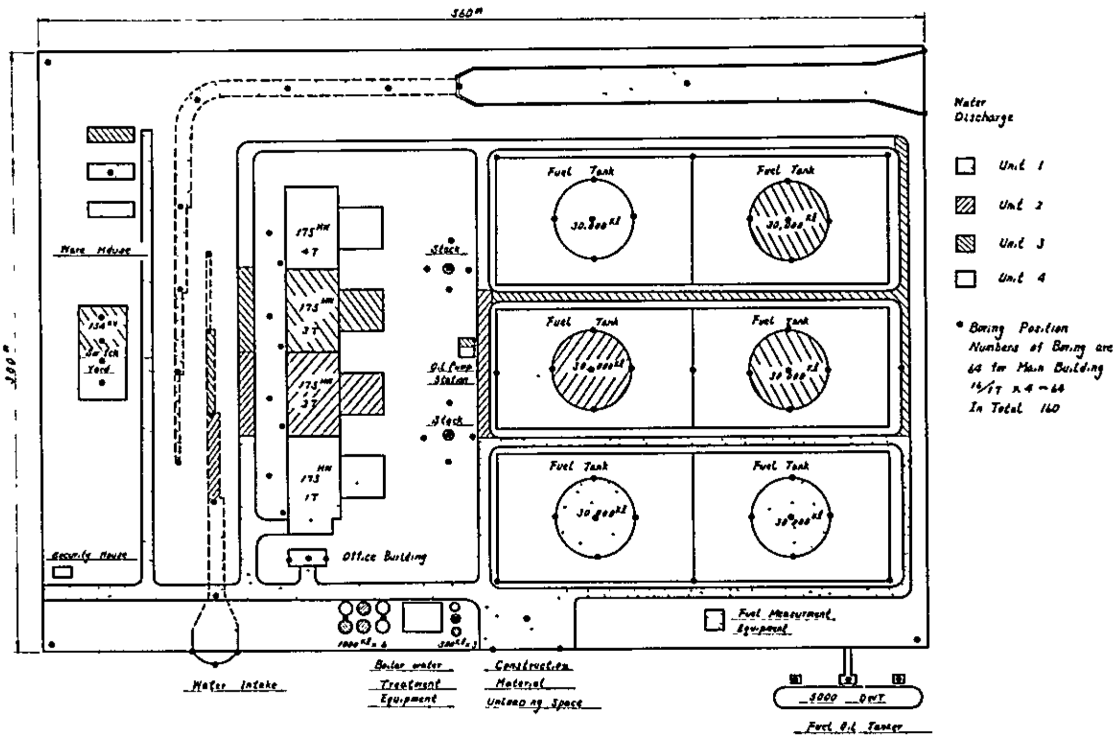
(iii) Climatic Survey

(iv) Marine Survey

(v) Existing Pollution Survey

(vi) Wind Tunnel Test

Fig. 5·2·12 Equipment in Each Unit



5-2-3 Rough Estimation of Construction Cost

Based upon the above result of conceptual design, construction cost shall be roughly estimated.

Equipments in each unit shall be shown in the attached drawing Fig. 5·2·12.

This estimation of construction cost is performed in Japanese cost basis.

For detail refer to the attached Table 5·2·3.

Table 5·2·3 Construction Cost in Rough Estimation for 175 MW x 4 Units

(Unit in Million Yen)

Item \ Unit No.	1T	2T	3T	4T	Total
Land & Compensation	2,530	0	200	0	2,730
Civil Eng. Works	1,100	80	100	80	1,350
Architectual Works	2,500	930	1,620	940	5,990
Mechanical Works	6,090	5,520	5,700	5,470	22,780
Electrical Works	860	500	660	490	2,510
Furniture & Apparatus	50	20	20	20	110
Office Operation	250	150	150	150	700
Contingency	150	100	100	100	450
Sub Total	13,530	7,300	8,550	7,250	36,620
Interest during Construction	680	370	430	360	1,840
Miscellaneous Allotment	120	80	90	80	370
Turn round to other unit	△60	△50	△40	△20	△170
Total	14,270	11,300	9,030	7,670	42,270

60,400 Yen/Kw

Item \ Unit No. / Specification		1T			2T			3T			4T			Remarks
		Q'ty	Unit Price	Total Price	Q'ty	Unit Price	Total Price	Q'ty	Unit Price	Total Price	Q'ty	Unit Price	Total Price	
[Land & Compensation]				2,530			0			200			0	
1) Purchase Land for Site		215,000 m^2					0			0			0	Including in conpensation for the area land
2) Purchase Land for Residence		20,000 m^2					0	10,000 m^2		200			0	
[Civil Eng. Works]				1,093			80			95			79	
1) Bank Rivetment				570			0			0			0	
a) Circumference of site	Sheet pile type	840 m												
b) Unloading space	1000 DWT													
c) Wharf for oil Fuel Oil Berth	5000 DWT													
2) Water Channel				302			43			41			37	
a) Intake Place														
b) Intake channel														
c) Discharge channel														
Culvert channel														
Open channel														
d) Discharge place														
e) Cooling Pipe & Foundation														
f) Cooling Pump & station														
g) Misc. works														

Item	Specification (Unit No.)	1T Q'ty	1T Unit Price	1T Total Price	2T Q'ty	2T Unit Price	2T Total Price	3T Q'ty	3T Unit Price	3T Total Price	4T Q'ty	4T Unit Price	4T Total Price	Remarks
3) Road				39			4			10			16	
a) Road in the site b) Access Road 4) Levelling				23			7			6			4	
5) Foundation of Tanks				36			17			31			17	
a) Oil Tank Foundation b) Oil Tank Dike c) Misc. Tanks 6) Investigation & measurements				100			3			3			2	
7) Deep Well				6			0			0			0	
8) Temporary Facilities				17			6			4			3	
a) Temporary Road b) Temporary Sewerage [Architectual Works]				2493.4			922.2			1615.4			931.2	
1) Main Building				843			765			843			765	
a) Foundation	Steel pile length 20m	Mad area 2,770 m^2			2500 m^2			Same as 1T			Same as 2T			
b) Turbine Room Steel Structure		1300 ton			1170 ton			Same as 1T			Same as 2T			Boiler Structure Steel and it's Erection is not included

Item	Specification	1T Q'ty	1T Unit Price	1T Total Price	2T Q'ty	2T Unit Price	2T Total Price	3T Q'ty	3T Unit Price	3T Total Price	4T Q'ty	4T Unit Price	4T Total Price	Remarks
c) Steel Structure Erection		1,300 ton			1,170 m^2			Same as 1T			Same as 2T			
d) Upper Finishing Works		51,440 m^3			46,300 m^3			Same as 1T			Same as 2T			Mechanical Equipment Foundation is included in this item.
e) Foundation of Outdoor Equipment														
2) Misc. Buildings				1,049.4			151.2			283.4			151.2	
a) Company's Residence		4 appartment houses ($24x60m^2$)			1 appartment house			1 appartment house			1 appartment house			
b) Indoor Switchyard Building		1,390 m^3						1,390 m^3						
c) Water Treatment House		4,550 m^3												
d) H_2 Vessel Storage House		$12m^2$												
e) Oil Pump House		$90m^2$						90 m^2						
f) Office Building		$2670m^2$												
g) Guardman Shack		$40m^2$												
h) Ware House		$330m^2$ x 2						$330m^2$ x 1						
i) Misc. Works														
3) Stack				480			0			480			0	
	Stack Height 125m Steel Structure Supporting Type 1 Stack for Two Units													

Item / Specification (Unit No.)		1T			2T			3T			4T			Remarks
Item	Specification	Q'ty	Unit Price	Total Price	Q'ty	Unit Price	Total Price	Q'ty	Unit Price	Total Price	Q'ty	Unit Price	Total Price	
a) Foundation		3,200 m^3						3,200 m^3						
b) Stack	Steel	1,030 ton						Same as 1T						
4) Temperary Facilities				91			0			0			0	
a) Construction Office		1500m^2												
b) Ware House		2 x 330 m^2												
5) Tree Planting	20,000m^2	10,000 m^2		30			6			9			15	
Mechanical Works				6,081						5,698			5,462	
1) Main Equipments				5,000			5,000			5,000			5,000	
a) Boiler	198kg/cm^2 571/543°C MCR 590T/H	1												Including Accessaries and Auxiliaries such as AH, BFP, etc.
b) Turbine-Generator	Turbine 175MW 169kg/cm^2 566/538 Generator 224 MVA Pf=0.85 SCR=0.64	1												Including Accessaries such as Condencer, House Transformer, Switchgears, Pumps etc.
2) Tanks				364			194			332			172	
a) Fuel Oil Tanks	30,000 kl	2			1			2			1			
b) Raw Water Tanks	10,000 kl	2			2			1			1			
c) Demineralized Water Tanks	5,000 kl	2			0			1			0			

Item	Specification (Unit No.)	1T Q'ty	1T Unit Price	1T Total Price	2T Q'ty	2T Unit Price	2T Total Price	3T Q'ty	3T Unit Price	3T Total Price	4T Q'ty	4T Unit Price	4T Total Price	Remarks
3) Misc. Facilities				621			266			272			232	
a) Dust Collector	E. P. 552,000 Nm3/H 2 section	1			1			1			1			
b) Water Treatment	300 T/H	2			1			1			0			
c) Oil Pumps (Transfer Pump)	Residual Oil 120 T/H	2			1			1			1			
	Light Oil 40 T/H	2			0			0			0			
d) Oil Flowmeter	1000 T/H	2			1			0			0			
	100 T/H	2			1			0			0			
e) Oil Unloading Facilities	300 ϕ	2			0			0			0			
f) Fire Extinguishing Equipment	400 T/H Diesel-Moter Driven Pump	1			0			0			0			
g) Waste Water Treatment					0			0			0			
h) Over Head Crane	120/30 Ton	2			0			0			0			
i) Station Boiler	6T/H 10kg/cm^2	1			0			0			0			
j) Emergency Diesel Generator	400 kw	1			0			0			0			
k) Misc. Facilities														Including Station Air Compressor etc.

Item	Specification	1T Q'ty	1T Unit Price	1T Total Price	2T Q'ty	2T Unit Price	2T Total Price	3T Q'ty	3T Unit Price	3T Total Price	4T Q'ty	4T Unit Price	4T Total Price	Remarks
4) Misc. Works				76			38			74			38	
a) Raw Water Piping	Trank line 6" ϕ	0.5 km			0			0			0			
b) Water Piping	Trank line 6" ϕ	0.5 km			0.1 km			0.1 km			0.1km			
c) Fuel Oil Piping	Trank line 12" ϕ	1 km			0.5 km			1 km			0.5 km			
d) Fire Extinguishing Piping	Trank line 6" ϕ	2.0 km			0.5 km			0.7 km			0.5 km			
e) Misc. Works														
5) Temporary Facility				20			20			20			20	
a) Raw Water Piping														
[Electrical Works]				860.1			495.4			655.9			482.4	
1) Transformers				248			207			248			207	
a) Main Trans	210MVA 11.7kv/150kv OF.AF.TYPE	1			1			1			1			Including Installation Fee
b) Start up Trans	15MVA 150/4.16kv ON.AN.TYPE	1			0			1			0			
2) Other Equipments				352.1			168.4			234.9			171.4	
a) Circuit Breaker	168kv 750MVA 2000A ABB	5			1			5			1			
b). Disconnecting Switch	3ϕ 154 kv 20 2000A	16			0			14			0			
	1ϕ 154kv/$\sqrt{3}$ 200A	3			0			3			0			

Item	Unit No. / Specification	1T Q'ty	1T Unit Price	1T Total Price	2T Q'ty	2T Unit Price	2T Total Price	3T Q'ty	3T Unit Price	3T Total Price	4T Q'ty	4T Unit Price	4T Total Price	Remarks
c) Potential Transformer	3ϕ 154kv/$\sqrt{3}$ 110 v/$\sqrt{3}$	2 set			0			2 set			0			
	1ϕ 154kv/$\sqrt{3}$ 110 v/$\sqrt{3}$	2			0			2 set			0			
d) Lighting Arrester	130 kv	2 set			0			2 set			0			
e) Neutral Equipment	200A 154kv/$\sqrt{3}$ Resister	1 set			0			1			0			
f) Air Compressor	pry.50kg/cm^2 sec.15kg/cm^2	1 set			0			0			0			
g) Telecommunication System	200 cct. X Bar	1 set			0			0			0			
h) Paging Equipment	250W x 2 Handset 45 Speaker 47	1 set		15	1 set		15	1 set		15	1 set			Including Power Supply Equipment
i) Cable OF Cable	154kv 1ϕ800 mm^2	600 m			300 m			300 m			600 m			Including Cable Head of both side & other equipment
	154kv 3ϕ 80 mm^2	600 m			0 m			300 m			0 m			
Other Cables (Power & Control)		10,400 m			78,000 m			98,000 m			78,000 m			
j) Battery	1100 AH 106V	1 set			1 set			1 set			1 set			Including Charger
k) Receiver System for Load Dispatching System (DPI)		1 set			1 set			1 set			1 set			
l) Insulation Oil		10,000			7,000			10,000			7,000			
m) Misc. Equipment														Including Power Cubicle for Illumination, and Oil Transfer Pump, etc.

Item \ Unit No.	Specification	1T Q'ty	1T Unit Price	1T Total Price	2T Q'ty	2T Unit Price	2T Total Price	3T Q'ty	3T Unit Price	3T Total Price	4T Q'ty	4T Unit Price	4T Total Price	Remarks
3) Misc. Works				210			87			147			87	
a) Switchyard Works														Including Wiring, Installation for Equipment
b) Piping & Wiring Works														Including Wiring, Piping for Cable in Power House
c) Communication Works														
d) Electric Works of the Office Building														Including Wiring, Illumination and Equipment, etc.
e) Lighting Work in Site														Including Wire, Instrument, Wiring, Piping & Installation
f) Lighting Works in Main Building														
g) Misc. Works														
4) Temporary Facilities				50			33			26			17	
a) Sub Station Equipment for Construction	4500KVA 60KV/6.6KV													
b) Distribution line for Construction	6.6KV60mm^2	2 km			1 km			1 km			1 km			
c) Communications Equipment for construction	60 cct Poutable Type													
Furniture & Apparatus				50			20			20			20	Including Test Equipment, Car & Furniture

Item / Unit No.	Specification	1T			2T			3T			4T			Remarks
		Q'ty	Unit Price	Total Price	Q'ty	Unit Price	Total Price	Q'ty	Unit Price	Total Price	Q'ty	Unit Price	Total Price	
[Office Operation]				250			150			150			150	
[Contingency]				150			100			100			100	
[Interest during Construction]				680			370			430			360	
[Misc. Alotment]				120			80			90			80	

5-3 Example of Rough Evaluation for Selecting Unit Size

5-3-1 Thermal Power Unit Size in West-Central Jawa in Future

Concerning thermal power unit size after the completion of interconnection of power systems between West Jawa and Central Jawa in 1977, a study has been roughly done both from long and short range view over the economy of the system. It proved to be clear that the unit size after Muara Karang No. 3 unit should preferably be 150 MW class.

(1) Development pattern

Economic study has been performed roughly concerning the following nine patterns. Refer to Table 5·3·1 and Fig. 5·3·1 to Fig. 5·3·9

Table 5.3.1 Development Patterns

Pattern A

Year of Commercial Operation	Unit MW
1980 - Jan.	100
1980 - Jun.	100
1982 - Dec.	100
1983 - Mar.	100
1983 - Jul.	100
1983 - Dec.	100
1984 - Apr.	100
1984 - Jul.	100
1984 - Oct.	100

Pattern B

Year of Commercial Operation	Unit MW
1980 - Jan.	100
1980 - Jun.	100
1982 - Dec.	150
1983 - Mar.	150
1983 - Sep.	150
1984 - Feb.	150
1984 - Oct.	150

Pattern C

Year of Commercial Operation	Unit MW
1980 - Jan.	100
1980 - Jun.	100
1982 - Dec.	200
1983 - Mar.	200
1983 - Dec.	200
1984 - Jun.	200

Pattern D

Year of Commercial Operation	Unit MW
1980 - Jan.	100
1980 - Jun.	100
1982 - Dec.	250
1983 - Feb.	250
1984 - Jan.	250
1984 - Oct.	250

Pattern E

Year of Commercial Operation	Unit MW
1980 - Jan.	150
1980 - Jul.	150
1983 - Jan.	150
1983 - Jul.	150
1984 - Jan.	150
1984 - Jul.	150

Pattern F

Year of Commercial Operation	Unit MW
1980 - Jan.	150
1980 - Jul.	150
1983 - Jan.	200
1983 - Jul.	200
1984 - Feb.	200
1984 - Oct.	200

Pattern G

Year of Commercial Operation	Unit MW
1980 - Jan.	150
1980 - Jul.	150
1983 - Feb.	250
1983 - Jul.	250
1984 - Apr.	250

Pattern H

Year of Commercial Operation	Unit MW
1980 - Jan.	200
1980 - May	200
1983 - Feb.	200
1983 - Dec.	200
1984 - Jul.	200

Pattern I

Year of Commercial Operation	Unit MW
1980 - Jan.	200
1980 - May	200
1983 - Mar.	250
1983 - Nov.	250
1984 - Aug.	250

(2) Condition for study

a. Steam conditions and design thermal efficiency

These conditions is shown in following Table 5. 3. 2.

Table 5·3·2· Steam Conditions and Design Thermal Efficiency

Unit Size MW	Steam Conditions	Design Thermal Efficiency
100	102 kg/cm^2, 510 °C	32.6 %
150	169 kg/cm^2, 566/538 °C	39.2 %
200	169 kg/cm^2, 566/538 °C	39.5 %
250	169 kg/cm^2, 566/566 °C	40 %

b. Construction cost

Construction cost for each unit size is supposed as following.

100 MW	46,500 Yen/Kw
150 MW	42,400 Yen/Kw
200 MW	40,600 Yen/Kw
250 MW	39,900 Yen/Kw

c. Fuel cost

7.5 Rp/l (US$ = 415 Rp = 270 Yen)

d. Interest

10 %

e. Rate of equalized annual expenditure

16 %

f. Study period

Study has been made for the following periods.

a. 1980 Jan. to 1984 Oct.

b. 1980 Jan. to 1995 Jan. (For 15 years)

(3) Result of study

The total present values of the annual expenditures for the above-mentioned periods are calculated to be as follows (Table 5·3·3).

Table 5·3·3 Result of Study

Development Pattern	1980, Jan. - 1984, Oct.	1980, Jan. - 1975, Jan.
A	100 %	100 %
B	98	99
C	102	102
D	105	103
E	95	98
F	98	100
G	100	102
H	105	102
I	107	103

Fig. 5·3·1 WEST-Central Jawa

Generating Power Development Program Beyond 1977

(Pattern A)

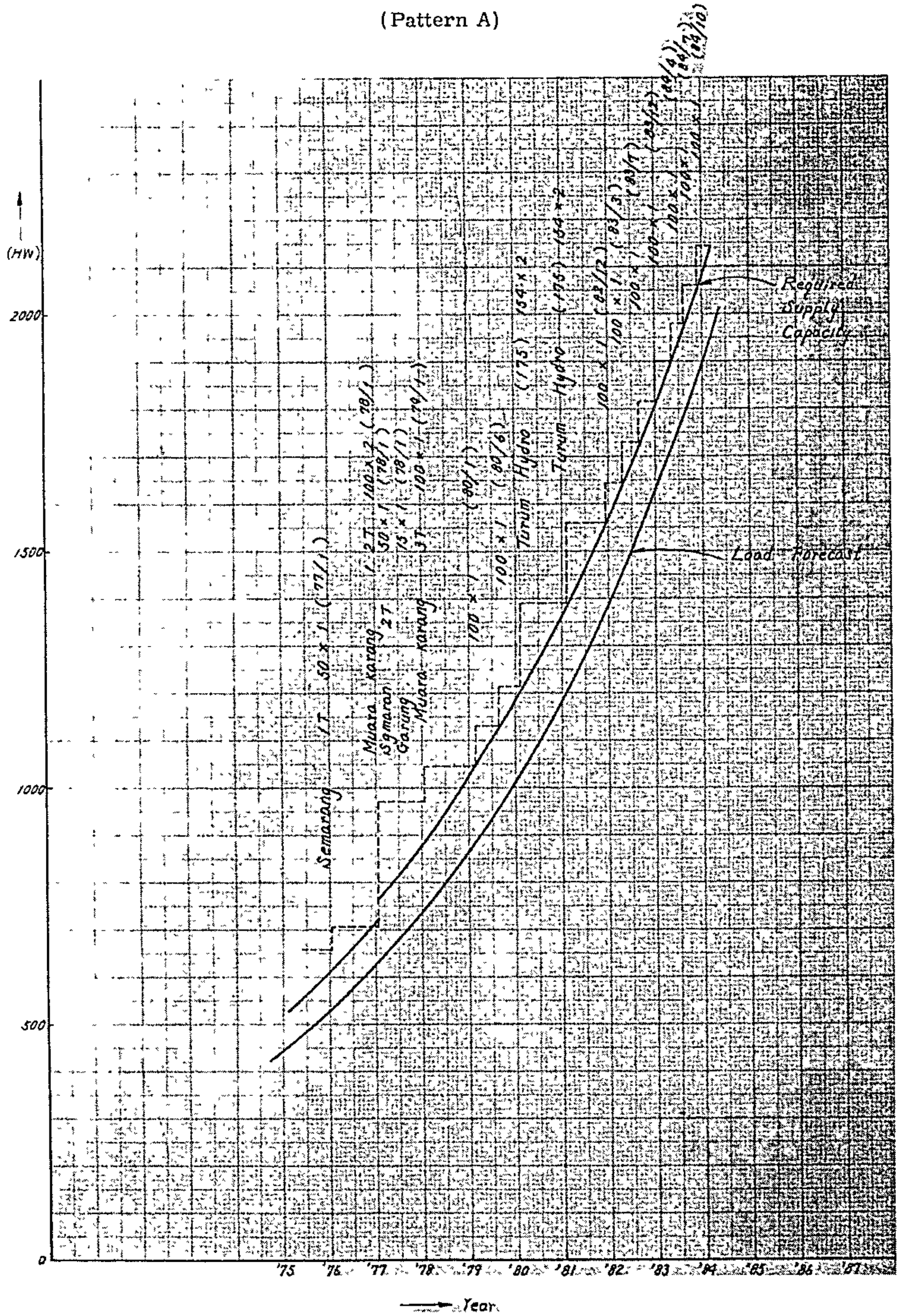


Fig. 5·3·2 West-Central Jawa

Generating Power Development Program Beyond 1977

(Pattern B)

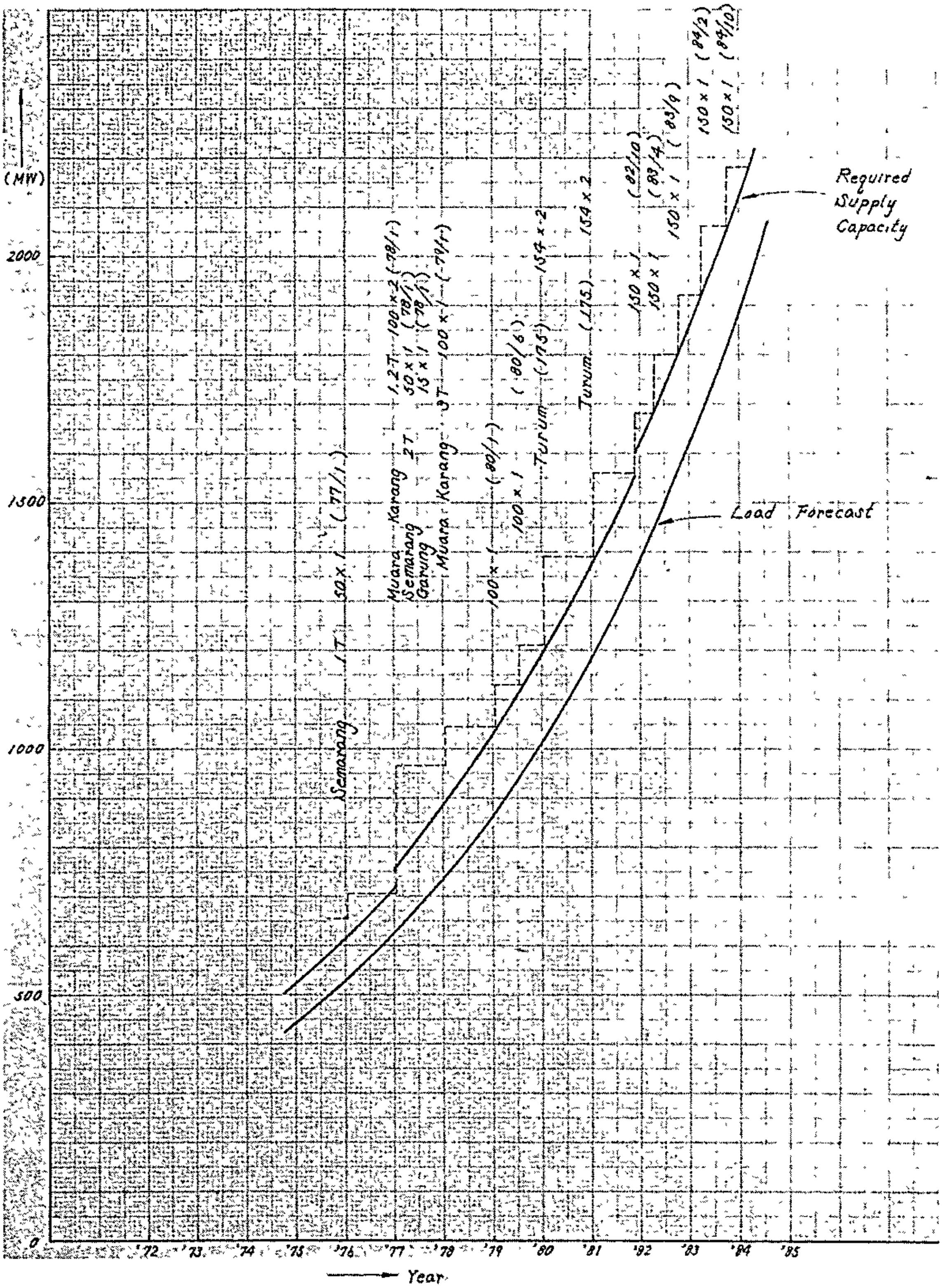


Fig. 5·3·3 West-Central Jawa

Generating Power Development Program Beyond 1977

(Pattern C)

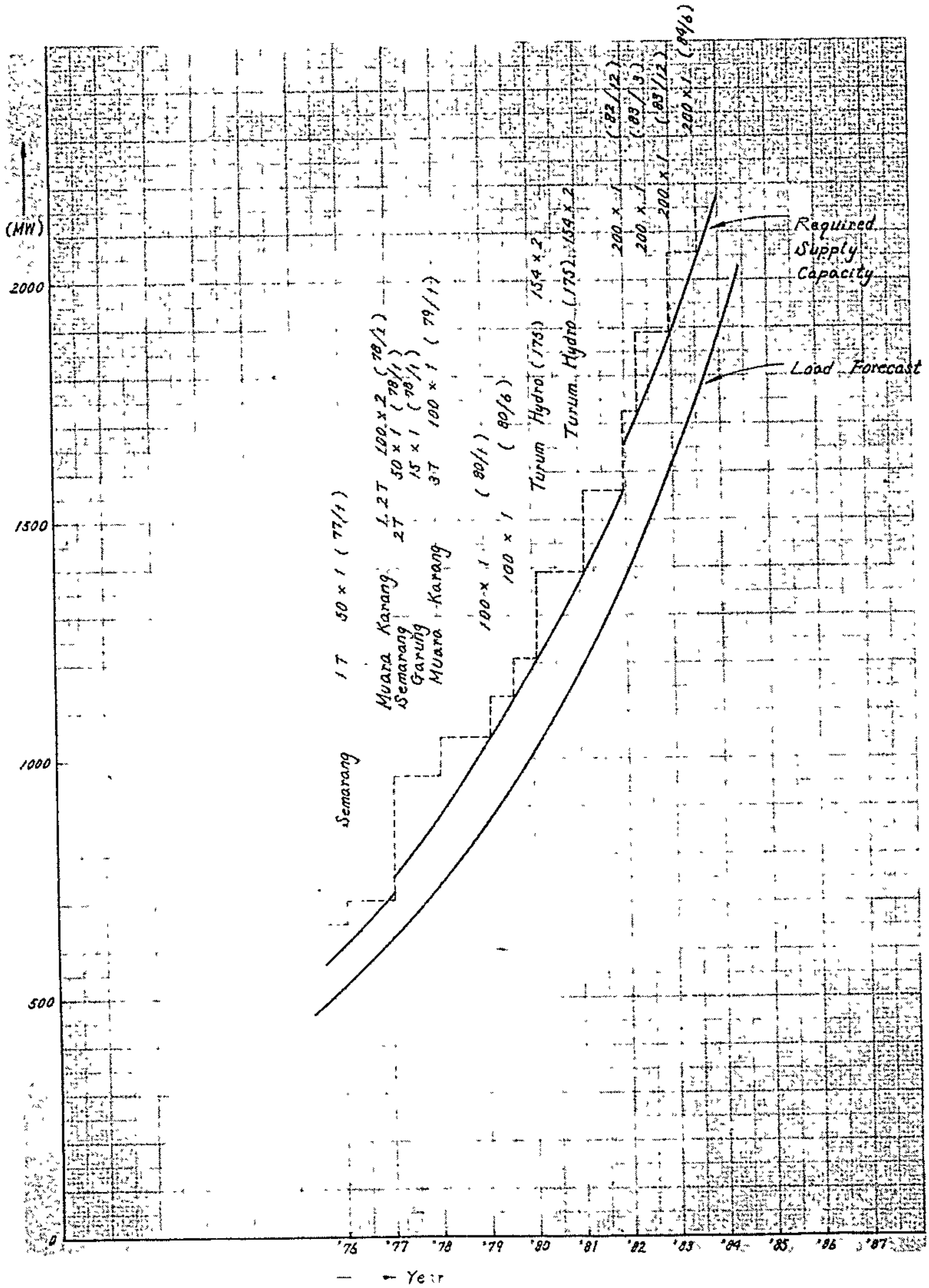


Fig. 5·3·4 West-Central Jawa

Generating Power Development Program Beyond 1977

(Pattern D)

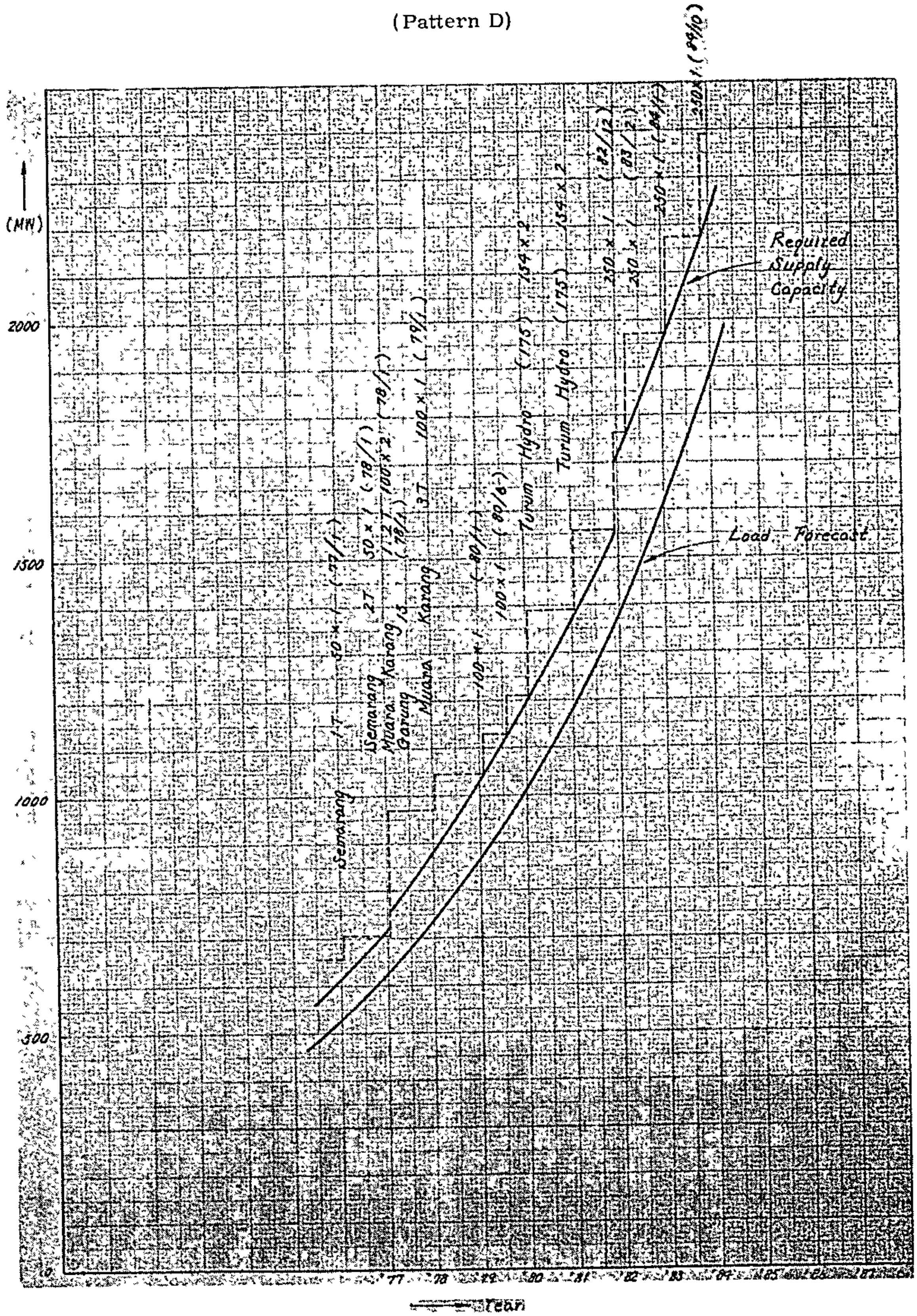


Fig. 5·3·5 West-Central Jawa
Generating Power Development Program Beyond 1977
(Pattern E)

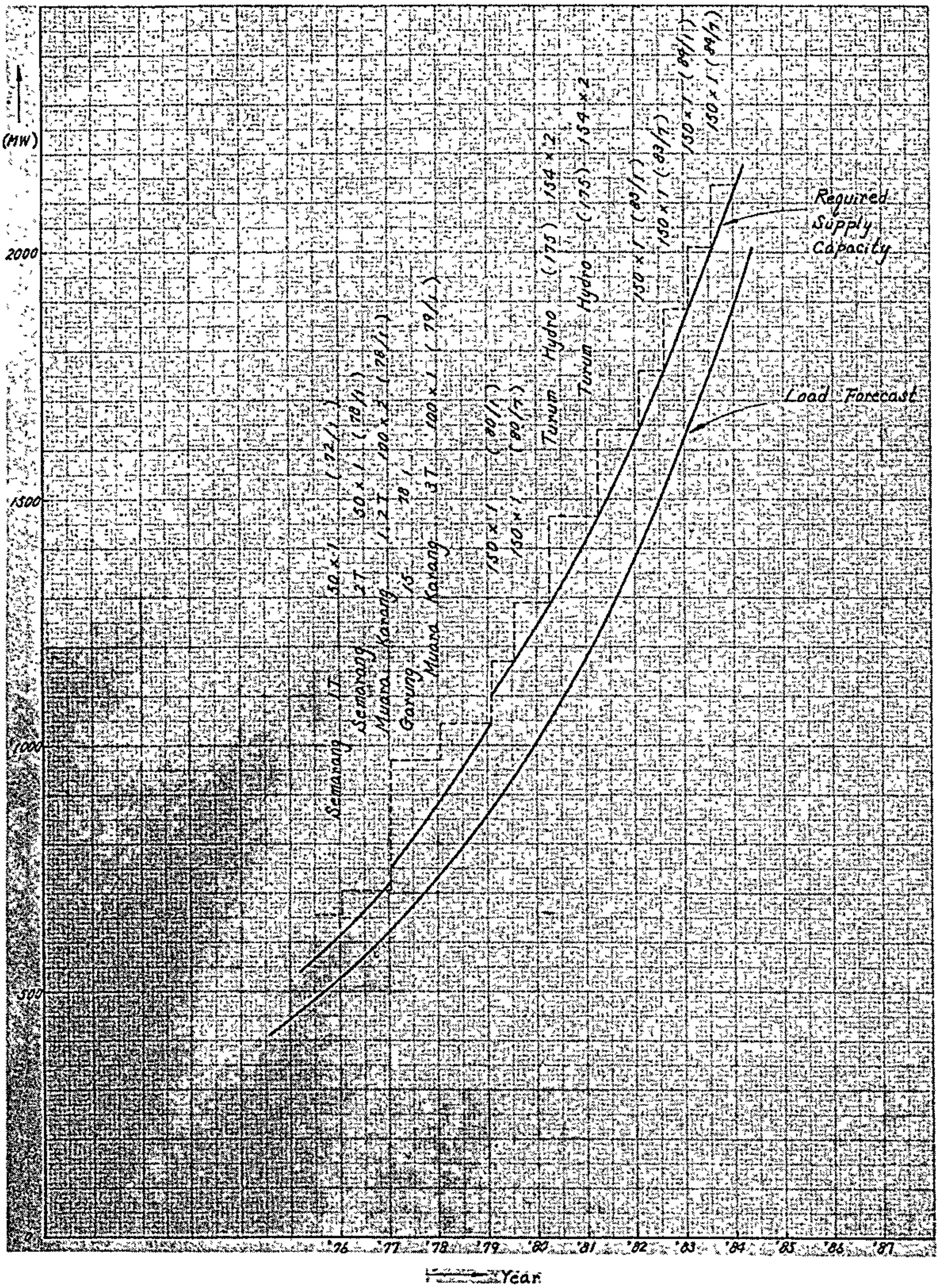


Fig. 5·3·6 West-Central Jawa

Generating Power Development Program Beyond 1977

(Pattern F)

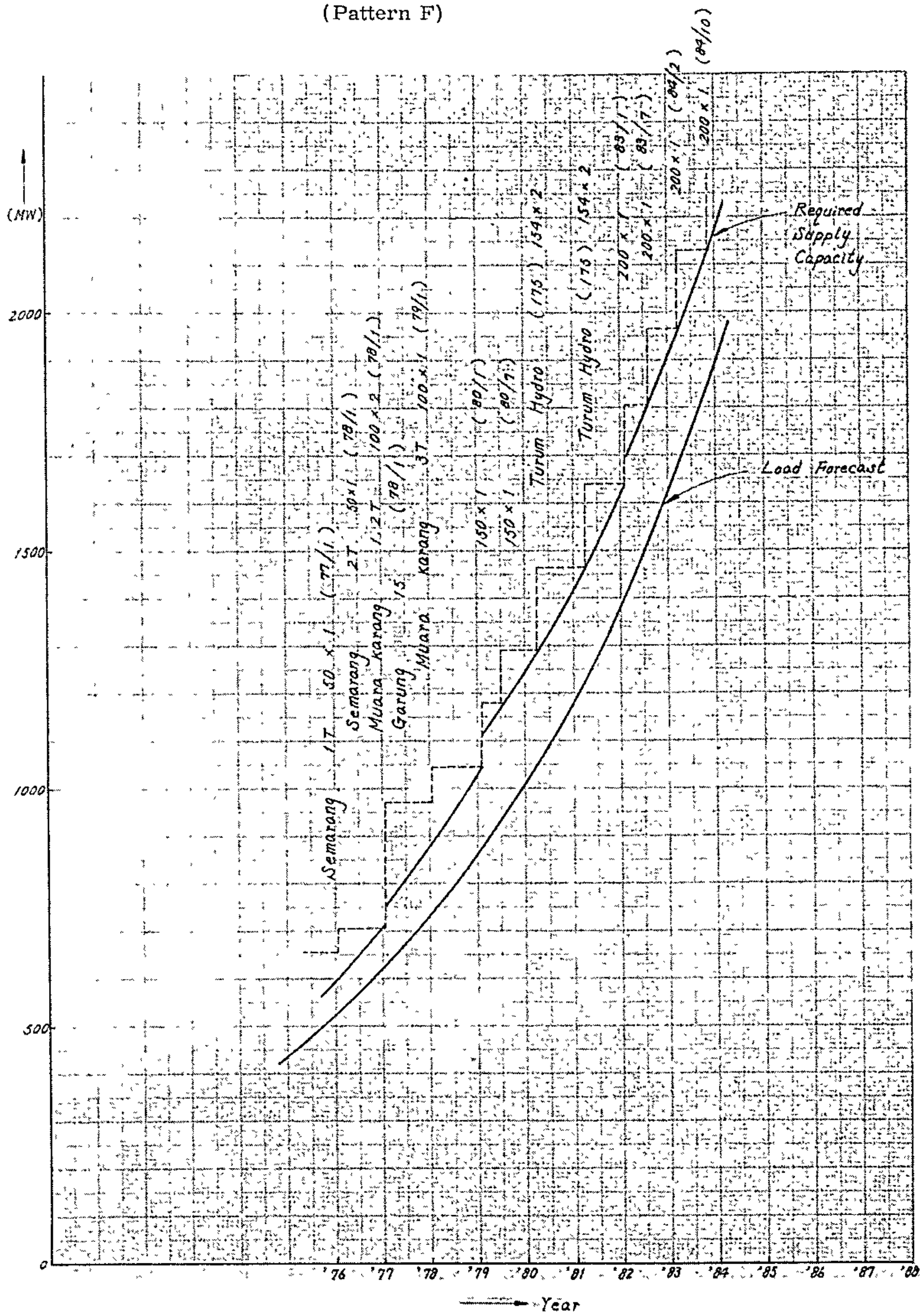


Fig. 5·3·7 West-Central Jawa

Generating Power Development Program Beyond 1977

(Pattern G)

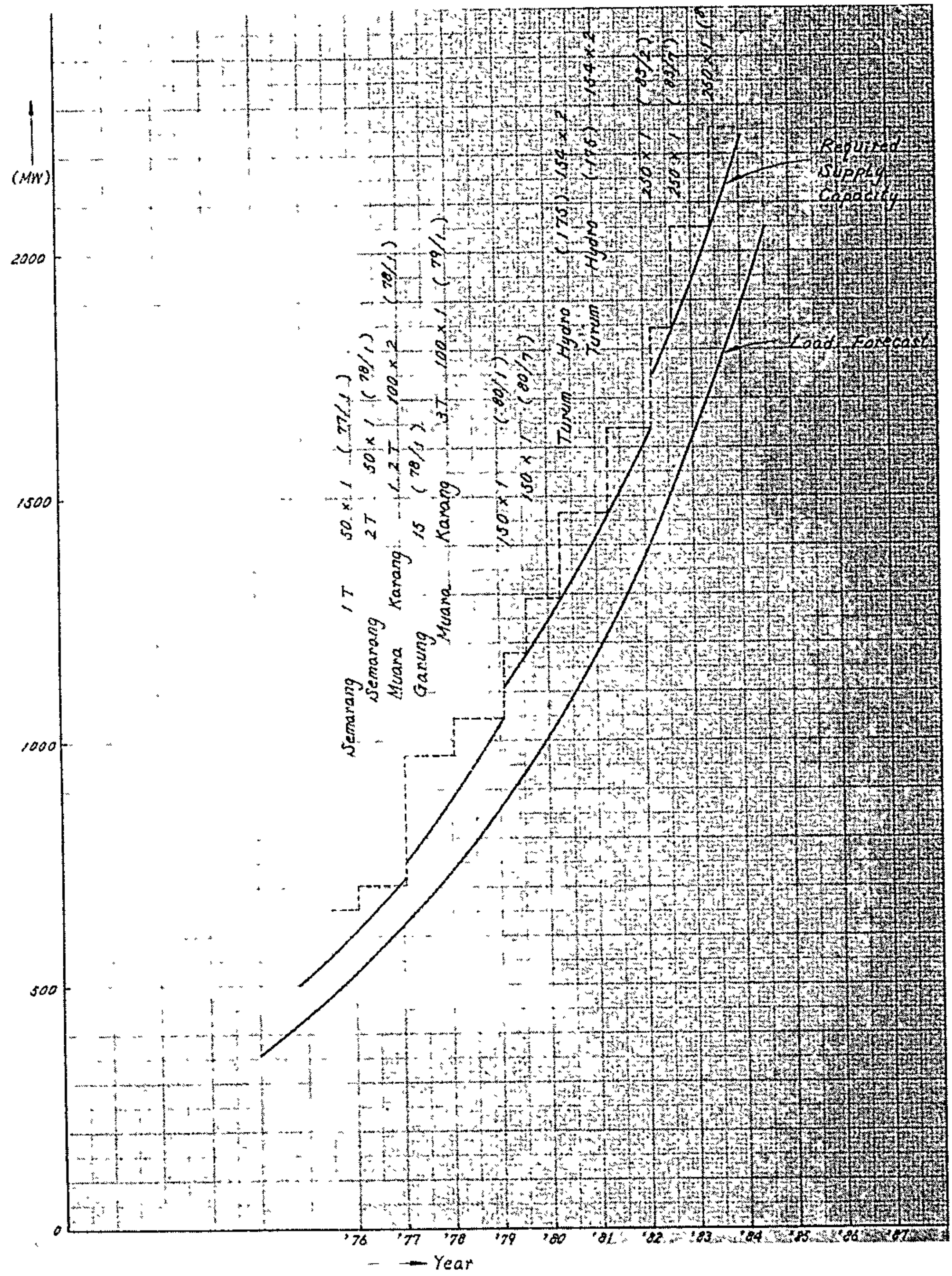


Fig. 5·3·8 West-Central Jawa

Generating Power Development Beyond 1977

(Pattern H)

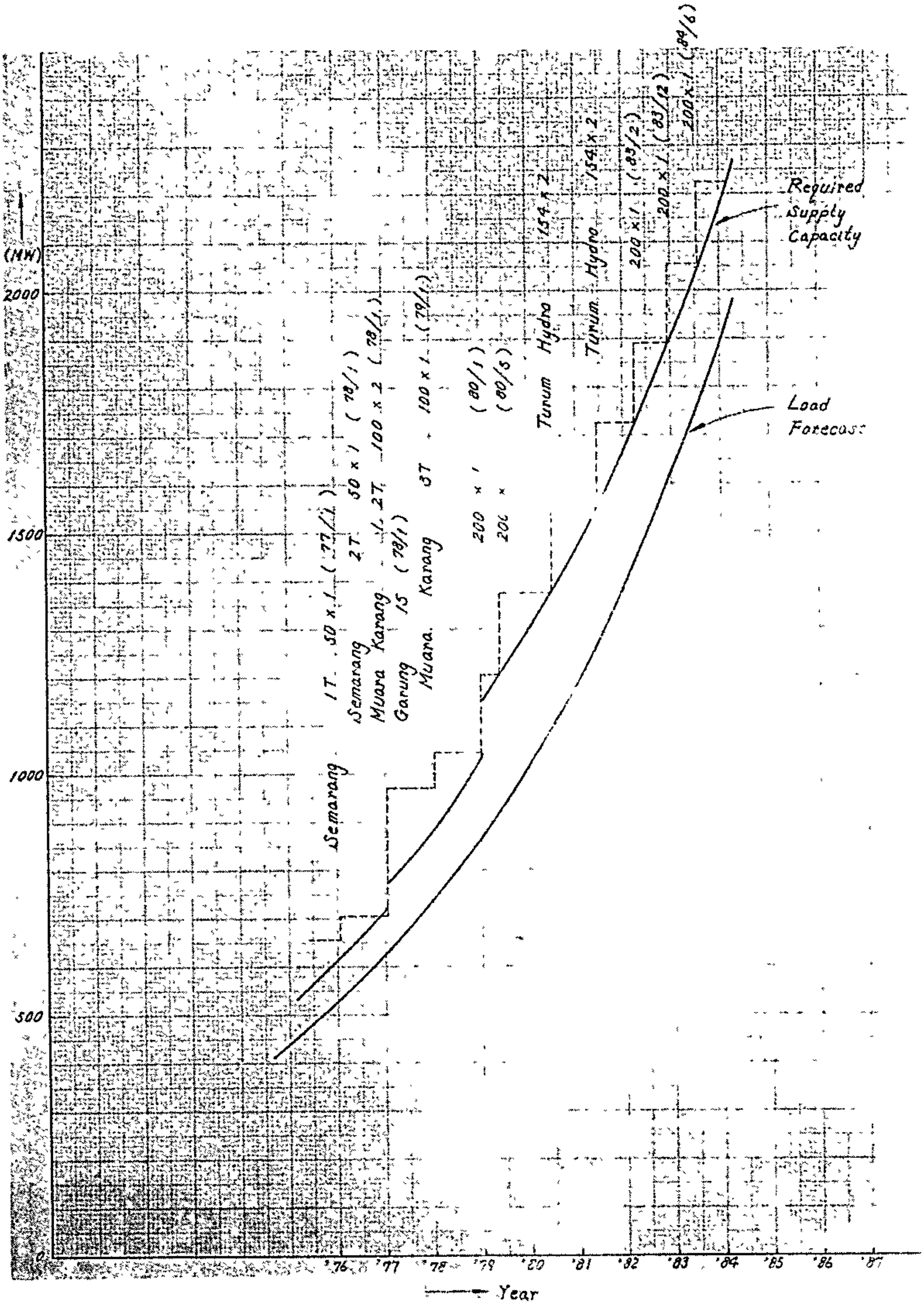
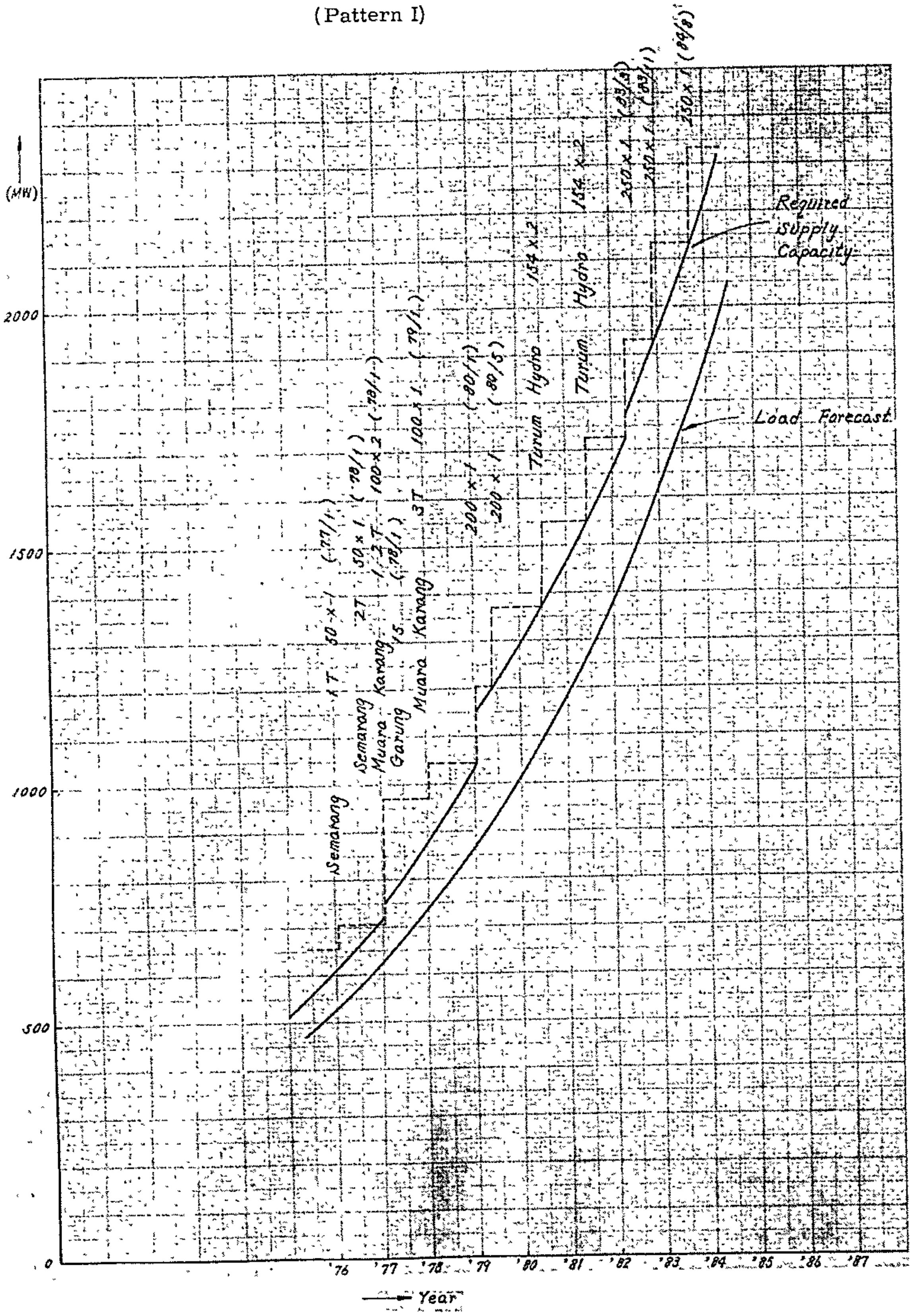


Fig. 5·3·9 West-Central Jawa

Generating Power Development Program Beyond 1977

(Pattern I)



5-3-2 Thermal Power Unit Size in East Jawa in Future

In order to select the future unit size, a rough economic study has been performed. The result of the study shows that the unit size after Tanjung Perak No. 3 & No. 4,

(1) The future unit size of 125 MW is advantageous for short range view

(2) 150 MW is preferable from long range view, but the difference of the merit between 125 MW is very small, about 1.5% of the absolute amount.

Therefore, it proved to be preferable to develop 125 MW for the time being.

(1) Development pattern

Economy study has been performed roughly concerning the following three patterns. Refer to Table 5.3.4 and Fig. 5.3.13.

Table 5·3·4 Development Pattern

Pattern A

Year of Commercial Operation	Unit MW
1979 - Jul.	100
1980 - Jul.	100
1982 - Jan.	100
1983 - Feb.	100
1984 - Mar.	100
1985 - Jan.	100

Pattern B

Year of Commercial Operation	Unit MW
1979 - Jul.	125
1980 - Jul.	125
1982 - Mar.	125
1983 - Sep.	125
1984 - Oct.	125
1985 - Oct.	125

Pattern C

Year of Commercial Operation	Unit MW
1979 - Jul.	150
1980 - Jul.	150
1982 - Jun.	150
1984 - Feb.	150
1985 - May	150

(2) Conditions for study

a. Steam conditions and design thermal efficiency

These condition is shown in following Table 5·3·5.

b. Construction cost

Construction cost for each unit size is supposed as following.

100 MW	46,500 Yen/Kw
125 MW	44,000 Yen/Kw
150 MW	42,400 Yen/Kw

Table 5.3.5 Steam Condition and Design Thermal Efficiency

Unit Size MW	Steam Conditions	Design Thermal Efficiency
100	102 kg/cm^2, 510 °C	32.6 %
125	127 kg/cm^2, 538/538 °C	37.5 %
150	169 kg/cm^2, 566/538 °C	39.2 %

c. Fuel cost

7.5 Rp/l (US$ = 415Rp = 270 Yen)

d. Interest

10 %

e. Rate of equalized annual expenditure

16 %

f. Study period

Study has been made for the following periods.

a. 1979, Jul. to 1986, May

b. 1979, Jul. to 1994, Jul.

(3) Result of study

The total present values of the annual expenditures for the above-mentioned periods are calculated to be as follows. (Table 5·3·6)

Table 5·3·6 Result of Study

Development Pattern	1979, Jul. - 1986, May	1979, Jul. - 1994, Jul.
A	100 %	100 %
B	97	96
C	100	95

Fig. 5·3·10 East Jawa

Generating Power Development Program

(Pattern A)

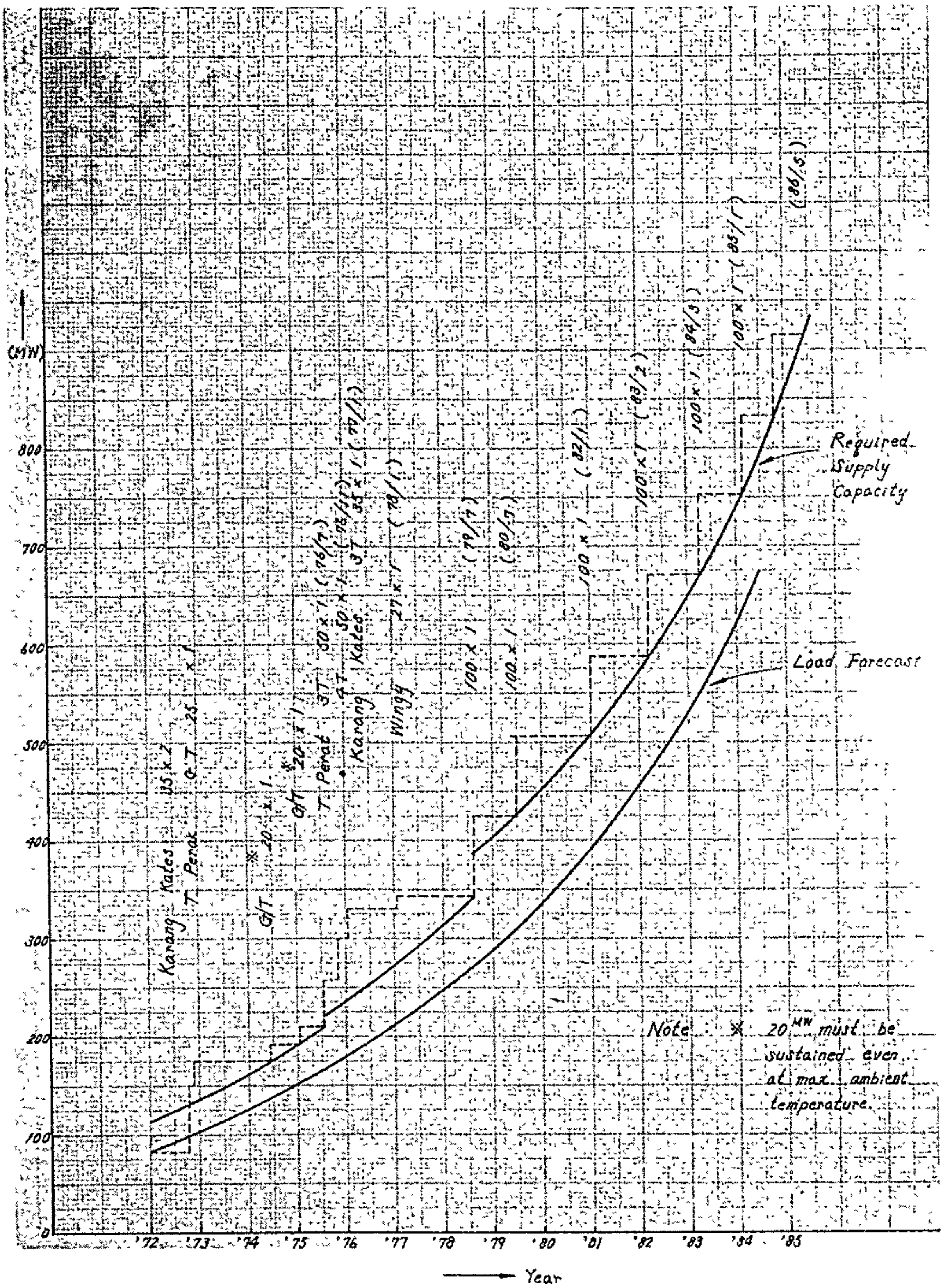


Fig. 5.3.11 East Jawa
Generating Power Development Program
(Pattern B)

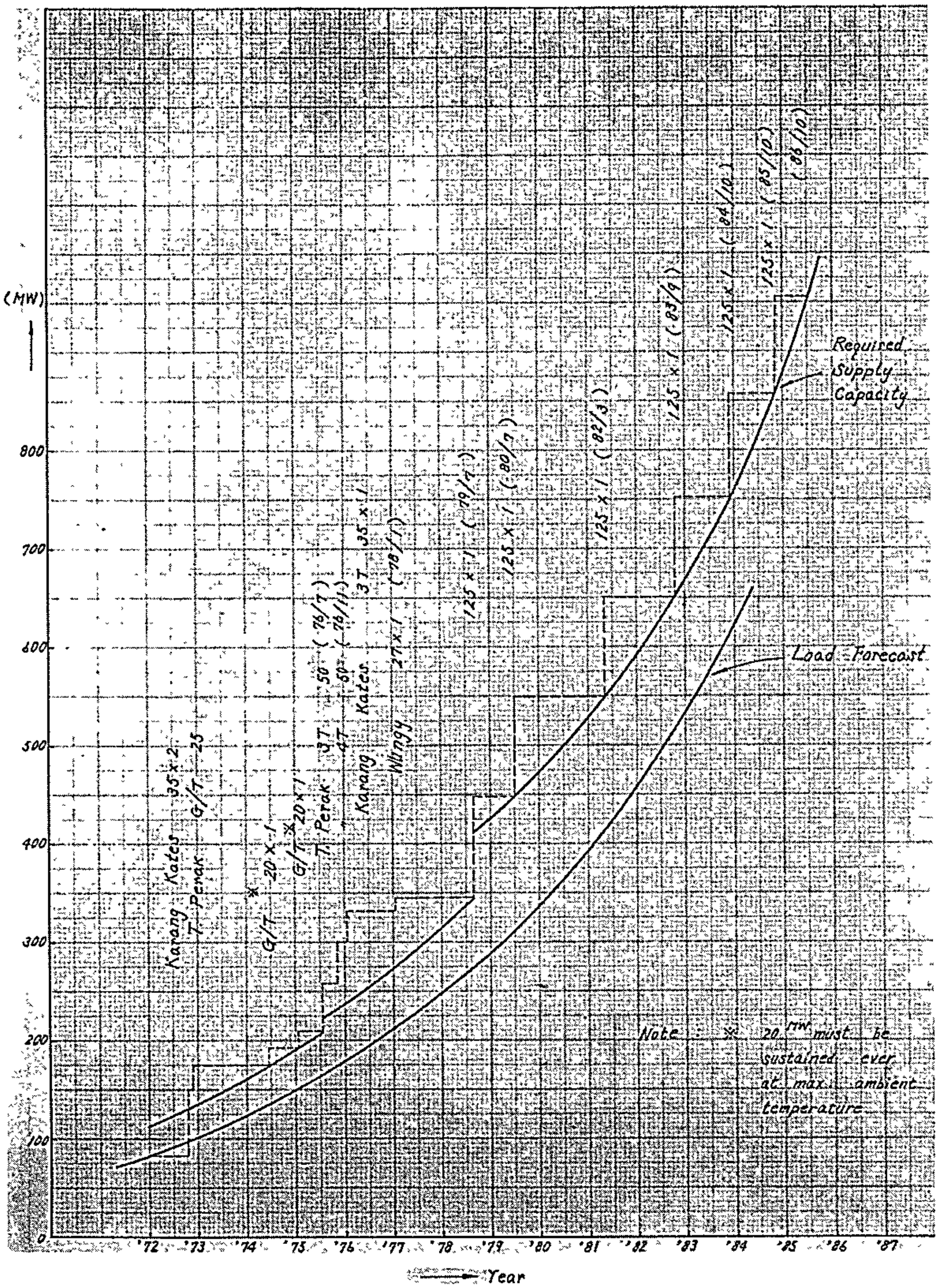


Fig. 5·3·12 East Jawa

Generating Power Development Program

(Pattern C)