ANNEX 9

SMOKELESS AND BRIQUETTED FUEL PROCESS

1. Introduction

This paper is to introduce a process of manufacturing smokeless briquette from Lakhra Coal. It is advisable to construct the briquette plant near the site of Lakhra Power Plant. Since the inherent moisture and sulphur contents of Lakhra coal are quite high, a series of basic tests must be carried out to design the briquette plant.

The following items would be the indispensable conditions of basic planning to construct the plant.

(a) Thermal Drying

The thermal drying equipment adopts the fluid-bed system which is comparatively capable for adjusting the retention time easily. This dryer reduces the total moisture of coal from 25 % to about 3 %.

The relative ignition temperature of Lakhra coal is so low that the hot gas temperature allows 150°C at the inlet of thermal dryer.

(b) Carbonization

Considering the continuous operation, characteristics of tar, the uniformity of heating in carbonizer as well as of product quality, the fluid-bed carbonizer is adopted. Outside of the carbonizer, a combustion chamber is attached for producing hot gas which is blown into the carbonizer.

In order to reduce the volatile matter of the product to less than 10 %, it is designed that the carbonizing temperature is 500°C and the retention time is around 5 minutes.

(c) Carbonizing Gas Treatment

Since the calorific value of carbonizing gas is rather low and the effective utilization of tar in the gas is unknown, only the value of tar is evaluated as a fuel. Accordingly, gas scrubbing devices are not provided and the tar is utilized to increase the heating capacity of gas as a heat source for drying and carbonizing raw materials.

When and after the normal operation of carbonizer has been secured and the composition of carbonizing gas has become available for the normal combustion, heavy oil which was being used for the combustion chamber, is replaced by the carbonizing gas as a main fuel.

(d) Briquetting

The carbonized materials less than 2 mm size are pressed while they keep high temperature and plasticity, so that hard briquette can be made. After carbonizing, hydrated lime, the amount of which is 10 to 15 % of raw materials, is added as desulphurizer and binder.

The increased hydrated lime may be effective for desulphurizing, but it is not so favourable because it results in the immediate increase of ash content in briquette. It means the ash contents of raw materials should be as low as possible.

Briquecte can be made in various shapes or sizes in accordance with purposes of users, but as a standard, the size of 50 mm x 50 mm x 35 mm is recommendable for domestic use.

2. Main Process

The main process is shown in the attached flow diagram.

The outline of the diagram is as follows;

Lakhra coal with moisture around 25 % in total is received in a raw coal hopper, then temporarily stored in a raw coal bin through feeder and bucket elevator.

The fixed amount of stored raw coal is fed into the fluid-bed dryer from the raw coal bin by a feeder and dried coal bin together with dust from cyclone through flow conveyor.

After measuring the scheduled amount of dried coal by a weighing device, the dried coal is fed from the bin through flow conveyor and screw conveyor into fluid-bed carbonizer where it is carbonized by hot gas charged from the bottom of carbonizer at a given temperature. At the same time, the carbonizing gas from carbonizer, without separating tar from it, is sent back with fans to a hot blast stove and a hot gas producer for combustion use there.

Carbonized coal is blended with hydrated lime at a fixed ratio in a paddle mixer and then formed into briquette by a pressing machine.

Smokeless briquette thus produced is screened and stored in product storages as briquette for domestic use.

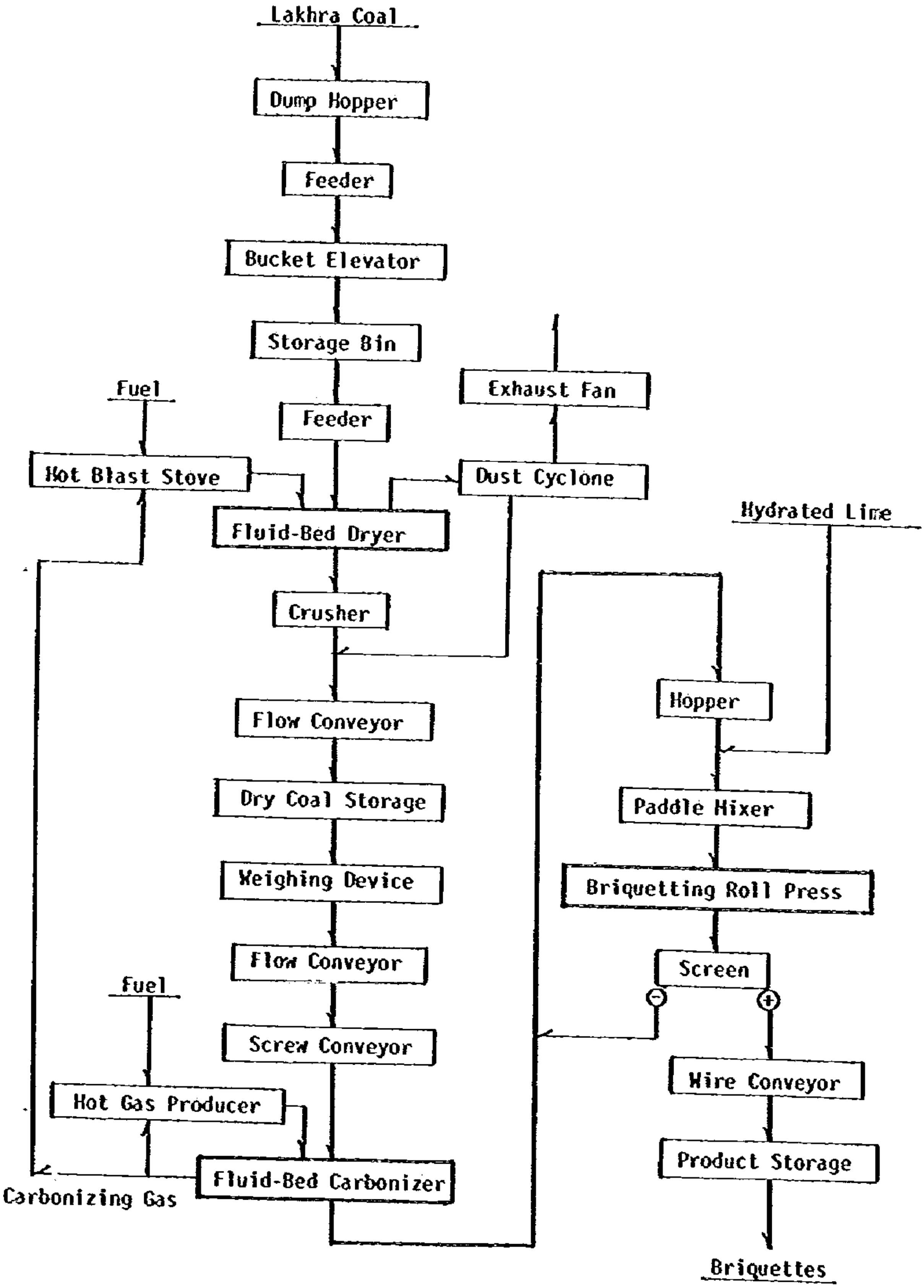


FIGURE 1 FLOW DIAGRAM OF SMOKELESS BRIQUETTED FUEL PROCESS

PART IV COAL-FIRED THERMAL POWER STATION

PART IV COAL-FIRED THERMAL POWER STATION

CHAPTER 1 CONCLUSIONS AND RECOMMENDATIONS

1-1 Conclusions

As far as the Lakhra Coal Mining and Coal-fired Thermal Power Station Project is concerned, it is judged to be technically and economically feasible to construct a 300 MW coal-fired thermal power station with a single unit of 300 MW at Jamshoro which is scheduled to be commissioned in March, 1987, based on the annual production of lignite as stated in the study of mine development.

1-1-1 Electric Power Demand Forecast and Electric Power Development Scheme

(1) Electric Power Demand Forecast

In making a long-range forecast for the future with the past record of electric power demand as the background, the JICA Survey Team adopted two approaches. One was a technique of analysis by category whereby a forecast is made based on the past records of customers by category and the estimations of future population increase and electrification. The other is a comprehensive statistical technique where a forecast is made using a performance statistics model of electric power demand and a gross national product model, with the purpose of augmenting the result obtained by the former category-by-category analysis technique. In making a prediction of the annual maximum power demand from the annual energy consumptions obtained by the above-mentioned techniques, the two hypotheses below were set up.

1) The overall transmission and distribution losses

Date	June 1980	June 1984	June 1990
Loss	31%	27%	25%

2) The annual load factor is estimated under the following equation.

$$Alf = 62.96 - 0.558x$$

Alf: Annual load factor

x: Number of years on the assumption of zero at the end of June 1980

Accordingly, the annual maximum power demand and annual average growth rate for the period from 1980 to 1990 which were forecast by the JICA Survey Team, based on the above energy consumptions, transmission and distribution losses and annual load factors in comparison with the studies made by WAPDA are as shown on the next page.

Calendar Year	Analytical Method by JICA Survey Team (A) (MW)	WAPDA (B) (MW)	(B) / (A)
1980	2,443	2,421	0.991
1985	3,808	3,841	1.009
1990	5,842	5,775	0.989
Growth Rate (% per annum)			
1980 to 85	9.3	9.7	
1985 to 90	8.9	8.5	

As seen from the above, there is hardly difference in the figures of the maximum power demand between the JICA Survey Team and WAPDA. Accordingly, the figure of the maximum power demand forecast by WAPDA is to be adopted in this Report.

It is planned for the KESC System to be merged with the WAPDA System in July 1984. The maximum power demand figures and the annual average growth rate for the KESC System are forecast to be 789 MW – 1,353 MW (1984 – 1990) and 9.4%, respectively, and the maximum power demand and annual average growth rate of the WAPDA System after absorption of the KESC system will be 4,183 MW – 6,920 MW (1984 – 1990) and 8.8%, respectively.

(2) Electric Power Development Scheme

The existing installed capacity of the WAPDA System was 2,685 MW as of July 1980, of which hydro power generating facilities comprised 1,567 MW or approximately 60%, while thermal power generating facilities comprised 1,118 MW or approximately 40%. However, the total effective installed capacity is reduced approximately 5% due to generating facilities which have become anticipated to be about 2,553 MW.

The electric power system of WAPDA is geographically divided into four power markets, with a feature being that the hydro generating facilities making up approximately 60% of the supply capability exist one-sidedly in the Northern power market in the north with the remaining 40% comprising thermal generating facilities existing in the three other power markets. Further, the hydro supply capability is influenced not only by the seasonal variations in river runoffs, but also to a great extent by operation of irrigation water facilities since water resources are used with priority for irrigation, so that there is also a feature of seasonal variations being severe.

The 4 power markets presently interconnected by 132-kV transmission lines and partially by 220-kV transmission lines together with KESC-owned power systems are to be interconnected by 220-kV and 500-kV transmission lines in the future.

It will be possible to interchange power effectively between the North and South through strengthening these transmission line networks. The development programs prepared by WAPDA indicate that the incremental capacity of hydro power stations including Tarbela, Mangla and Warsak will be 3,010 MW in total in the 1980's. In addition, if 300 MW of Lakhra

Coal-fired Thermal Power Station is developed, the total installed capacity of WAPDA-owned thermal power stations is scheduled to reach 2,475 MW.

The demand and supply balance considered from the generating capability of the WAPDA Electric Power System, the maximum demand and the maximum unit capacity will be as described below.

The capability margin will be 30% to 60% in the high-water season (in September) and 7 to 9% in the low-water season (in May) except for the years of 1987 and 1988. The supply capability is below the maximum demand in the low-water season during the period from 1980 to 1985.

The power installed capacity of the system is relatively bigger, compared with the maximum demand. In spite of this fact, there will be serious shortage of power in the low-water season. The ratio of the size of the largest unit in the system to the maximum demand within the sphere of the system is 6 to 8%. The margin capability corresponding to more than 15% of the maximum demand would be required in consideration of possible stopping of the capacity of the two biggest units.

1-1-2 Electric Power System

(1) Method of Power Transmission of Lakhra Coal-fired Thermal Power Station

There will be two methods of transmission of power from the Lakhra Coal-fired Thermal Power Station through 132 kV and 220 kV transmission lines.

The economic comparisons of construction costs of transmission lines of the two voltages have proved that the former would be more economical than the latter. Accordingly, it is considered advisable that power from the above-mentioned power station be transmitted to 500 kV Jamshoro Substation adjacent to Lakhra Coal-fired Thermal Power Station.

(2) System Analysis

With the peak load hours in the low water season in 1987 when Lakhra Coal-fired Thermal Power Station with a capacity of 300 MW is to be commissioned as the times for studies, the power flows and stability of the WAPDA System were examined.

1) Power Flow

Electric power on 500 kV transmission lines will flow from Multan and Guddu Thermal Power Stations in the central part of Pakistan to the North and South of the country. Since the power flow will be relatively light, there will be a tendency for the 500 kV bus voltages of the various 500 kV substation to rise.

As power required in the Hyderabad area is fully sent from the hydro power stations in the North during the high-water months, the transmission lines to send power from the 500 kV Jamshoro Substation to the Hyderabad area and necessary equipment including 220/132 kV transformers should be planned to meet the full requirements of the area.

2) Stability

As a result of transient stability calculations, it has proved that the power system would be unstable and would hardly discharge its functions should three-phase ground faulting take place at the end closest to Jamshoro of the 500 kV transmission lines between Dadu and Jamshoro.

However, in the event that the 500 kV transmission lines should be designed as double circuit lines, the system will be quite stable even if faults occur on one circuit of the 500 kV transmission lines.

1-1-3 Location of Coal-fired Thermal Power Station

For selection of the location of the Coal-fired Thermal Power Station, studies were made based on conditions of location of possible sites at Jamshoro, Khanot and Lakhra. It is judged that the Jamshoro site is the most promising as a result of overall comparison of the physical conditions, availability of condenser cooling water, transportation of fuel and materials, necessity for a transmission line, approximate construction cost, etc.

The outlines of the 3 sites of Jamshoro, Khanot, and Lakhra are as descibed below.

(1) Jamshoro Site

The greatest advantages of the Jamshoro site are that condenser cooling water can be taken from the Indus River throughout the year, and further, that if the Coal-fired Thermal Power Station is constructed adjacent to the 500-kV Jamshoro Substation, construction of a transmission line will not be necessary. Other than these, a pipeline for natural gas to be used as one of the supplementary fuels runs at a distance of 3.5 km from this site and this pipeline can readily be extended, while for transportation of materials and equipment for construction and maintenance, a railroad and roads can be readily used. Further, the infrastructure for maintaining daily livelihood such as educational facilities, hospitals, government agencies, etc. is more or less complete. In comparisons of approximately construction costs also, Jamshoro is cheaper than the others.

The disadvantage of this site is that it is approximately 30 km distant from Lakhra Coal Mine and the coal hauling distance would be the longest and the transportation fost the highest. Also, there is concern about the effect on residents nearby due to air pollution from firing lignite of high sulfur content.

(2) Khanot Site

The drawback of the Khanot site is that it will be difficult to select the intake site for condenser cooling water because of variations in the center line of the Indus River and it is impossible to secure a large quantity of cooling water throughout the year. Consequently, cooling towers will have to be adopted for the condenser cooling system, and this will result in increase in construction cost and reduction in plant thermal efficiency. It will be necessary for new construction of a 220-kV, 2-cct line of distance of approximately 35 km from the Coal-fired Thermal Power Station to the 500-kV Jamshore Substation. In the comparison of the approximate construction costs also Khanot is costlier than the Jamshoro site. Other than these points, this site is approximately 18 km distant from Lakhra Coal Mine and since transportation of coal would be by the railway to be newly built the transportation costs would be high. Also, an infrastructure is practically non-existent at this site and it would be necessary for a colony to be constructed at an early date to build up the living environment.

The favorable conditions of this site are that for access and transportation of materials and equipment, a railroad and a road from Karachi can be utilized, and also since there are practically no residents in the vicinity, considerations about air pollution will not be necessary.

(3) Lakhra Site

Disadvantageous conditions of the Lakhra site are the same as for the Khanot site with regard to securing condenser cooling water, in addition to which water pump-up for a length of approximately 15 km and height of approximately 140 m will be needed to Lakhra. Regarding new construction of a transmission line, similarly to Khanot, a length of approximately 48 km, 220-kV, 2-cct will be needed to the 500-kV Jamshoro Substation. The approximate construction cost will also be the highest. Other than the above, with respect to access and transportation of materials and equipment, they will be the same as for the Khanot site up to Khanot, while a road must be newly constructed from Khanot to Lakhra. The infrastructure is not complete as in the case of the Khanot site, and it will be necessary to build up a colony at an early date.

The greatest advantage of this site is that it is adjacent to Lakhra Coal Mine so that hauling of lignite can be done directly by truck and the transportation cost will thus be the cheapest. Furthermore, this site is a barren plateau with practically no residents, and it will not be necessary for special considerations to be given regarding air pollution.

1-1-4 Power Station Scale and Unit Size

It is quite natural that the scale of Lakhra Coal-fired Thermal Power Station should be determined according to annual production of lignite from the possible mine site at Lakhra. The study of mine development has proved that lignite production of one million tons per annum would be possible on an air dry basis consecutively for thirty years. On the assumption that the annual production of lignite is to reach one million tons as stated above, it is possible to determine the scale of this power station as 300 MW in consideration of annual plant factor and thermal efficiency, etc.

There are two alternatives such as employment of single unit of 300 MW and of two units of 150 MW each. It is advisable to employ the alternative of adopting a single unit of 300 MW for the reasons listed below.

(1) In case comparisons are made on capital costs of the alternative of 300 MW x 1 unit and that of 150 x 2 units, the former will be cheaper than the latter by around 10%. The former is also more advantageous in respect of operating costs in view of decrease in lignite consumption because of improvement of thermal efficiency. In other words, the alternative of employment of a single unit of 300 MW will provide scale-merit and is considered to be economically favorable.

(2) According to WAPDA, Tarbela with a capacity of 406 MW x 5 units and Mid Country with a capacity of 400 MW will have already been commissioned in WAPDA System prior to the commissioning of 300 MW Lakhra Coal-fired Thermal Power Station.

1-1-5 Outline of Facilities of Coal-fired Thermal Power Station

(1) Location — Jamshoro, District Dadu, Hyderabad Division, Sind Province

(2) Power Station Compound Area — 397,000 m² (incl. space for extension, excl. ash disposal site)
Colony Compound Area — 378,000 m² (incl. space for extension)
Total — 775,000 m²

(3) Building Area — 19,540 m²

(4) Installed Capacity — 300 MW (300 MW x 1 unit)

(5) Equipment Outline

1) Boiler

Type	Single drum, natural circulation, outdoor type (Burner, coal bunker will be covered.)
Evaporation	980 t/hr (at max. continuous rating)
Steam Conditions	173 kg/cm^2 g x 541°C (at superheater outlet) 36 kg/cm^2 g x 541°C (at reheater outlet)
Fuel	Lignite

2) Turbine

Type	Tandem compound, two-cylinder, double-flow reheat turbine
Rated Output	300,000 kW
Steam Condition	169 kg/cm^2 g x 538°C (at main stop valve inlet)
Speed	3,000 rpm
Number of Extractions	7
Vacuum	700 mmHg

3) Generator

Type	Horizontal, rotating field, closed hydrogen-cooled, explosion-proof type
Rated Capacity	353,000 kVA (at rated hydrogen pressure 3.2 kg/cm^2 g)
Power Factor	0.85 (lagging)
Voltage	18 kV
Current	11,323 A

4) Main Transformer

Type	3-phase, forced-oil, forced-aircooled, outdoor type
Rated Capacity	333,000 kVA
Primary Voltage	18 kV
Secondary Voltage	132 kV ± 10%

(6) Countermeasures against Corrosion of Boiler due to Combustion of Lignite with High Sulfur Contents

SO_3 contained in flue gas produces sulfuric acid at a temperature of dew point thereby corroding metals in which the said sulfuric acid is made. Accordingly, the following measures should be taken.

1) Countermeasures against Corrosion of Air Preheater
   a) The temeperature of gas at an exit of the air preheater should be kept at a temperature of 130°C so that the temperature of metals of air preheater can be maintained at a temperature of more than 85°C.
   b) It should be arranged that the air temperature at an entrance of air preheater can be risen up to 70°C by means of steam air preheater in winter and during low load hours.
   c) The materials of low-temperatured elements should be of acid-proof ceramic.

2) Flue Gas Duct
   The materials of flue gas duct is to be completely kept warm by wrapping the said duct by means of insulators lest the temperature of flue gas should fall.

3) Stack
   Inner lining materials are to be of acid-proof bricks.

4) Countermeasures against Closure of Air Preheater Elements
   a) Closure of air preheater elements is to be prevented beforehand by rise in the temperature and drying of elements, providing bypass lines of cold air in the air preheater.
   b) Closure of elements is to be prevented beforehand by means of removing ash, using steam type soots blower to be furnished with air preheater, in case ash should adhere to elements.
   c) In case elements are closed, closure is to be removed by washing such elements with pressurized flush warm water.

(7) Possibility of Operation of Turbine-Generator as Synchronous Condenser

It is considered technically possible for a turbine-generator to be operated as synchronous condenser within the limits of the generating capability curve.

When a turbine-generator is operated as synchronous condenser, it must be separated from a steam-turbine. Several ways of "start-up" are conceivable. The start-up system by means of a synchronous induction motor would be realistic among said ways since it is most economical and has been used for a turbine-generator of small capacity.

In the event that a turbine-generator should be manufactured so that operation of a synchronous condenser can be made within the limits of the generating capability curve, incremental costs of auxiliary equipment and start-up apparatus could be estimated at around 73 million Rupees. While installation of a synchronous condenser with the same capacity as that of reactive power of generator and installation of static condenser and shunt reactor will cost approximately 130 million Rupees and 135 million Rupees, respectively. Accordingly, operation of a turbine-generator as synchronous condenser would be more economical.

As described above, there exist actual records of having used turbine-generators of small capacity as synchronous condenser in the past.

However, the proposed turbine-generator will have a capacity of 300 MW for the Project. Unfortunately, no actual records of having used such a big scaled turbine-generator as synchronous condenser have been observed. Therefore, it will be essential that WAPDA conduct careful and strict examinations prior to their finalization of employment of the turbine generator as synchronous condenser.

I-1-6 Construction Schedule of Coal-fired Thermal Power Station

It was estimated various schedules prior to the start of construction such as investigation work necessary for definite design, preparation of bid documents, bidding, award of contract, etc. would require approximately 24 months. The subsequent construction schedule including design and manufacture of equipment to be done by the contractor, transportation, civil and building construction, installation and erection of equipment and facilities, acceptance tests, etc. was set taking into account the annual coal production projected for Lakhra Coal Mine. As a result, it was considered that construction of the 300 MW coal-fired thermal power station would require approximately 47 months. Accordingly, the total period of time for implementing construction of the coal-fired thermal power station will be 71 months comprising 24 months and 47 months.

In consideration of the above, the coal-fired thermal power station will be commissioned in March 1987.

I-1-7 Estimated Construction Costs

The construction costs of the coal-fired thermal power station have been calculated in the foreign and domestic currency portions, based on prices prevailing as of June 1980.

The Contingency given in Item G of the following table was calculated to be 5% of the Sub-total shown in Item F comprising Items A through E. Import Duty (Item I) quoted in the domestic currency portion has been estimated at 40% of C&F prices of materials, equipment and supplies included in Items A through D of the table. The Engineering Fee shown in Item J has been estimated at 5% of the Total Direct Cost of Item H. The Administration Cost (Item K) corresponding to be 4% of the Total Direct Cost (Item H) in both currency portions has been assumed to be incurred in the domestic currency portion.

The amount of Interest during Construction given in N has been calculated at a rate of 8.75% per annum for the foreign currency portion and at a rate of 12.5% for the domestic currency portion, respectively.

Thus, the construction costs have been calculated to be 6,225 million Rupees in total. Of this amount, 2,673 million Rupees correspond to the amount of costs to be incurred in the foreign currency portion while 3,552 million Rupees are estimated to be incurred in the domestic currency portion. However, escalation in prices due to inflation is not considered.

Estimated Construction Costs of Coal-fired Thermal Power Station

(Rs in million)

Item \ Category	Construction Cost		
	Foreign Currency	Domestic Currency	Total
A. Equipment	1,727	–	1,727
B. Civil Work	295	300	595
C. Building Work	144	266	410
D. F.G.D. Plant	109	84	193
E. Installation	130	415	545
F. Sub-total	2,405	1,065	3,470
G. Contingency	121	53	174
H. Total Direct Cost	2,526	1,118	3,644
I. Import Duty	–	905	905
J. Engineering Fee	147	35	182
K. Administration Cost	–	146	146
L. Total Indirect Cost	147	1,086	1,233
M. Total	2,673	2,204	4,877
N. Interest during Construction			1,348
Foreign Currency Portion		620	
Domestic Currency Portion		728	
O. Total Construction Cost	2,673	3,552	6,225

1-1-8 Economic Analysis

(1) Development of Lakhra Coal Mine was planned with the purpose of supplying lignite as fuel for Lakhra Coal-fired Thermal Power Station. It would be possible to save 380 million m^3 to 530 million m^3 of natural gas annually, which can be utilized as a raw material for fertilizer and other gas-chemical industries.

(2) In order for the heavy oil-fired thermal power station to be able to compete with the Lakhra Coal-fired Thermal Power Station Project, the escalation rate of crude oil price in case of a plant factor in a range of 50 to 70% annually must be held to a level of 4.7% to 5.6% at a discount rate of 10% and also the escalation rate of crude oil price will be in a range of 5.2% to 6.6% at a discount rate of 13%.

(3) Even if the escalation rate of crude oil prices were to be held to about 8% annually, that is at the same level as commodity prices in general, the Lakhra Thermal Power Project will show high benefit-cost ratios of 1.40 to 1.63 at a discount rate of 10% and 1.23 to 1.44 at a discount rate of 13%, respectively.
Accordingly, although this Project will require funds 1.9 times more than a heavy oil-fired thermal power project, it will be advantageous in consideration of the above-mentioned economic superiority.

1-1-9 Considerations regarding Environmental Problem

(1) Air Pollution Countermeasures

Substances influencing air pollution produced as a result of firing the lignite at the Coal-fired Thermal Power Station will mainly be soot and dust, and sulfur oxides.

1) Soot and Dust Countermeasure
The ash content of the lignite is approximately 24% and relatively high, and approximately 80% of ash produced in combustion of the lignite will be scattered in the atmosphere as fine-particled fly ash to contribute to air pollution. As the measure to prevent this, high-efficiency electrostatic precipitators are to be installed to collect the fly ash. Further, since the apparent electric resistance of the ash is high, dust collection is to be efficiently maintained by means of increasing in the capacity of EP (electric precipitator) and of selection of discharge terminals to obtain effective corona current and through strengthening of hammering capability.

2) Smoke and Soot Countermeasure
In the Islamic Republic of Pakistan, environmental standards desirable to be maintained to protect the health of people and secure the living environment have not been established. However, since the sulfur content of the lignite is of a comparatively high value at approximately 7%, it is expected that the concentration of sulfuric oxides in flue gas will be high. As a countermeasure, a concentration of sulfuric oxide is to be maintained at less than 0.14 ppm as set forth in U.S. Federal by treating half of flue gas at a desulfurization plant (under the Limestone/Gypsum Recovery Process Method) from the economical standpoints.

(2) Drainage Countermeasures

Oil separation, settling and filtering and neutralization treatment will be provided drainage to be discharged from the Coal-fired Thermal Power Station according to the properties of the waste water so that the environment will not be affected.

1) Domestic Waste Water
Waste water from privies are to be conducted to septic tanks for purification, while drainage from hot water supply rooms is to be subjected to filtering and settling treatment after which it is to be discharged.

2) Waste Water from Apparatus
Waste water from water treatment apparatus and the chemical analysis laboratory is to be conducted to a waste water neutralizing tank where it is to be neutralized and then discharged. Washing water from electrostatic dust precipitators, electric preheaters and chimneys, and waste water from chemical cleaning of boilers will be produced irregularly and are to be subjected to neutralization treatment at a temporary pond and then discharged into the ash disposal lot. Drainage from around the coal yard is to be settled and filtered, and then discharged.

3) Waste Water with Oil Content
Waste water containing oil such as drainage from bulldozer garage and drains from various equipment are to be subjected to oil separation and then discharged.

1-2 Recommendations

(1) Preparation of Documents for Financial Arrangements

It is recommended that WAPDA make financial arrangements in haste for materialization of the Project. In this context, it will be required that WAPDA make an approach through the Government of Pakistan to appropriate overseas financial source(s) to secure the necessary funds in the foreign currency portion. It is also believed necessary for budgets to be complied for appropriation of costs to be incurred in the domestic currency portion. A series of documents required for approaches to the authorities concerned and financing agenci(es) at home and abroad should be prepared without any delay in order that a loan agreement can be concluded not later than October, 1981.

(2) Materialization of Project

It is suggested that WAPDA coordinate with PMDC and associated governmental agencies smoothly and effectively in the materialization of this Project in order that WAPDA and PMDC may fulfill their respective functions and fully utilize their valuable experience in development of power facilities and coal mines.

(3) Training of Personnel to Be Assigned to the Project

Since WAPDA will go into the performance of definite studies, construction supervision, maintenance and operation, etc. of such a large-scaled project as the Lakhra Coal Mining and Coal-fired Thermal Power Station Project, it is recommended that WAPDA as the implementing agency of the said Project train personnel who will be engaged in the aforementioned work and related assignments in advance to fully meet the requirements of the Project.

(4) Geological Surveys and Preparation of Topographic Maps

It is recommended that in view of the urgency of the Project implementation, WAPDA undertake geological surveys on the proposed Project sites and prepare topographic maps thereof which will be essential to the definite studies for the Project. It is advisable for WAPDA to take prompt action for this purpose.

CHAPTER 2 PRESENT STATE OF ELECTRIC POWER INDUSTRY

2-1 Historical Background

At the time of the independence of Pakistan in 1947, Mandi Hydroelectric Power Station (48 MW) which had been a principal source of electric power in Punjab Province was handed to India making the electric power situation of the province severe, and it had to depend on India for most of its power supply.

However, there were private electric power companies existing at Lahore, Rawalpindi, Multan and small townships which were supplying power to their respective districts as isolated systems.

In North West Frontier (N.W.F.) Province there was Jabban Hydroelectric Power Station (9.6 MW) on the Upper Swat River. In this province, there were also private power companies possessing small diesel power stations for supplying isolated places such as Dera Ismail Khan and Bannu.

In Bahawalpur State there were diesel power stations (318 kW) owned by the state.

The Pakistani Government immediately after independence tackled plans for new generating stations in view of the power shortage in Northern Pakistan.

In Punjab Province, construction work of Rasul Hydroelectric Power Station (22 MW) was speeded up to be completed in 1952. Montgomery Thermal Power Station (6 MW) was completed in 1955, while a thermal power station (8 MW) was also constructed at Lyallpur.

In N.W.F. Province, an addition (10 MW) was made to Jabban Hydroelectric Power Station, and Daragai Hydroelectric Power Station (20 MW) was constructed.

In Bahawalpur State, small diesel power stations at Ahmedpur, Rahimyarkhan, Khanpur, Chistian Mandi and Bahawalnagar were expanded from 200 kW to 650 kW.

About this time in Pakistan it was possible to operate Jabban Hydroelectric Power Station and Dargai Hydroelectric Power Station in N.W.F. Province in parallel, but this could not be done with other power stations which were capable only of carrying out isolated power supply in specific areas.

Merging was done of provinces in Pakistan in 1953. There was still a shortage of electric power as a whole at this time, but formerly isolated power systems could now be operated in paralle, and it was recognized that the shortage in electric power could be greatly alleviated if interconnections were to be made with a power transmission network like Jabban-Dargai and with the surplus power of Montgomery.

As 1956 came about, the Jabban-Dargai System and the Rasul System were put into parallel operation to result in expansion of the power transmission network. In succession, other power stations were also put into parallel with the newly structured power transmission network.

It was about this time that the Government of Pakistan, keenly feeling the necessity of forming and building up power systems between provinces on a nation-wide scale, integrated the electricity departments of provinces and states by federal ordinance to form the single organization of WAPDA, the activities of which were henceforth started.

Warsak Hydroelectric Power Station (40 MW x 2) and Multan Thermal Power Station (65 MW x 2) were completed in 1960, and about the same time a 132-kV, 2-cct transmission line with a length of 461 miles was constructed between Warsak and Lyallpur, and power was supplied to large-scale gridstations at Peshawar, Wah, Rawalpindi, Gujranwala, K. S. Kaku, Kot Lakhat, Lyallpur, Ludewala and Daudkhel. This new 132-kV transmission line was also connected at Multan Thermal Power Station with the 220-kV transmission line between Multan and Lyallpur.

By 1967, Mangla Hydroelectric Power Station (200 MW, ultimate output 600 MW), an addition (65 MW x 2) to Multan Thermal Power Station, and Faisalabad Thermal Power Station (66 MW x 2) were constructed, and 220-kV, 2-cct transmission line were constructed between Mangla and Kot Lakhpat, and between K. S. Kaku and Lyallpur.

With the development of industry, agriculture and commerce, and as a result of sócio-economic improvement, the electric power system of Pakistan was expanded from the North to Upper Sind, Lower Sind and Quetta until a connection was made by 132-kV transmission line with the transmission network of Karachi Electric Supply Corporation (KESC). Up to this time, large-scale facilities such as Tarbela Hydroelectric Power Station (total output 700 MW), Guddu Thermal Power Station (total output 700 MW), Guddu Thermal Power Station (110 MW x 2), Faisalabad Gas Turbine Power Station (total output 200 MW), and Kotri Gas Turbine Power Station (total output 80 MW) were constructed, and the power generating facilities of Pakistan grew to 3,552 MW by 1979.

The growth of the power generating facilities of Pakistan between 1959 and 1979 is shown in Table 2-2, the power generating facilities of WAPDA as of 1979 in Table 2-3, and the power generating facilities of KESC in Table 2-6.

2-2 Structure of Electric Utility Industry

The organizations comprising the electric utility industry of Pakistan at present are the following:

Water and Power Authority	WAPDA
Karachi Electric Supply Corporation	KESC
Pakistan Atomic Energy Commission	PAEC
Rawalpindi Electric Power Company	REPCO
Multan Electric Supply Company	MESCO

Of these, WAPDA owns 75.6% of the electric power facilities of electric utilities industry in Pakistan, and KESC 17.1%. The supervisory government agency over these electric utility organizations is the Ministry of Water and Power in Islamabad.

2-3 Functions and Organizations of Electric Utility Institutions

2-3-1 WAPDA

WAPDA was established by federal ordinance in February 1958 and went into full operation in September of the same year. The existing electricity departments of provinces and states were absorbed into WAPDA in March 1959.

(1) Activities

1) Irrigation, water supply and drainage, and recreational use of water resources
2) Generation, transmission and distribution of power, and contribution, maintenance and operation of powerhouses and grids
3) Flood control
4) Prevention of waterlogging and reclamation of waterlogged and salted lands
5) Inland navigation
6) Any ill-effects on public health resulting from the operation of WAPDA

In addition to the above activities, the Government of Pakistan has given WAPDA as a federal government agency the responsibility of implementing the giant Indus Basin Projects.

(2) Organization

Under a chairman, there are 4 managing directors who are responsible for the wings of Finance & Administration, Power, Water, and Project Planning & Review Organization.

1) Power Wing
The Power Wing is supervised by a managing director under whom there are assigned 5 general managers responsible for the divisions of power generation, power transmission and grid station, power distribution, planning, design & protection, and coordination.

2) Water Wing
The Water Wing is supervised by a managing director under whom there are 7 general managers in charge of dams, irrigation projects, planning, the Basin Project (Chashma Right Bank Canal), Tarbela, North, and South. As in the case of the Power Wing, several chief engineers are assigned to each general manager.

3) Project Planning & Review Organization
A managing director is responsible for peoject planning and reviews.

4) Finance & Administration Wing
This wing provides services in common to the various wings and departments, and is responsible for finance and administration of entire WAPDA. The wing is supervised by a managing director under whom are assigned 2 general managers in charge of administration and a computer center. Chief engineers, a legal adviser, and directors of medical services and public relations are assigned to the general managers.
The number of employees of WAPDA as of 1980 was approximately 40,000,600 persons of whom were professional staff.
Details are indicated in the organization chart of WAPDA in Table 2-1.

2-3-2 KESC

KESC was established in 1913 as a private electric power company. The identity as a privately-owned electric power corporation continued until 1951, when the Pakistan Government acquired 73% of outstanding stock, and with establishment of a 100%-owned holding company, it was changed into an enterprise having the nuance of a public corporation.

This holding company is called Pakistan Electric Agencies and has a board of directors consisting of three persons, namely, a chairman, a representative of the Ministry of Petroleum & Natural Resources, and a representative of the Ministry of Finance, Planning & Development.

These three members of the holding company also are numbers of the Board of Directors of KESC, the highest organ of KESC, and the chairman concurrently serves as the chairman of the KESC board.

The board of directors of KESC is composed of 9 other persons from business and financial circles who represent shareholders.

KESC is the second largest electric power company of Pakistan and is responsible for power supply to the city of Karachi, its surroundings, and a part of Baluchistan Province.

The activities of KESC consist of investigations, planning, designing, construction, maintenance and operation of generation, transmission, grid and distribution facilities, sales of electric power, and collection of electricity charges. The power generating facilities of KESC as of the end of June 1979 amounted to 608 MW, all of which consisted of thermal generating facilities.

There is interconnection with WAPDA by a 132-kV transmission line and power of KESC is vended from WAPDA with a maximum limit of approximately 80 MW. The number of employees of KESC as of the end of January 1978 was approximately 8,000 persons of whom 422 were professional staff.

2-3-3 PAEC

PAEC is an organ for nuclear power generation which owns a CANDU type heavy water nuclear power station (137 MW). This power station was constructed with aid from Canada and went into commercial operation in 1971, but in October 1977, with the reason given as shortage of fuel, the aid of the Canadian Government to the nuclear power program of Pakistan was discontinued, forcing the power station to go out of operation. Although subsequently, the remaining fuel was utilized and power generation was continued operating at low load, it is not clear when a return to normal operation will become possible.

2-3-4 REPCO

REPCO started out as a privately-owned electric power company with a license obtained in May 1920, but in 1972 it was taken over by the federal government and is now under the supervision of managing director appointed by the federal government.

This managing director is responsible to the Board of Administration for Taken-over Company under the jurisdiction of the Ministry of Water and Power.

The power generating facilities of REPCO as of the end of June 1979 amounted to approximately 9 MW.

2-3-5 MESCO

MESCO is supplying electric power to a part of the city of Multan in an area of approximately 130 km^2. MESCO was also taken over in 1972 by the federal government. The power generating facilities as of the end of June 1979 amounted to 23 MW.

2-3-6 Private Power Generating Enterprises

Enterprises owning private power generating facilities are scattered throughout the country with the total capacity as of June 1979 comprising 2.5% of the facilities of the entire country.

2-4 Electric Power Facilities

2-4-1 Entire Power Generating Facilities of Pakistan

This entire power generating facilities of Pakistan as of June 1979 amounted to 3,552 MW. The ratios of power generating facilities of the various electric power enterprises making up the whole are as indicated below.

Name	Generating Facility (MW)	Composition (%)
WAPDA	2,685.00	75.58
KESC	608.00	17.11
PAEC	137.00	3.86
Private Owner	90.37	2.54
REPCO	9.08	0.26
MESCO	23.00	0.65
Total	3,552.45	100.00

The growth of the power generating facilities of Pakistan is indicated in Table 2-2.

2-4-2 Electric Power Facilities of WAPDA

(1) Power Generating Facilities

The power generating facilities of WAPDA as of June 1979 consisted of the following:

Hydro facilities	1,567 MW
Thermal facilities	1,118 MW
Total	2,685 MW

Details of the facilities are indicated in Table 2-3, "Power Generating Facilities of WAPDA."

(2) Power Transmission Facilities

The power transmission facilities of WAPDA as of June 1979 consisted of the following in terms of length:

500-kV	transmission line	330 km
220-kV	transmission line	1,219 km
132-kV	transmission line	5,885 km
66-kV	transmission line	6,217 km
	Total	13,651 km

The details of these lines by province are indicated in Table 2-4, "Power Transmission Facilities of WAPDA."

(3) Power Grid Facilities

The power grid facilities of WAPDA as of June 1979 consisted of the following:

220-kV grid stations, 4 sites	1,310 kVA
132-kV grid stations, 166 sites	4,608 kVA
66-kV grid stations, 182 sites	1,951 kVA
Total	7,869 kVA

Details of these by province are indicated in Table 2-5, "Power Grid Facilities of WAPDA."

(4) Expansion Plans for Power Transmission and Power Grid Facilities

Construction work on a 500-kV transmission line from Faisalabad to Karachi via Guddu and related grid stations is now going on. According to plans, these are large-scale facilities involving the following:

500-kV transmission line (length)	1,071 km
Grid station, 5 sites	3,470 kVA

There are also the following expansion plans for power transmission and grid facilities of systems of other voltages.

220-kV transmission line (length)	139 km
132-kV transmission line (length)	4,742 km
66-kV transmission line (length)	1,570 km

2-4-3 Electric Power Facilities of KESC

(1) Power Generating Facilities

The power generating facilities of KESC as of June 1979 amounted to 608 MW, all thermal facilities. The details of these facilities are indicated in Table 2-6, "Power Generating Facilities of KESC." However, according to information obtained in the present survey, the thermal power generating facilities as of June 1980 amounted to 673 MW.

608 MW -- West Wharf Station A (15 MW) + Karangi Gas Turbine Power Station (80 MW) = 673 MW

(2) Power Transmission and Grid Facilities

The power transmission facilities of KESC as of June 1979 consisted of the following:

132-kV transmission line (length)	334.2 km
66-kV transmission line (length)	98.3 km

The power grid facilities of KESC as of June 1979 consisted of the following:

132/66/11-kV grid station, 16 sites	1,135 MVA

2-5 Electricity Tariffs

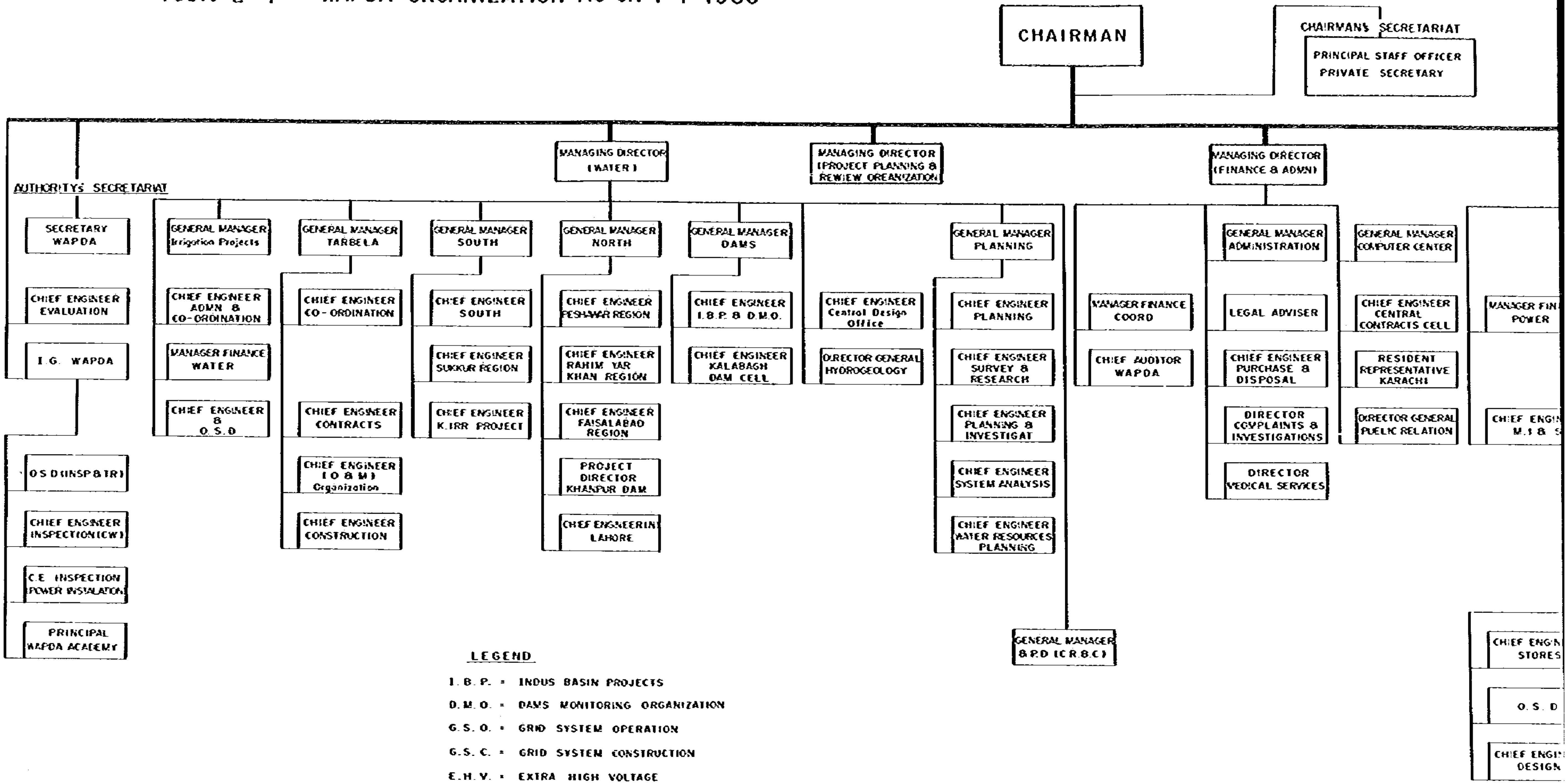
Electricity tariffs of WAPDA, effective from July 1, 1979.

(1)	Domestic and General	
	First 40 units	31.0 Paisa/kWh
	For the balance	35.0 Paisa/kWh
	Minimum charge	Rs 5.00 Point/month
(2)	Offices and Commercial	
	First 100 units	85.0 Paisa/kWh
	For the balance	95.0 Paisa/kWh
	Minimum charge	Rs 15.00 Point/month
(3)	Industrial Supply	
	Single phase 230V and 3 phase 440V	
	Up to and including 70 kW	52.0 Paisa/kWh
	Minimum charge	
	Up to and including 20 kW	Rs 20.00/kW/month
	Exceeding 20 kW to 70 kW	Rs 25.00/kW/month
(4)	Industrial Supply	
	3 phase 400V	
	Above 70 kW to 500 kW	Rs 50.00/kW/month of declared load + 36.0 Paisa/kWh
(5)	Industrial Supply	
	At 11 kV, all load	Rs 45.00/kW/month of declared load + 35.0 Paisa/kWh

(6)	Industrial Supply	
	At 33 kV, 66 kV and 132 kV	
	All load in excess of 5,000 kW	Rs 42.00/kW/month of declared load + 32.0 Paisa/kWh
(7)	Bulk Supply	
	At 400V	
	Licensees and non-licensees	32.0 Paisa/kWh
	Others	40.0 Paisa/kWh
	Railway, public facilities, etc.	Rs 45.00/kW/month of declared load + 35.0 Paisa/kWh
	In flate rate	28.0 Paisa/kWh
(8)	Bulk Supply	
	At 11 kV	
	Licensees and non-licensees	35 Paisa/kWh
	Railway, public facilities, etc.	Rs 41.00/kW/month of declared load + 34.0 Paisa/kWh
(9)	Bulk Supply	
	At 33 kV, 66 kV and 132 kV	
	Licensees and non-licensees	34.0 Paisa/kWh
	Railway, public facilities, etc.	Rs 39.50/kW/month of declared load + 33.0 Paisa/kWh
(10)	Agricultural Tube Wells and Lift Irrigation Pumps	
	SCARP	31.0 Paisa/kWh
	Pumjab and Sind regions	Rs 11.00/kW/month of declared load + 19.0 Paisa/kWh
	N.W.F.P. and Quetta areas	Rs 9.00/kW/month of declared load + 13.0 Paisa/kWh
(11)	Temporary General Supply	
	Domestic	70.0 Paisa/kWh
	Commercial	125 Paisa/kWh
	Minimum bill	Rs 13.00/day
	but not less than Rs 51.00 for the period of temporary supply	
(12)	Temporary Industrial and Bulk Supply	
	Industrial supply	77.0 Paisa/kWh
	Licensees and non-licensees	
	At 400V	51.0 Paisa/kWh
	At 11 kV	46.0 Paisa/kWh
	Railway, public facilities, etc.	68.0 Paisa/kWh

(13)	Seasonable Industrial Supply	125% of the charge for regular industry
(14)	Public Lighting	
	1) Supply charge	65.0 Paisa/kWh
	2) Fixed line charge per month per miles	
	Entire capital cost is borne by WAPDA.	Rs 109.50
	Entire capital cost is borne by the local body.	Rs 9.75
	Capital cost in laying street lighting supply line over the existing distribution system is borne by WAPDA.	Rs 68.50
	Capital cost is borne by the local body.	Rs 14.00
	3) Fixed lamps and fixtures charge per month per lamp of capacity	
	Ordinary lamps, provided and installed by WAPDA.	
	Up to 60W	Rs 2.25
	From 60W to 100W	Rs 2.75
	Above 100W to 200W	Rs 6.00
	Above 200W to 300W	Rs 7.50
	Above 300W	on application
	Fluorescent tubes, provided by local body but installed by WAPDA.	
	For all wattage	Rs 5.00
	Special mercury vapor lamps, provided by local body but installed by WAPDA	
	For all wattage	Rs 7.50
(15)	Supply to residential colonies attached to the premises of industrial supply consumers having their own distribution facilities at their colonies	
	1) Consumers who provided their own transformers for receiving and controlling the supply	52.0 Paisa/kWh
	2) Consumers who do not provide the above at item (1)	53.0 Paisa/kWh
(16)	Tariff for Electric Traction	
	(Lahore-Khanewal section)	17.5 Paisa/kWh

Table 2-1 WAPDA ORGANIZATION AS ON 1-1-1980



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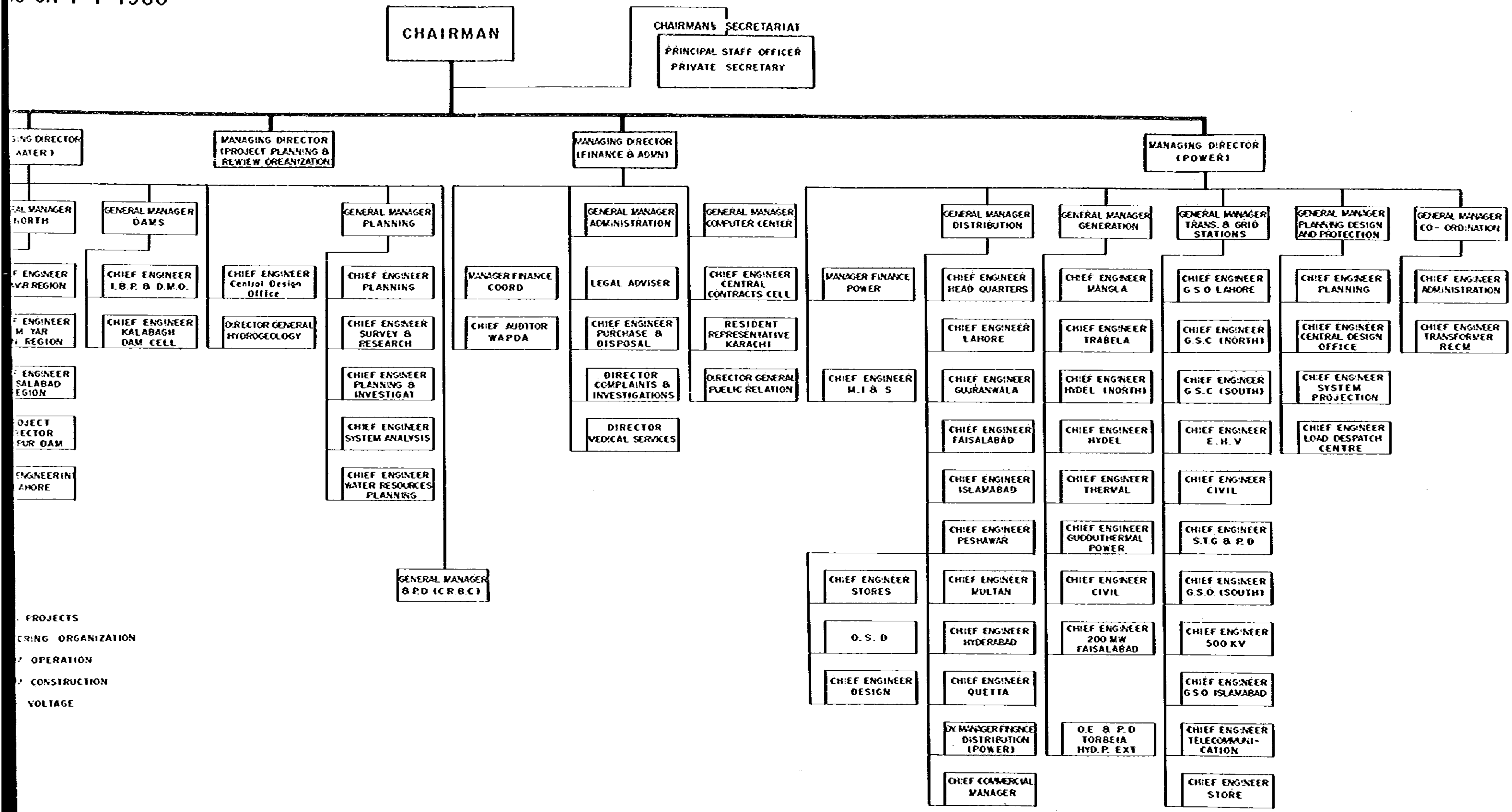
CHAIRMAN
CHAIRMANS SECRETARIAT
PRINCIPAL STAFF OFFICER
PRIVATE SECRETARY
ING DIRECTOR
ATER)
MANAGING DIRECTOR (PROJECT PLANNING & REWIEW ORGANIZATION)
MANAGING DIRECTOR (FINANCE & ADMN)
MANAGING DIRECTOR (POWER)
AL MANAGER NORTH
GENERAL MANAGER DAMS
GENERAL MANAGER PLANNING
GENERAL MANAGER ADMINISTRATION
GENERAL MANAGER COMPUTER CENTER
GENERAL MANAGER DISTRIBUTION
GENERAL MANAGER GENERATION
GENERAL MANAGER TRANS. & GRID STATIONS
GENERAL MANAGER PLANNING DESIGN AND PROTECTION
GENERAL MANAGER CO-ORDINATION
F ENGINEER
VR REGION
F ENGINEER
M YAR
REGION
F ENGINEER
SALABAD
EGION
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ECTOR
FUR DAM
NGINEERIN
AHORE
CHIEF ENGINEER I.B.P. & D.M.O.
CHIEF ENGINEER KALABAGH DAM CELL
CHIEF ENGINEER Central Design Office
DIRECTOR GENERAL HYDROGEOLOGY
CHIEF ENGINEER PLANNING
CHIEF ENGINEER SURVEY & RESEARCH
CHIEF ENGINEER PLANNING & INVESTIGAT
CHIEF ENGINEER SYSTEM ANALYSIS
CHIEF ENGINEER WATER RESOURCES PLANNING
GENERAL MANAGER & P.D (C R B C)
MANAGER FINANCE COORD
CHIEF AUDITOR WAPDA
LEGAL ADVISER
CHIEF ENGINEER PURCHASE & DISPOSAL
DIRECTOR COMPLAINTS & INVESTIGATIONS
DIRECTOR MEDICAL SERVICES
CHIEF ENGINEER CENTRAL CONTRACTS CELL
RESIDENT REPRESENTATIVE KARACHI
DIRECTOR GENERAL PUBLIC RELATION
MANAGER FINANCE POWER
CHIEF ENGINEER M.I & S
CHIEF ENGINEER STORES
O. S. D
CHIEF ENGINEER DESIGN
CHIEF ENGINEER HEAD QUARTERS
CHIEF ENGINEER LAHORE
CHIEF ENGINEER GUJRANWALA
CHIEF ENGINEER FAISALABAD
CHIEF ENGINEER ISLAMABAD
CHIEF ENGINEER PESHAWAR
CHIEF ENGINEER MULTAN
CHIEF ENGINEER HYDERABAD
CHIEF ENGINEER QUETTA
DY. MANAGER FINANCE DISTRIBUTION (POWER)
CHIEF COMMERCIAL MANAGER
CHIEF ENGINEER MANGLA
CHIEF ENGINEER TRABELA
CHIEF ENGINEER HYDEL (NORTH)
CHIEF ENGINEER HYDEL
CHIEF ENGINEER THERMAL
CHIEF ENGINEER GUDDUTHERMAL POWER
CHIEF ENGINEER CIVIL
CHIEF ENGINEER 200 MW FAISALABAD
O.E & P.D TORBELA HYD.P. EXT
CHIEF ENGINEER G.S.O LAHORE
CHIEF ENGINEER G.S.C (NORTH)
CHIEF ENGINEER G.S.C (SOUTH)
CHIEF ENGINEER E.H.V
CHIEF ENGINEER CIVIL
CHIEF ENGINEER S.T.G & P.D
CHIEF ENGINEER G.S.O. (SOUTH)
CHIEF ENGINEER 500 KV
CHIEF ENGINEER G.S.O ISLAMABAD
CHIEF ENGINEER TELECOMMUNI-CATION
CHIEF ENGINEER STORE
CHIEF ENGINEER PLANNING
CHIEF ENGINEER CENTRAL DESIGN OFFICE
CHIEF ENGINEER SYSTEM PROJECTION
CHIEF ENGINEER LOAD DESPATCH CENTRE
CHIEF ENGINEER ADMINISTRATION
CHIEF ENGINEER TRANSFORMER RECM
PROJECTS
ERING ORGANIZATION
OPERATION
CONSTRUCTION
VOLTAGE

Table 2-2 Growth of the Power Generating Facilities in Pakistan

As of June 1979

Year	WAPDA MW			KESC MW	PAEC MW	Private MW	REPCO MW	MESCO MW	Total MW
	Hydro	Thermal	Sub-total						
1959 – 60	253	113	366						366
1960 – 61	267	197	464						464
1961 – 62	267	190	457						457
1962 – 63	267	202	469						469
1963 – 64	267	332	599						599
1964 – 65	267	369	636	258					894
1965 – 66	267	375	642	258					900
1966 – 67	267	441	708	258					966
1967 – 68	567	573	1,140	258					1,398
1968 – 69	667	567	1,234	258					1,492
1969 – 70	667	656	1,323	383					1,706
1970 – 71	667	650	1,317	383					1,700
1971 – 72	667	650	1,317	383	137				1,837
1972 – 73	667	656	1,323	383	137				1,843
1973 – 74	867	753	1,620	383	137				2,140
1974 – 75	867	873	1,740	383	137	90.22			2,350
1975 – 76	867	1,068	1,935	383	137	90.22			2,545
1976 – 77	1,567	1,068	2,635	383	137	90.22			3,245
1977 – 78	1,567	1,068	2,635	508	137	90.37			3,370
1978 – 79	1,567	1,118	2,685	608	137	90.37	9.08	23	3,552

Table 2-3 Power Generating Facilities of WAPDA

As of June 1979

Name of Station		Capacity x No. of Unit	Total Capacity
Hydro Power			1,567
Tarber		175 x 4	700
Mangla		100 x 6	600
Warsak		40 x 4	160
Rasul		11 x 2	22
Malakand		3.2 x 2 5 x 2	20
Dargai		5 x 4	20
Nandipur		4.6 x 3	14
Chichoki		4.4 x 3	13
Shadiwal		6.75 x 2	13
Kurram Garhi		1 x 4	4
Renala		0.22 x 5	1
Thermal Power			1,118
Multan	Steam	65 x 4	260
Guddu	Steam	110 x 2	220
Faisalabad	Gas Turbine	25 x 8	200
Faisalabad	Steam	66 x 2	132
Shahdara	Gas Turbine	13.25 x 2 14.75 x 4	85
Sukkur	Steam	12.25 x 4	50
Quetta	Steam	7.5 x 2	15
Quetta	Gas Turbine	7 x 1 12.25 x 1 25 x 1	33
Hyderabad	Steam	7.5 x 2	15
Hyderabad	Gas Turbine	5 x 1 8 x 1 15 x 1	28
Kotri	Gas Turbine	15 x 2 25 x 2	80
Total			2,685

Table 2-4 Power Transmission Facilities of WAPDA

As of June 1979
In terms of length: km

Province	500 kV	220 kV	132 kV	66 kV	Total
Punjab	330	939	3,352	4,363	8,984
Sind	–	120	1,705	971	2,796
N.W.F.	–	8	538	649	1,195
Baluchistan	–	152	290	234	676
Total	330	1,219	5,885	6,217	13,651

Table 2-5 Power Grid Facilities of WAPDA

As of June 1979

Province	220 kV		132 kV		66 kV		Total	
	No.	Capacity (MVA)	No.	Capacity (MVA)	No.	Capacity (MVA)	No.	Capacity (MVA)
Punjab	4	1,310	111	3,380.45	125	1,416.43	240	6,106.88
Sind	–	–	35	649.27	20	166.00	55	815.27
N.W.F.	–	–	16	489.50	27	260.00	43	749.50
Baluchistan	–	–	4	89.00	10	109.00	14	198.00
Total	4	1,310	166	4,608.22	182	1,951.43	352	7,869.65

Table 2-6 Power Generating Facilities of KESC

As of June 1979

Name of Power Station	Capacity (MW)
Thermal Power	
West Wharf Station A	15
West Wharf Station B	30
West Wharf Station BX	66
Dual Fuel Power Station	15
Korangi Creek Station 1, 2	132
Korangi Creek Station 3	125
Korangi Creek Station 4	125
Site Gas Turbine	100
Total	608

CHAPTER 3 ELECTRIC POWER DEMAND FORECAST AND DEVELOPMENT SCHEME

3-1 Electric Power Demand Forecast

3-1-1 General

The power demand forecast is very important and necessary for the development scheme to ensure a continued supply of electricity for generating facilities to energy requirements. However, the installation of new generation, transmission and distribution facilities will require a long term and an enormous sum of cost. Therefore, the power demand forecast should be the most sound and probable estimation as much as possible. But it would be difficult to forecast power demand and energy requirements for a long term.

Generally speaking, it is said that the term for forecasting is appropriate for around ten years.

Two methods are considered for estimating and analyzing the future electric power requirements. One is an analytical method that is based on detailed information of power demand available. The other is a macroscopic method projecting the growth of energy consumption in relation to the development of the national economy, forecasting a target in the national plan.

The JICA Survey Team was able to obtain the necessary data and information to carry out the Analytical Method for power demand forecast.

On the other hand, WAPDA's report of "Studying Programme for Power Development 1980–90", March, 1980 including WAPDA System Power Demand Forecast is available. The results of the studies made by the JICA Survey Team and WAPDA can be compared, as shown in (1) of 3-1-5.

3-1-2 Data and Information

The data and information collected by the JICA Survey Team in August 1980 are summarized in the following tables.

- Table 3-1 Historical Data of Power & Energy Demands from 1965 through 1980
- Table 3-2 Power Demand Forecast by WAPDA
- Table 3-3 Basic Data on GNP, GNP/capita and Energy Consumption/capita throughout Pakistan by WAPDA
- Fig. 3-1 Daily Load Curve

A meeting was held between the JICA Survey Team and the representatives of the Ministry of Water and Power, WAPDA and PMDC in Tokyo on the 11th of November and then, such fundamental information as overthrows the studies which had been performed was presented: That is, the load shedding amounting to around 300 MW should be added to the figure of the actual maximum power demand. Accordingly, the total maximum power demand should be increased.

The value of the shedding informed by WAPDA could be converted to 1,000 GWh in terms of energy consumption and requirements from the beginning of January to the end of December, 1980.

Table 3-1 Historical Data of Power & Energy Demands from 1965 through 1980

Name of Organization: WAPDA

Descriptions \ Year		1965/66	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80
(1) Installed Capacity	(MW)	642.2	708.7	1,140.7	1,234.7	1,323.7	1,317.7	1,317.7	1,323.7	1,633.7	1,836.7	1,936.7	2,636.7	2,636.7	2,686.7	2,686.7
(i) Hydel	(MW)	267	267	567	667	667	667	667	667	867	867	867	1,567	1,567	1,567	1,567
(ii) Thermal	(MW)	375.2	441.7	573.7	567.7	656.7	650.7	650.7	656.7	766.7	969.7	1,069.7	1,069.7	1,069.7	1,119.7	1,119.7
(2) Annual Gross Generation	(GWh)	2,909	3,016	3,648	4,371	5,074	5,740	6,029	6,836	7,179	8,041	8,276	8,736	10,074	10,603	12,124
(i) Hydel	(GWh)	1,425	1,530	2,482	2,792	2,915	3,449	3,679	4,355	4,141	4,359	5,436	5,183	7,466	8,357	8,717
(ii) Thermal	(GWh)	1,484	1,486	1,166	1,579	2,159	2,291	2,350	2,481	3,038	3,481	2,840	3,553	2,608	2,250	3,407
(3) Annual Energy Sold (Consumption)	(GWh)	2,089	2,097	2,486	2,939	3,600	3,966	4,137	4,599	4,742	5,212	5,315	5,452	6,490	6,981	8,160
(i) Residential	(GWh)	213	232	288	308	367	388	392	454	516	566	678	780	1,004	1,240	1,564
(ii) Comercial	(GWh)	71	72	89	93	124	146	142	159	175	184	222	246	305	336	389
(iii) Small Industries / (iv) Medium & Large Industries	(GWh)	1,042	1,095	1,242	1,361	1,646	1,756	2,109	2,222	2,251	2,244	2,261	2,295	2,596	2,770	3,154
(v) Agricultural	(GWh)	480	389	501	752	956	1,072	997	1,170	1,131	1,531	1,386	1,400	1,717	1,666	2,056
(vi) Public Lighting	(GWh)	17	12	27	16	20	22	19	22	19	20	26	29	42	70	50
(vii) Bulk and Others	(GWh)	266	297	339	409	487	582	478	572	650	667	742	702	826	899	947
(4) Population within Grid System Area	(10^3)	49,150	51,010	52,920	54,930	57,010	59,160	61,390	63,230	65,130	67,080	69,090	71,070	73,300	75,500	77,760
(5) Per Capita Energy Consumption	(kWh)	43	41	47	54	63	67	67	73	73	78	79	77	89	92	105
(6) Number of Consumers as of the End of Fiscal Year		801,475	890,100	994,680	1,072,460	1,174,625	1,284,224	1,377,788	1,477,309	1,581,154	1,706,582	1,856,373	2,049,857	2,260,441	2,528,215	2,728,767
(i) Residential		595,331	655,582	726,699	779,994	853,943	930,350	998,922	1,070,192	1,137,678	1,232,613	1,347,122	1,498,474	1,670,213	1,866,550	2,031,253
(ii) Commercial		142,110	160,617	181,239	192,993	211,901	238,147	258,328	275,273	300,219	322,250	347,168	376,284	422,901	462,950	490,084
(iii) Small Industries / (iv) Medium & Large Industries		41,317	45,804	50,728	55,812	61,330	64,494	67,056	72,158	78,277	80,735	84,250	91,365	95,636	100,946	104,942
(v) Agricultural		21,914	27,201	34,889	42,729	46,453	50,212	52,342	58,472	63,730	69,687	76,508	81,813	90,341	95,667	100,166
(vi) Public Lighting		497	541	555	555	573	587	663	684	718	740	801	926	1,118	1,315	1,505
(vii) Bulk and Others		306	355	370	377	425	434	477	530	532	557	524	722	832	787	817
(7) Energy Consumption per Consumer																
(i) Residential	(kWh)	358	354	396	395	430	417	392	424	454	459	503	521	601	664	770
(ii) Commercial	(kWh)	500	448	491	482	585	613	550	578	583	571	639	654	721	726	794
(iii) Small Industries / (iv) Medium & Large Industries	(kWh)	25,220	23,906	24,484	24,385	26,838	27,227	31,451	30,794	28,757	27,795	26,837	25,119	27,316	27,440	30,050
(v) Agricultural	(kWh)	21,904	14,301	14,360	17,599	20,580	21,349	19,048	20,010	17,747	21,970	18,116	17,112	19,006	17,415	20,526
(vi) Public Lighting	(kWh)	34,205	22,181	48,649	28,828	34,904	37,479	28,658	32,164	26,462	27,027	32,459	31,317	37,567	53,232	33,223
(vii) Bulk and Others	(kWh)	869,281	836,620	916,216	1,084,881	1,145,682	1,341,014	1,002,096	1,079,245	1,221,805	1,197,487	1,416,031	972,299	992,788	1,142,313	1,159,119
(8) System Losses Station Use	(GWh)	820	919	1,162	1,432	1,474	1,774	1,892	2,237	2,437	2,829	2,967	3,284	3,554	3,622	3,964
(i) System Losses	(GWh)	664	750	976	1,275	1,295	1,555	1,718	2,054	2,219	2,645	2,739	3,026	3,348	3,430	3,695
Loss Factor	(%)	24.1	26.3	28.2	30.3	26.5	28.2	29.3	30.9	31.9	33.7	34.0	35.7	34.0	33.0	31.2
(ii) Station Use	(GWh)	156	169	186	157	179	219	174	183	218	184	222	258	236	192	269
(iii) System Loss Factor	(%)	28.2	30.5	31.9	32.8	29.1	30.9	31.4	32.7	34.0	35.2	35.8	37.6	35.6	34.2	32.7
(9) Total System Use (3) + (8)	(GWh)	2,909	3,016	3,648	4,371	5,074	5,740	6,029	6,836	7,179	8,041	8,276	8,736	10,074	10,603	12,124
(10) Load Factor	(%)	64.2	72.3	66.6	67.9	69.5	69.1	67.2	67.8	66.0	65.8	65.5	61.6	62.6	63.1	66.7
(11) Maximum Demand	(MW)	517	476	625	735	834	948	1,024	1,148	1,242	1,396	1,437	1,620	1,836	1,972	2,076
(12) Growth Rate of Maximum Demand	(%)	–	–	31.3	17.6	13.5	13.7	8.0	12.1	8.2	12.4	2.9	12.7	13.3	7.4	5.3

Note: (1) The words "Annual Gross Generation" indicate the total amount of electric energy produced by a generating station or stations per annum, measured at the generator terminals.
(2) The number of consumers for the categories of "Agricultural" and "Public Lighting" shall be identical with that of watthour-meters, subject to WAPDA's practice.
(3) The words "Load Factor" given in (10) of the table indicate the ratio of the average load over a designated period to the peak-load occurring in that period within the grid system area.

Table 3-2 Demand Forecast by WAPDA

Year	WAPDA (MW)	KESC (MW)	Total (MW)
1980	2,421	–	–
1981	2,683	–	–
1982	2,941	–	–
1983	3,221	–	–
*1984	3,520	789	4,183
1985	3,841	856	4,560
1986	4,183	930	4,964
1987	4,547	1,009	5,394
1988	4,933	1,097	5,854
1989	5,342	1,250	6,400
1990	5,775	1,353	6,920
1991	6,225	1,460	7,461

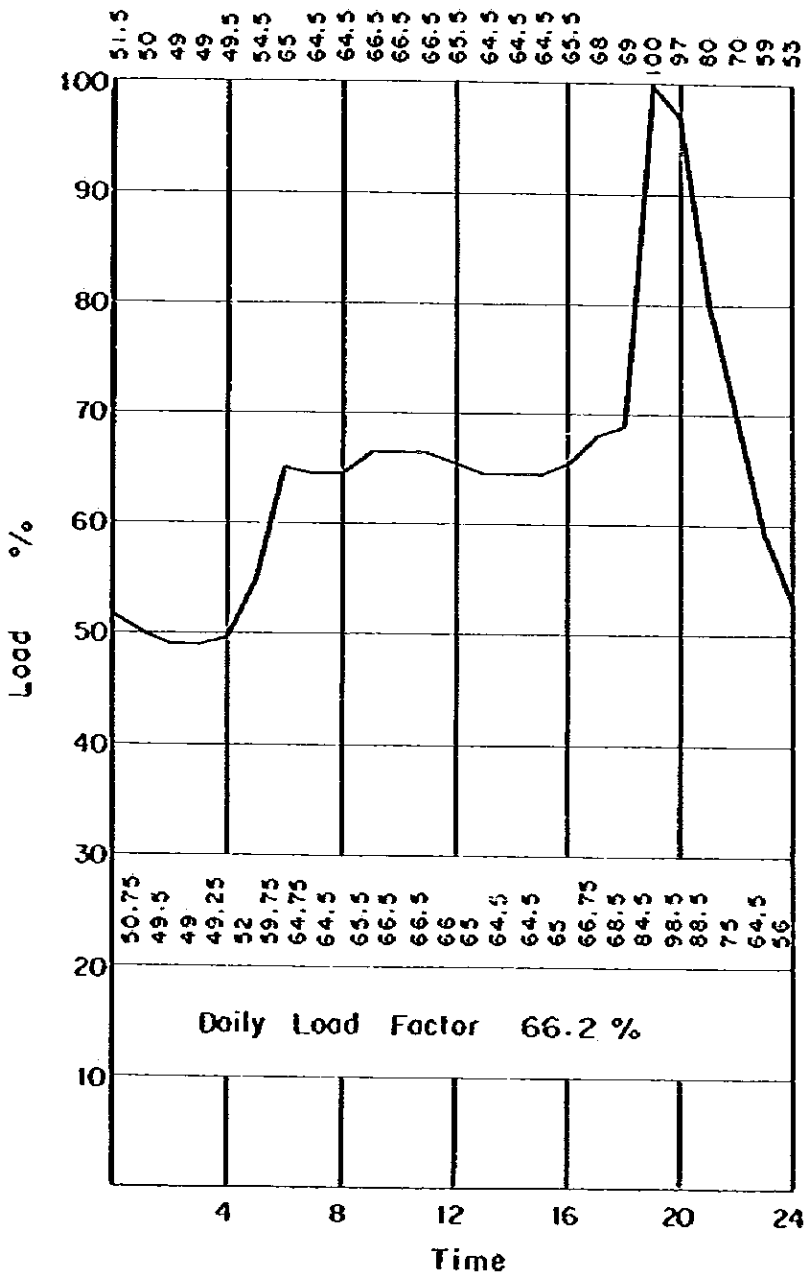
* Integration with KESC on EHV in 1984

Table 3-3 Basic Data on GNP, GNP/Capita and Energy Consumption/Capita throughout Pakistan by WAPDA

Year	Population (10^6)	GNP (10^6 Dollars)	GNP/ Capita (US$)	GNP/ Capita at Factor Cost in 1959–60 year (US$)	Energy Consumption (GWh)	Energy Consumption per Capita (KWh)	Remarks
		(at 1959–60 factor cost)			(WAPDA & KESC)	(WAPDA & KESC)	
1972	64.93	3,321	51.14	51.11	5,425	83	The figures from the year 1980 to 1995 have been forecasted.
1973	66.93	3,572	53.36	53.37	6,097	91	
1974	68.94	3,847	55.80	55.80	6,354	92	
1975	71.00	4,095	57.67	57.68	6,828	96	
1976	73.14	4,183	57.19	57.20	6,929	95	
1977	75.33	4,346	57.69	57.69	7,131	95	
1978	77.58	4,778	61.58	61.59	8,347	108	
1979	79.92	5,081	63.57	63.58	8,965	112	
1980	82.31	5,386	65.43	65.45	10,061	122	
1981	84.78	5,709	67.33	67.34	11,301	133	
1982	87.33	6,052	69.30	69.30	12,706	145	
1983	89.95	6,415	71.31	71.32	14,296	160	
1984	92.64	6,800	73.40	73.40	16,096	174	
1985	95.42	7,207	75.52	75.53	18,137	184	
1986	98.29	7,640	77.72	77.73	20,451	208	
1987	101.24	8,098	79.98	78.00	22,976	227	
1988	104.27	8,584	82.32	82.32	26,054	249	
1989	107.40	9,099	84.72	84.72	29,433	274	
1990	110.62	9,645	87.19	87.19	33,269	300	
1991	113.94	10,224	89.73	89.73	37,626	330	
1992	117.36	10,837	92.33	92.34	42,574	362	
1993	120.88	11,488	95.03	95.04	48,196	398	
1994	124.51	12,177	97.79	97.77	54,585	438	
1995	128.24	12,907	100.64	100.65	61,846	482	

Fig. 3 - 1 DAILY LOAD CURVE

(Mar . 26 . 1979 Monday)



3-1-3 Power Demand Forecast by Analytical Method on WAPDA System

The power demand forecast by the analytical method has been made in the following steps:

- Firstly, energy requirement of each category are to be forecast.
- Secondly, system loss factor and annual load factor are to be predicted.
- Finally, the maximum power demand forecast is to be made.

The data and information for this analysis are given in 3-1-2.

(1) Forecast on Energy Demand of Each Category

The category for energy demand forecast consists of the following items:

(a) Residential
On the assumption of:
- Population growth rate = 3%/year
- Incremental electrification ratio = 7%/year
- Number of customers = $(2{,}031)\,(1.07 \times 1.03)^X \times 10^3$ and
- Assumed periods for modernization = 10 years

$Y_{(a)}$ is shown in Table 3-3.

(b) Commercial

$$Y_{(b)} = (363.2)\,(1.1199)^X \quad \text{(GWh)}$$
(by least square method)

(c) Industrial

$$Y_{(b)} = (2{,}995.1)\,(1.0569)^X \quad \text{(GWh)}$$
(by least square method)

(d) Agricultural

$$Y_{(d)} = (1{,}899.1)\,(1.0733)^X \quad \text{(GWh)}$$
(by least square method)

(e) Public Lighting, Bulk and Others

$$Y_{(e)} = (983.3)\,(1.0705)^X \quad \text{(GWh)}$$
(by least square method)

(f) Latency
The latent energy of 1,000 GWh is composed of the energy demands of the "Residential", "Commercial", "Industrial", etc. as shown in (a) through (e). The above latent energy is obtained from the following proportional expression.

$$Y_{(f)} = \frac{Y_{(a)} + Y_{(b)} + Y_{(c)} + Y_{(d)} + Y_{(e)}}{9,202} \times 1,000 \text{ (GWh)}$$

where

$Y_{(a)}$: residential energy demand (GWh)
$Y_{(b)}$: commercial energy demand (GWh)
$Y_{(c)}$: industrial energy demand (GWh)
$Y_{(d)}$: agricultural energy demand (GWh)
$Y_{(e)}$: public lighting, bulk and others of energy demand (GWh)
$Y_{(f)}$: latency energy demand (GWh)
x: number of years from end of June 1980

(2) Predicted System Loss Factor

The system loss factor has come down from 37.6% in 1976–77 to 32.7% in 1970–80.

This will be anticipated to decrease mainly because of the following reasons:

- Extension of 11 kV distribution lines
- Setting up of grid stations
- Energization of 500 kV transmission lines

At the meeting held on the 11th of November 1980, JICA Survey Team and WAPDA agreed to apply the following factors as system loss factor to the prediction.

Year	Jun. 1981	Jun. '84	Jun. '90
System Loss Factor	31%	27%	25%

Interpolation method was applied to obtain the forecasts between the years of 1981–1984 and 1984–1990.

(3) Predicted Annual Load Factor

Although available daily load curve can be used for prediction of annual load factor, and it is presented in Fig. 3-1 for reference.

The actual load factors were plotted on the graph in Fig. 3-2 and the regression line was derived by the least square method.

$$ALf = 62.96 - 0.588x$$

where

Alf: Annual load factor
x: Years from the end of June 1980

(4) Forecast of Power Demand

The maximum power demand for each year is calculated by the following equation:

$$P_{max} = \frac{Y_{(a)} + Y_{(b)} + Y_{(c)} + Y_{(d)} + Y_{(e)} + Y_{(f)}}{(1 - \text{Losses factor})(AL_f)(8{,}760)} \quad (GW)$$

where

P_{max}: Maximum power demand (GW)

(5) Results

The results of the demand forecast calculated by the above-mentioned equation are as shown in Table 3-5 and such maximum power demand is plotted in Fig. 3-3.

As seen from Table 3-5, the maximum power demand in the forecast increases from 2,443 MW in 1980 to 3,808 MW in 1985 and to 5,842 MW in 1990.

The annual growth rate in the forecast comes to 9.3% from 1980 to 1985 and 8.9% from 1985 to 1990.

Fig. 3.2 Predicted System Loss Factor and Annual Load Factor

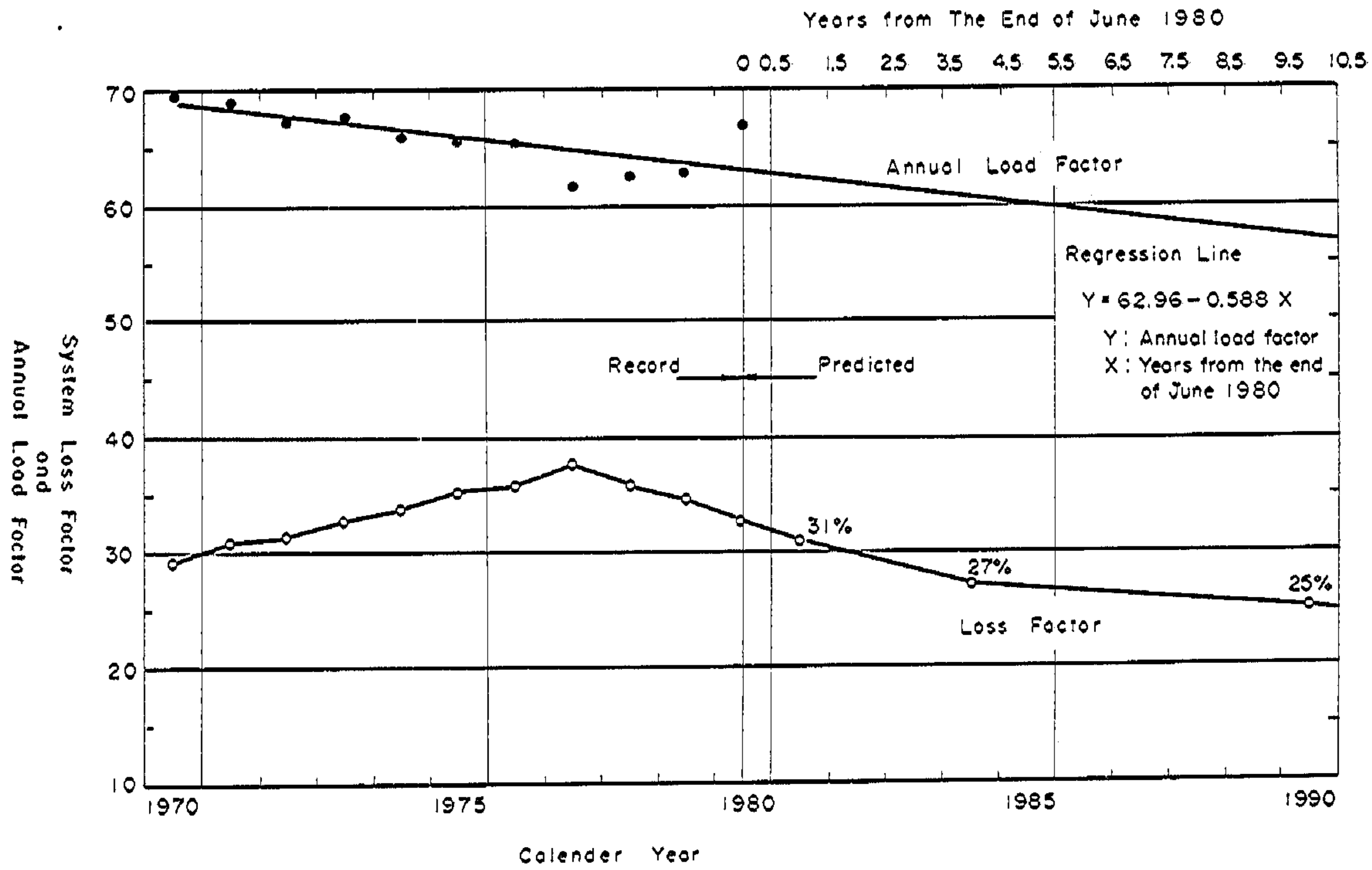


Table 3-4 Energy Demand Forecast for Residential Use

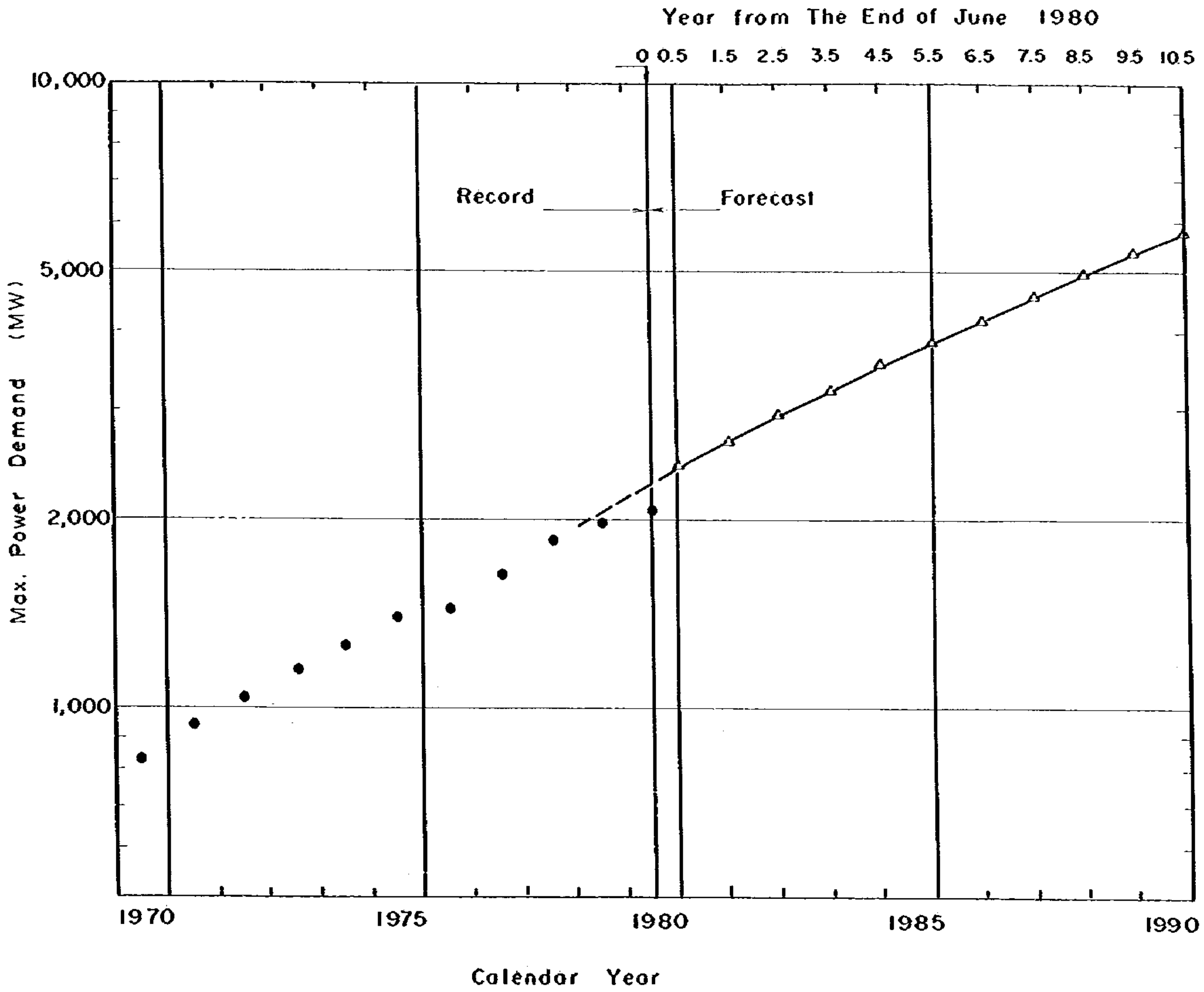
	Unit Demand (kWh)	Number of Customers x 10	Energy Demand Y(a) (GWh)	Growth Rate (%)
1975/76	503	1,347	678	–
1976/77	521	1,498	780	15.0
1977/78	602	1,670	1,004	28.7
1978/79	664	1,866	1,240	23.5
1979/80	770	2,031	1,564	26.1
1980	825	2,132	1,759	26.5
1981	932	2,350	2,190	24.5
1982	1,024	2,590	2,652	21.1
1983	1,094	2,854	3,122	17.7
1984	1,150	3,146	3,618	15.9
1985	1,176	3,467	4,077	12.7
1986	1,187	3,820	4,534	11.2
1987	1,198	4,211	5,045	11.2
1988	1,208	4,641	5,606	11.2
1989	1,219	5,115	6,235	11.2
1990	1,230	5,637	6,934	11.2

Table 3-5 Demand Forecast by Analytical Method (WAPDA Grid)

Calendar Year	WAPDA										Years from the end of June 1980
	Residential $Y_{(a)}$ (GWh)	Commercial $Y_{(b)}$ (GWh)	Industries $Y_{(c)}$ (GWh)	Agricultural $Y_{(d)}$ (GWh)	Public Lighting Bulk and Others $Y_{(e)}$ (GWh)	Latency $Y_{(f)}$ (GWh)	$Y_{(a)} + Y_{(b)} + Y_{(c)} + Y_{(d)} + Y_{(e)} + Y_{(f)}$ (GWh)	Annual Load Factor (%)	Loss Factor (%)	P_{max} (MW)	x
1980	1,759	384	3,079	1,967	1,017	1,000	9,206	62.7	31.4	2,443	0.5
1981	2,190	430	3,254	2,112	1,089	1,105	10,181	62.1	30.3	2,685	1.5
1982	2,652	482	3,440	2,266	1,166	1,219	11,225	61.5	29	2,935	2.5
1983	3,122	540	3,635	2,433	1,248	1,338	12,316	60.9	27.7	3,193	3.5
1984	3,618	605	3,842	2,611	1,336	1,464	13,476	60.3	26.8	3,485	4.5
1985	4,077	677	4,061	2,802	1,430	1,590	14,637	59.7	26.5	3,808	5.5
1986	4,534	758	4,292	3,008	1,531	1,721	15,844	59.1	26.2	4,147	6.5
1987	5,045	849	4,536	3,228	1,639	1,864	17,161	58.6	25.8	4,505	7.5
1988	5,606	951	4,794	3,465	1,755	2,019	18,590	58.0	25.5	4,911	8.5
1989	6,235	1,065	5,067	3,719	1,878	2,189	20,153	57.4	25.2	5,358	9.5
1990	6,934	1,193	5,355	3,991	2,011	2,374	21,858	56.8	24.8	5,842	10.5
a		363.2	2,995.1	1,899.1	983.3						
b		1.1199	1.0569	1.0733	1.0705						

Note: $Y = ab^x$

Fig. 3-3 Power Demand Forecast of WAPDA Grid



3-1-4 Power Demand Forecast by Macroscopic Method

It is a well-known fact that the electric energy consumption of a country has a very good correlation with economic potentials of that country. The economic activity of a country is most comprehensively expressed by the index called GNP. Since electric power is practically used in every sector of national economic activity from production to consumption, it may be considered to have an extremely good correlation with GNP when looked at over a long period of time.

Macroscopic forecasting of power demand consists of estimating the power demand over a long period of time based on the correlation between GNP per individual, that is, GNP/capita and the electric energy consumption per individual, kWh/capita. Such a correlation is governed by the economic scale and the personal income level in each country, and consequently, there is considerable difference depending on the country. However, according to statistical investigations by countries recognized by the International Atomic Energy Agency(IAEA) and the World Bank – International Bank of Reconstruction and Development (IBRD), there are several rough trend curves which exist corresponding to the respective electric energy consumption scales. The parameters necessary for this method of long-range forecasting are as listed below.

- Forecast value of average-type growth rate of GNP/capita,
- Scale of GNP/capita at present,
- Scale of kWh/capita at present,
- Degree of variation in kWh/capita corresponding to variation in scale of GNP/capita.

The basic data used in obtaining the above parameters are as follows:

- Basic data on GNP, GNP/capita and energy consumption/capita throughout Pakistan
- New method of long-range or very-long-range demand forecast of energy including electricity viewed from worldwide standpoint

The average growth rates of GNP/capita and kWh/capita of the Islamic Republic of Pakistan obtained based on these data and the values of these items for 1980 (1968 worth) are the following:

- Average growth rate of GNP/capita: 2.9%/yr
- Average growth rate of kWh/capita: 4.9%/yr
- GNP/capita as of 1980: US$104/capita (1968 worth)
- kWh/capita as of 1980: 122 kWh/capita

(1) Growth Rate for GNP/Capita

According to the data previously mentioned, the population and GNP in 1980 will be as indicated below.

- population as of 1980: 82.31×10^6
- GNP as of 1980: US$$8,584 \times 10^6$ (1968 worth)

Assuming that the average growth rates of population and GNP from 1980 to 1990 are 3%/yr and 6%/yr, respectively, the GNP/capita for 1990 will be the following:

- 1990 GNP/capita: US$139/capita (1968 worth)

(2) Correlation between GNP/Capita and kWh/Capita

According to statistical investigations by country, there is a rough correlation between GNP/capita and kWh/capita. This correlation is not the same for all countries of the world, but as shown in Fig. 3-4, it is possible to make classification into a number of groups having approximately the same correlations. On plotting a trend curve of GNP/capita and kWh/capita of the Islamic Republic of Pakistan for 1975 and 1980, it may be ascertained that it is higher than the average curve for the world.

Fig. 3-4 shows that the GNP/capita and kWh/capita for 1980 and 1990 are as follows:

- GNP/capita
  - 1980: US$104/capita
  - 1990: US$139/capita
- kWh/capita
  - 1980: 122 kWh/capita
  - 1990: 199 kWh/capita

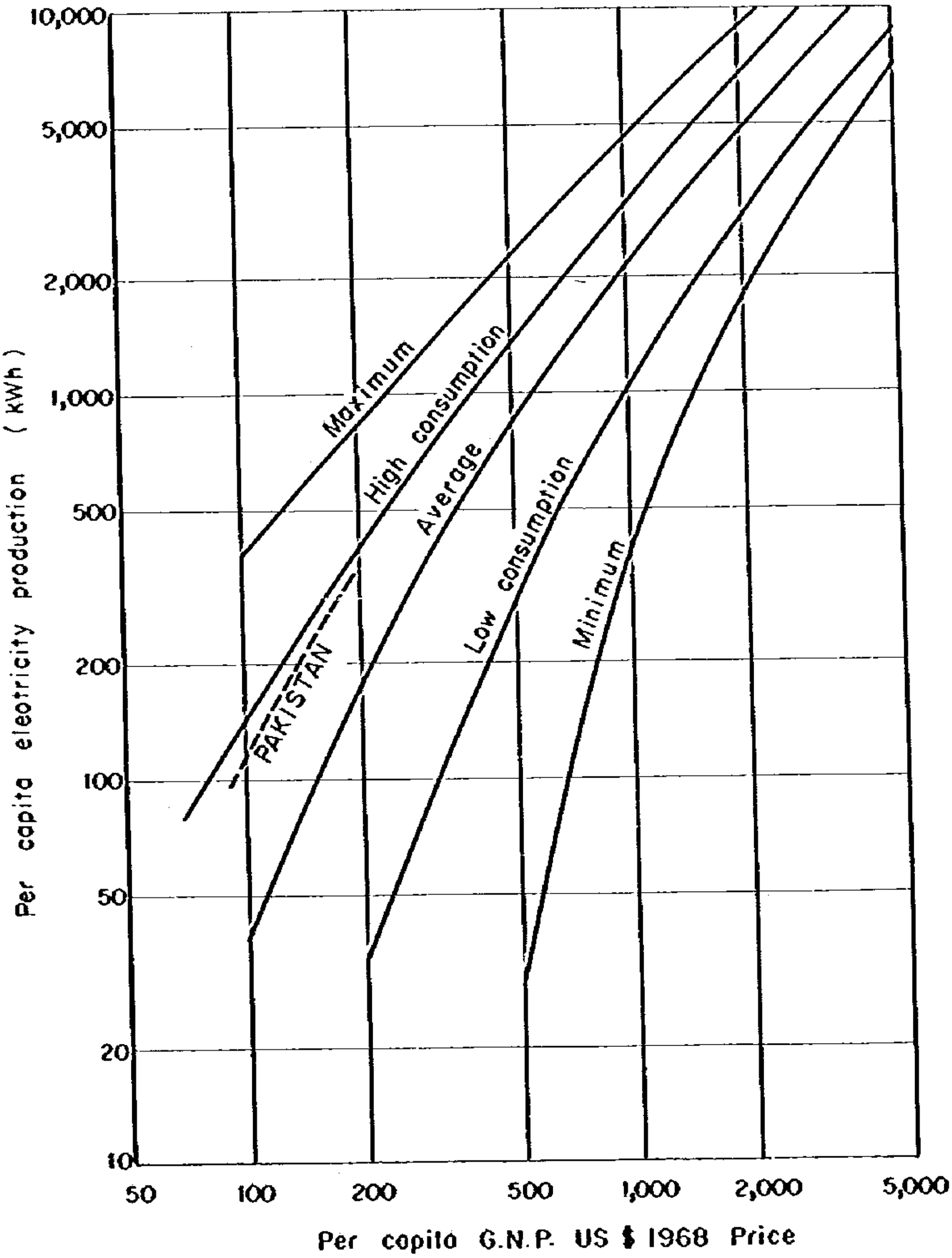
From the above results, the average growth rate for kWh/capita from 1980 to 1990 is 5%/yr.

(3) Demand Forecast for WAPDA System

The anticipated annual increase rate of 8.2% for energy requirement of the whole WAPDA system has been obtained by multiplying an annual average population growth rate of 3% by an annual average increase rate of 5% of energy requirement (kWh/capita) in the WAPDA system during the period from 1980 to 1990.

$$1.03 \times 1.05 = 1.082$$

Fig. 3-4 CORRELETION BETWEEN PER CAPITA G.N.P AND PER CAPITA ELECTRICITY PRODUCTION.



3-1-5 Conclusions for Power Demand Forecast

(1) WAPDA System

The results of power demand forecast made by WAPDA and the JICA Survey Team in connection with the present WAPDA System (not including KESC System to be amalgamated with the present WAPDA System in 1984) for the period from 1980 to 1990 are shown in the following table.
As seen from the table, there are scarcely differences in the figures of the predicted power demand between both studies.

Calendar Year	A By Analytical Method (MW)	B By WAPDA (MW)	$\frac{B}{A}$
1980	2,443	2,421	0.991
1981	2,685	2,683	0.999
1982	2,935	2,941	1.002
1983	3,193	3,221	1.008
1984	3,485	3,520	1.010
1985	3,808	3,841	1.009
Growth Rate	9.3%	9.7%	–
1985	3,808	3,841	1.009
1986	4,147	4,183	1.009
1987	4,505	4,547	1.009
1988	4,911	4,933	1.004
1989	5,358	5,342	0.997
1990	5,842	5,775	0.989
Growth Rate	8.9%	8.5%	–

(2) KESC System

It is planned for the KESC System to be amalgamated with the WAPDA System in July 1984. The maximum power demands of the KESC System from 1984 to 1990, according to the data furnished by WAPDA, are as follows:

Calendar Year	Max. Demand (MW)
1984	789
1985	856
1986	930
1987	1,009
1988	1,097
1989	1,250
1990	1,353
Growth Rate	9.4%

(3) Demand of Amalgamated WAPDA System

The forecast results for the Systems of WAPDA and KESC are shown in Table 3-6 and FIG. 3-3-5. The diversity factor is considered as being 103 %.

The maximum power demand will be 2,421 MW in December 1980. The maximum demand will reach 4,183 MW in December 1984, the year when the KESC System is to be amalgamated with WAPDA System and 6,920 MW in December of 1990.

The growth rate of annual average demand will be 8.8% in the period from 1984 through 1990.

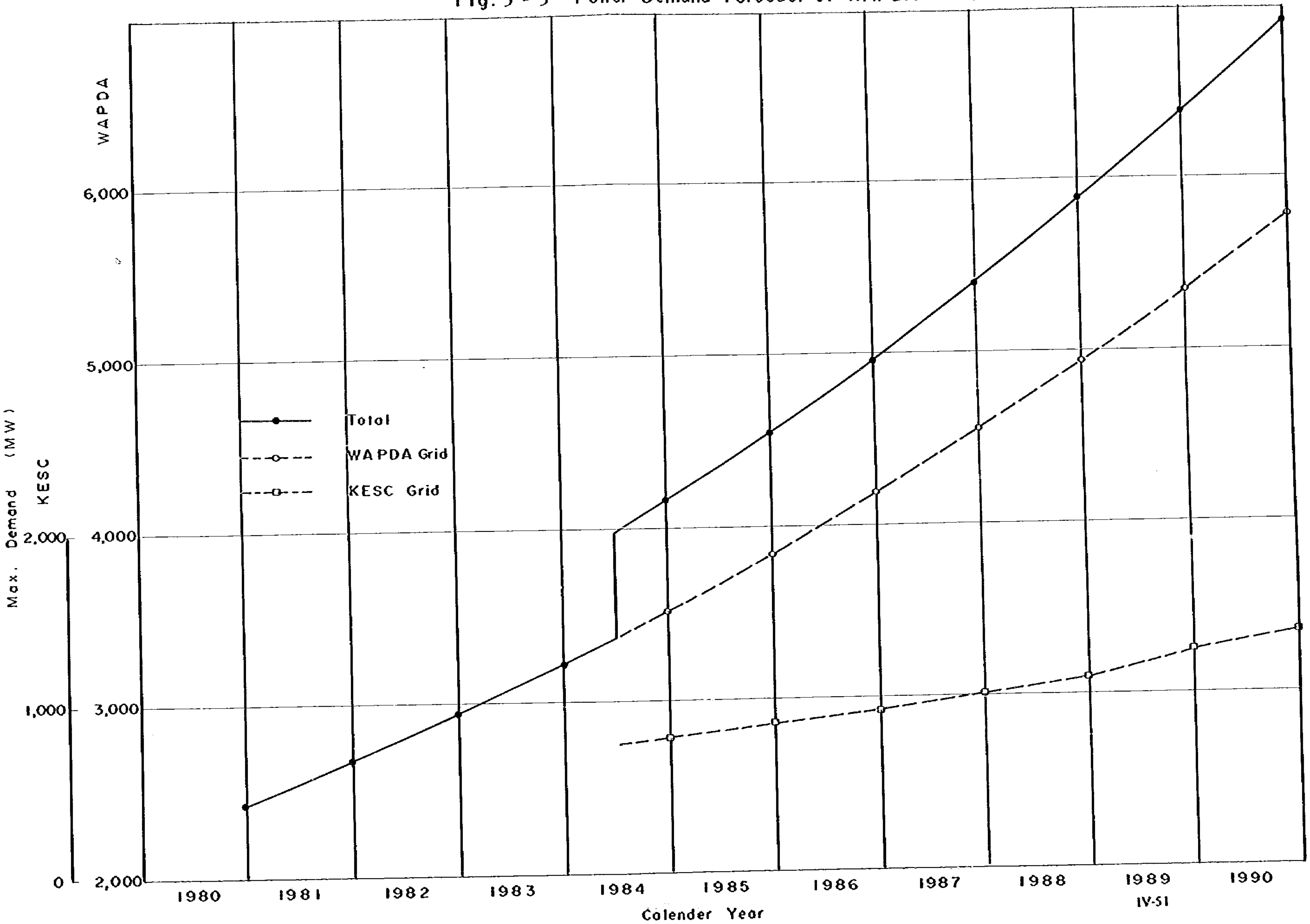
Table 3-6 Power Demand Forecast by WAPDA

Year	WAPDA (MW)	KESC (MW)	Total	
			Undiversified (MW)	Diversified (MW)
1980	2,421	–	–	–
1981	2,683	–	–	–
1982	2,941	–	–	–
1983	3,221	–	–	–
*1984	3,520	789	4,309	4,183
1985	3,841	856	4,697	4,560
1986	4,183	930	5,113	4,964
1987	4,547	1,009	5,556	5,394
1988	4,933	1,097	6,030	5,854
1989	5,342	1,250	6,592	6,400
1990	5,775	1,353	7,128	6,920
1991	6,225	1,460	7,685	7,461

* Integration with KESC on EHV in 1984

As stated before, the annual average growth rate of maximum power demand throughout Pakistan during the period from 1980 to 1990 according to the macroscopic method is calculated at 8.2%. When comparisons are made on the growth rate of maximum power demand between the figure (8.2%) obtained by the macroscopic method and the figure (8.8%) obtained from Table 3-6, there are hardly differences between both results. Accordingly, it is judged that the forecast made by WAPDA of the maximum power demand is acceptable and usable.

Fig. 3 - 5 Power Demand Forecast of WAPDA & KESC Systems



3-2 Electric Power Development Program

3-2-1 Energy Resources in Islamic Republic of Pakistan

In the Islamic Republic of Pakistan, water power and natural gas are presently the principal indigenous energy resources, and these two varieties make up a greater part of electric power energy. The production quantities of crude oil and coal are so small that these two energies are scarcely utilized for generation of electric power.

(1) Natural gas was first discovered in 1952 at Sui, and since then, there has been a number of gas fields discovered. According to the "Pakistan Year Book – 1979", it is estimated that the extractable reserves of natural gas amount to approximately 502×10^9 m^3, while the production up to the end of March 1979 was approximately 61×10^9 m^3, the production per year having been $5 - 6 \times 10^9$ m^3. The largest consumers of gas are the two large electric power companies of WAPDA and KESC, the consumption by the two making up approximately one third of the gas consumption in Pakistan. The gas is being used for producing electric energy at thermal power stations. Of WAPDA-owned thermal power generating facilities amounting to 1,118 MW, with the exception of 7.5 MW x 2 using Quetta coal, 1,103 MW, or as much as 98.7% consists of power generating facilities using natural gas.
Recently, however, prevention of exhaustion of gas resources and utilization in other fields such as chemical products have been contemplated by the Pakistani Government, and it is thought that the proportion of natural gas used for electric power will decline in the future.

(2) Hydroelectric power potentials in the Islamic Republic of Pakistan are estimated to be 25,000 – 30,000 MW, corresponding to more than 10 times the present total installed capacity of hydroelectric power generation. Hydroelectric power, as the cheapest of power sources, presently, makes up a major part of the supply capability of WAPDA, and development of hydroelectric power will continue to be carried out in the future.

(3) The first oil field in the Islamic Republic of Pakistan was discovered in 1915 in the Potwar Region near Islamabad, and since then a number of oil fields have been discovered in the same region. The petroleum production in 1977–1978 was 505×10^3 tons contrasted to which imports of crude oil and refined oil amounted to $4,551 \times 10^3$ tons. The production of domestic oil is only about 10% of the total supply of $5,056 \times 10^3$ tons (Pakistan Economic Survey 1978–79). At present, most of the thermal power stations owned by WAPDA use natural gas as fuel, and although there is no thermal power station exclusively oil-fired, WAPDA has capacity where natural gas is partially used in combination.

(4) The reserves of coal in the Islamic Republic of Pakistan are estimated to be approximately 440×10^6 tons, of which approximately 50% is concentrated in the 155-km^2 area of Lakhra Coal Mine (Pakistan Year Book – 1979). According to the survey results of the JICA Survey Team of 1980 on a 54-km^2 part of Lakhra Coal Mine, the extractable coal in this region is estimated to be approximately 35 million tons. This coal mine is located at a point approximately 30 miles north of Hyderabad, and there are expectations for supply of fuel to be made a thermal power station which will be a promising power source to satisfy demand increases in Southern Pakistan starting with

Sind Province.

3-2-2 Existing Supply Capability of WAPDA System

The capacity of the existing power generating facilities of the WAPDA System is 2,685 MW (as of July 1980), of which 1,567 MW corresponding to approximately 60% comprise hydro power generating facilities and the remaining 1,118 MW corresponding to approximately 40% comprise thermal power generating facilities. However, there are some obsolete facilities in addition to facilities which do not fully produce the rated output because of unsatisfactory design, and the total effective installed capacity is decreased about 5% to 2,553 MW.

Regarding the water resources which comprise the principal energy source, they are being used with priority for irrigation because of which the generating capability of hydro is affected not only by seasonal variations in stream flows, but also operation of irrigation facilities. In the wintertime or in the low-water season, reduction in stream flow and operation of irrigation facilities coincide so that reservoir water levels of large-capacity hydroelectric power stations such as Tarbela and Mangla are lowered, and the supply capability of hydro is reduced as much as 40 to 50%. This condition becomes severest in May with the supply capability of Tarbela declining to 30% of installed capacity, and the total capability of the WAPDA System at this time becomes 1,988 MW.

The installed capacity of WAPDA as of July 1980 is given in Table 3-7, and the monthly generating capabilities of the three largest hydro power stations in Table 3-8.

The peak demand of the WAPDA System at present is about 2,000 MW (actually 1,972 MW in 1978–79, 2,076 MW in 1979–80), and in case there should be demand of this degree in the low-water season, the situation would be one where load restrictions could not be avoided because of a lack of supply capability.

Fig. 3-6 GENERATING CAPABILITY VS MAXIMUM DEMAND

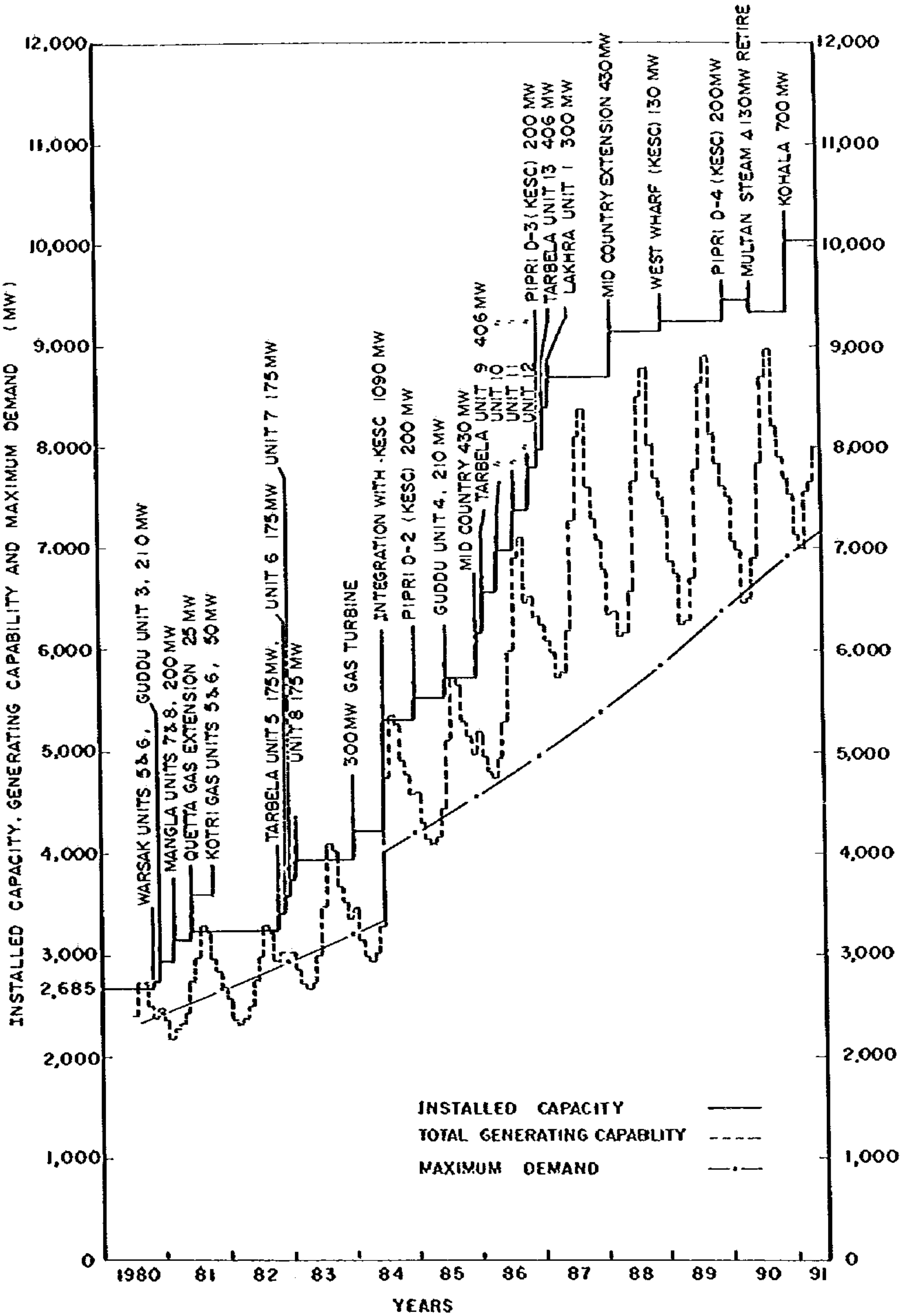


Table 3-7 Existing Generating Stations of WAPDA
(As of July 1980)

A. Hydro Power Stations (in MW)

Name of Power Station	Date of Commissioning	No. & Capacity of Units	Installed Capacity
Tarbela	May 1977 June 1977 July 1977	2 x 175 1 x 175 1 x 175	700
Mangla	July 1967 March 1968 June 1969 December 1973 March 1974	2 x 100 1 x 100 1 x 100 1 x 100 1 x 100	600
Warsak	May 1960 June 1960 July 1960	2 x 40 1 x 40 1 x 40	160
Dargai	April 1954	4 x 5	20
Malakand	1938 1951	3 x 3.2 2 x 5	20
Rasul	May 1951	2 x 11	22
Chichoki	May 1959 June 1959 August 1959	1 x 4.4 1 x 4.4 1 x 4.4	13
Shadiwal	June 1961	2 x 6.75	13
Nandipur	March 1963	3 x 4.6	14
Kurram Garhi Renala	February 1958 1925	4 x 1 5 x 0.22	4 1

Total Installed Hydro Capacity 1,567 MW

B. Thermal Power Stations (in MW)

Name of Power Station	Date of Commissioning	No. & Capacity of Units	Installed Capacity
Multan Steam	June 1960 December 1963	2 x 65 2 x 65	260
Faisalabad Steam	June 1967 November 1967	1 x 66 1 x 66	132
Faisalabad Gas Turbines	March 1975 June 1975 September 1975 October 1975 November 1975	2 x 25 2 x 25 1 x 25 2 x 25 1 x 25	200
Shahdara Gas Turbines	August 1966 October 1969	2 x 13.25 4 x 14.75	85
Guddu Steam	March 1974 October 1974	1 x 110 1 x 110	220
Sukkur Steam	March 1965 April 1967	2 x 12.5 2 x 12.5	50
Hyderabad Steam (Gas Turbine Auxiliary)	May 1960 June 1965	2 x 7.5 1 x 5.7 1 x 8 1 x 15	43
Kotri Gas Turbines	February 1970 April 1970 December 1978	1 x 15 1 x 15 2 x 25	80
Quetta	September 1964 May 1972 June 1973 January 1975	2 x 7.5 (S) 1 x 5.7 (G) 1 x 12.25(G) 1 x 25 (G)	48

Total Installed Thermal Capacity 1,118 MW

Note: S = Steam G = Gas Turbine

Table 3-8 Monthly Generating Capability of the Hydro Power Stations

Name of Power Station / Month	Tarbela (4 units)	Mangla (6 units)	Warsak (4 units)
Jul.	488	600	160
Aug.	700	600	160
Sep.	700	600	160
Oct.	700	600	120
Nov.	688	558	80
Dec.	648	492	80
Jan.	592	444	80
Feb.	500	348	80
Mar.	372	300	160
Apr.	268	408	160
May	228	572	160
Jun.	228	600	160

Source: Power Market Survey and Forecast of System Loads up to 1982/2000 by WAPDA.

3-2-3 Structure and Power Station Locations of WAPDA Power System

The electric power system of WAPDA geographically consists of the 4 power market areas of Northern, Upper Sind, Lower Sind and Quetta.

(1) Northern Power Market

This power system covers the two provinces of North West Frontier and Punjab and comprises the largest grid of the WAPDA System. The installed power generating capacity in this power system was 2,244 MW (1,567 MW hydro, 677 MW thermal) as of August 1980.

The generating capabilities of the power stations are as indicated in Table 3-9. The maximum demand in 1980 according to the forecast of WAPDA will be 2,000 MW, so that in this system at present supply capability is secured in the high-water season but there is a shortage in the low-water season.

Table 3-9 Installed Capacity and Generating Capability of Northern Power Market

(MW)

Name of Power Station	Installed Capacity	Generating Capability	
		Sept.	May
Hydro:			
Tarbela	4 x 175 = 700	800	228
Mangla	6 x 100 = 600	690	522
Warsak	4 x 40 = 160	160	160
Small Hydro	107	70	70
Sub-Total (A)	1,567	1,720	980
Thermal:			
Multan (Steam)	4 x 65 = 260	240	240
Faisalabad (Steam)	2 x 66 = 132	120	120
Faisalabad (Gas)	8 x 25 = 200	195	195
Shahdera (Gas)	2 x 13.25, 4 x 14.75 = 85	70	70
Sub-Total (B)	677	625	625
Total: (A) + (B)	2,244	2,345	1,605

Source: Working Paper for the Committee for Studying Program for Power Development (1980 – 1990)

(2) Upper Sind (Sukkur) Power Market

This power system covers Sukkur Civil Division. The power generating facilities of this system are the Guddu and Sukkur thermal power stations using natural gas as fuel, and the installed capacity of the generating facilities as of August 1980 amounted to 270 MW. Since the forecast value of maximum demand for 1980 is approximately 160 MW, it may be said that the balance of demand and supply of this system will be maintained if there is no shut-down of a unit at Guddu Thermal Power Station.

Installed Capacity and Generating Capability of Upper Sind Power Market

(MW)

Name of Power Station	Installed Capacity	Generating Capability
Guddu Steam	2 x 110	200
Sukkur Steam	4 x 12.5	40
Total	270	240

Source: Working Paper for the Committee for Studying Program for Power Development (1980 – 1990)

(3) Lower Sind (Hyderabad) Power Market

This power system is supplying electric power to Hyderabad Division. The installed power generating capacity within this system is a total of 123 MW of the Hyderabad and Kotri Thermal Power Stations. Since the forecast value of maximum demand in 1980 for this system is approximately 200 MW, the situation is one of supply capability being insufficient in this system.

Installed Capacity and Generating Capability of Lower Sind Power Market

(MW)

Name of Power Station	Installed Capacity	Generating Capability
Hyderabad Thermal	2 x 7.5, 1 x 5.7 1 x 8 , 1 x 15	30
Kotri Gas	2 x 15, 2 x 25	73
Total	123	103

Source: Working Paper for the Committee for Studying Program for Power Development (1980 – 1990)

(4) Quetta Power Market

The Power System covers the Quetta Region in Baluchistan Province. The power generating facilities in this system consist of a gas turbine at Sheibhmanda near Quetta and Quetta Thermal Power Station (48 MW) which uses Quetta coal. Since the forecast value of maximum demand in 1980 for this system is approximately 80 MW, the situation is that the supply capability is inadequate in this system.

As described in the foregoing, the WAPDA System has a feature that geographically, hydro power stations making up roughly 60% of the supply capability of the system are all located in the area of the Northern Power Market in the north with the other three power markets having the remaining 40% consisting of only thermal power stations, while the hydro supply capability consisting of the dam-type hydros of Warsak, Tarbela and Mangla are greatly affected by river runoff and irrigation water requirements to be subject to extreme seasonal variations in output.

These four power markets are presently interconnected into one grid system by 132-kV transmission lines, and partially, a 220-kV transmission lines, but in the future, the Quetta Power Market and the Upper Sind Power Market are to be interconnected by a 220-kV transmission line (November 1980), and the Northern Power Market, the Upper Sind Power Market and the Lower Sind Power Market by 500-kV transmission lines (1983–1984).

Strengthening of the power transmission network to interconnect these regions has a close relationship with the composition and distribution of electric power sources of Pakistan. Due to the strengthening of the network, it will be possible in the high-water season to transport cheap and abundant hydroelectric power from the northern region to the south allowing the thermal facilities in the southern regions to be shut down for repairs, and in the low-water season when there will be a shortage in the supply capability of hydro power stations for power generation at the thermal power stations in the south to be increased for transmission to the north.

3-2-4 Electric Power Development Program

(1) Development Program of Hydro Power Stations

In the electric power development program WAPDA puts emphasis on the development of domestic energy resources, among which hydroelectric power is valued as the most inexpensive of energy resources and its development takes priority. At present, projects for capacity increases at Tarbela, Mangla and Warsak are planned as indicated below.

Development Program of Hydro Power Stations (1980–85)

Name of Power Station	Installed Capacity	Date of Commissioning
1. Warsak Units 5 & 6	80 MW	Oct. 1980
2. Mangla Units 7 & 8	200 MW	Feb. 1981
3. Tarbela Unit 5	175 MW	Oct. 1982
4. Tarbela Unit 6	175 MW	Nov. 1982
5. Tarbela Unit 7	175 MW	Dec. 1982
6. Tarbela Unit 8	175 MW	Jan. 1983
7. Tarbela Unit 9	406 MW	Jan. 1986
8. Tarbela Unit 10	406 MW	Apr. 1986
9. Tarbela Unit 11	406 MW	Jul. 1986
10. Tarbela Unit 12	406 MW	Oct. 1986
11. Tarbela Unit 13	406 MW	Jan. 1987
Total	3,010 MW	

WAPDA is presently exploring for sites to be developed after Tarbela Unit 13 commissioned and the sites below have been listed as requiring investigations.

a) Kalabagh
b) Kohala
c) Abbasian
d) Neelam
e) Thakot
f) Upper Indus Gorge
g) Swat
h) Kunhar
i) Mangla expansion
j) Tarbela expansion

Investigations of Kalabagh have made the most progress among the sites mentioned above, while the other sites are at a prefeasibility study stage.

It is looked forward to that development of installed capacity of 1,760 MW (880 MW x 2) will be possible at Kalabagh. In view of utilization for irrigation it is planned for this site to be developed in the 1990s, and if necessary funds were to be made available, it is considered that the power station should be completed during the first of the 1990s.

At the Kohala site, topographic surveys have been made and it is considered that in case of a run-of-river type the generating capability will be 3,760 – 306 MW. This project requires further detailed investigations and it is considered that development should be in the 1990s.

(2) Development Program of Thermal Power Stations

Since hydro supply capability will decline greatly in the wintertime, even if these hydro capacities are increased, it will be necessary for thermal power stations to be simultaneously developed to secure adequate supply reliability. WAPDA is considering the use of natural gas for a supply capability next to hydro, and at present, Guddu Unit 3 (210 MW) is under construction with commissioning targeted for November 1980.

Power development projects to follow this are as listed below, with all using natural gas as fuel.

Development Program of Thermal Power Stations (1981–85)

Name of Power Station	Installed Capacity	Date of Commissioning
1. Kotri Gas Units 5 & 6	50 MW	May 1981
2. Quetta	25 MW	May 1981
3. 300 MW Gas Turbines	300 MW	Dec. 1983
4. Guddu Unit 4	210 MW	Jun. 1985
5. Mid Country Steam	430 MW	Dec. 1985
6. Pipri D-2 Steam (KESC)	200 MW	Dec. 1984
Total	1,215 MW	

According to WAPDA, there are no other hydroelectric power generating facilities scheduled to be commissioned during the 1980s following the construction of Tarbela Unit No. 13. Consequently, in order to satisfy power demand up to 1990, it will be absolutely necessary for thermal power generating facilities to be provided, and WAPDA is contemplating to materialize the following development projects:

Development Program of Thermal Power Stations (1986–90)

Name of Power Station	Installed Capacity	Date of Commissioning
Pipri D-3 Steam (KESC)	200 MW	Dec. 1986
Lakhra Steam (Coal)	300 MW	Mar. 1987
Mid Country Steam Unit No. 2	430 MW	Feb. 1988
West Wharf (KESC)	130 MW	Dec. 1988
Pipri D-4 Steam (KESC)	200 MW	Dec. 1989
Total	1,260 MW	

The development project for Lakhra Steam (coal) in the table above is the original plan of WAPDA altered as a result of the present feasibility study.

3-2-5 Demand and Supply Balance

The transitions in the installed power generating capacity of the WAPDA System based on the beforementioned electric power development program is indicated in Table 3-10. Since it is planned for WAPDA to absorb the KESC Power System in 1984, the installed capacity in 1984 and subsequent years includes the generating facilities of KESC.

The monthly generating capabilities of the WAPDA System for the next ten years have been estimated, based on the results of the present feasibility study in addition to the data furnished by WAPDA, including those on Lakhra Coal-fired Thermal Power Station.

The annual variations of the installed power generating capacity, generating capability and maximum demand of the WAPDA System are as indicated in Fig. 3-6.

As seen from the above Figure, the generating capability varies with the seasonal fluctuations in output.

In the next five years the generating capability in the high-water season (August – October) has enough capability margin for maximum demand, but that in the low-water season (February – May) is fairly less than maximum demand and so load shedding could not be avoided.

After increase in units at Tarbela is completed, the generating capability in the high-water season will provide a considerable surplus in comparison with maximum demand, and that in the low-water season will be surpass the maximum demand, with a capability margin ratio of 11 to 12% in 1987/88. However, generating capability will decrease to be less than the figure of the maximum demand in the low-water month in 1990.

According to Table 3-11, the capability margin ratio in the high-water season (as represented by the month of September) will be nearly 30% to 60%, but that in the low-water season (as represented by the month of May) will be nine to minus seven percent except for 1987–88.

Meanwhile, the ratio of the maximum unit capacity in the system to the maximum demand will be 6 to 8%.

The capability margin ratio should be at least more than 15 to 16% of the maximum demand, considering shut-down of the two largest units which will be needed for inspection and/or repair of faults and/or accidents.

The installed capacity is fairly larger, compared with the maximum demand, but the power system will not have adequate supply capability against serious power shortages during the low-water months.

In order to secure a maintenance reserve and possess ample reserve capacity of the system, it will be necessary for a development program to be formulated for the following dependable capacity:

Dependable Capacity = Generating Capability — Combined Capacity of Two Largest Units

and simultaneously the following should be considered to make a power system with high reliability:

(1) Minimizing as much as practicable the seasonal variations in outputs of hydro power stations

(2) Developing power sources such as thermal power stations to compensate for output reduction of hydro power stations in the low-water season

(3) Making unit capacities small to raise the activity rate of facilities

(4) Lowering of outage rates of units through proper maintenance and control

(5) Increasing reliabilities of transmission lines

Table 3-10 Power Development Plan and Total Installed Capacity

Year	Total Installed Capacity (MW)	Power Development Plan
1980 July	2,685	Existing total installed capacity of WAPDA System
Nov.	2,765	Warsak Units 5 & 6, 80 MW, Oct. 1980
Dec.	2,965	Guddu Unit 3, 210 MW, Nov. 1980
1981 Mar.	3,175	Mangla Units 7 & 8, 200 MW, Feb. 1981
Jun.	3,250	Quetta Gas Extension 25 MW, May 1981
		Kotri Gas Units 5 & 6, 50 MW, May 1981
1982 Nov.	3,425	Tarbela Unit 5, 175 MW, Oct. 1982
Dec.	3,600	Tarbela Unit 6, 175 MW, Nov. 1982
1983 Jan.	3,775	Tarbela Unit 7, 175 MW, Dec. 1982
Feb.	3,950	Tarbela Unit 8, 175 MW, Jan. 1983
1984 Jan.	4,250	300 MW Gas Turbine, Dec. 1983
	5,340	Integration with KESC, 1,090 MW, 1984
1985 Jan.	5,540	Pipri D-2 (KESC) 200 MW, Dec. 1984
Jul.	5,750	Guddu Unit 4, 210 MW, Jun. 1985
1986 Jan.	6,180	Mid Country 430 MW, Dec. 1985
Feb.	6,586	Tarbela Unit 9, 406 MW, Jan. 1986
May	6,992	Tarbela Unit 10, 406 MW, Apr. 1986
Aug.	7,398	Tarbela Unit 11, 406 MW, Jul. 1986
Nov.	7,804	Tarbela Unit 12, 406 MW, Oct. 1986
1987 Jan.	8,004	Pipri D-3 (KESC) 200 MW, Dec. 1986
Feb.	8,410	Tarbela Unit 13, 406 MW, Jan. 1987
Mar.	8,710	Lakhra Unit 1, 300 MW, Mar. 1987
1988 Mar.	9,140	Mid Country Extension 430 MW, Feb. 1988
1989 Jan.	9,270	West Wharf (KESC) 130 MW, Dec. 1988
1990 Jan.	9,470	Pipri D-4 (KESC) 200 MW, Dec. 1989
Jun.	9,340	Multan Steam Δ130 MW Retire, Jun. 1990
1991 Jan.	10,040	Kohala 700 MW, Dec. 1990

Table 3-11 Yearly Demand Supply Balance

Item \ Year / Month	1981		'82		'83		'84		'85		'86		'87		'88		'89		'90	
	May	Sept.	May	Sept.	May	Sept.	May	Sept.	May	Sept.	May	Sept.	May	Sept.	May	Sept.	May	Sept.	May	Sept.
1. Generating Capability (MW)	2,442	3,224	2,508	3,224	2,736	4,024	3,021	5,265	4,167	5,655	4,950	7,101	5,768	8,388	6,168	8,788	6,293	8,913	6,483	8,983
2. Maximum Demand (MW)	2,460	2,623	2,697	2,875	2,953	3,149	3,227	4,089	4,181	4,457	4,551	4,852	4,946	5,273	5,368	5,722	5,868	6,256	6,345	6,764
3. Capability Margin (MW) (1) − (2)	−18	601	−189	349	−217	875	−206	1,176	−14	1,198	399	2,249	822	3,115	800	3,066	425	2,657	138	2,219
4. Capability Margin Ratio (%) $\frac{(3)}{(2)} \times 100$	−0.7	22.9	−7.0	12.1	−7.3	27.8	−6.4	28.8	−0.3	26.9	8.77	46.4	16.6	59.1	14.9	53.6	7.24	42.5	2.11	32.8
5. Capacity of the Largest Unit (MW)	200 (Hydro)	200	200	200	200	200	200	200	200	200	400 (Thermal)	406 (Hydro)	400	406	400	406	400	406	400	406
6. Largest Unit Capacity Ratio (%) $\frac{(5)}{(2)} \times 100$	8.1	7.6	7.4	7.0	6.8	6.4	6.2	4.9	4.8	4.5	8.8	8.4	8.1	7.7	7.5	7.1	6.8	6.5	6.3	6.0
7. (4) − (6) (%)	−8.8	15.3	−14.4	5.1	−14.1	21.4	−12.6	23.9	−5.1	22.4	−0.03	38.0	8.5	51.4	7.4	46.5	0.44	36	−4.2	26.8

Note: 1) Generating capability is estimated based on the data offered by WAPDA.
2) Maximum demand is based on "Working Paper for the Committee for Studying Programme for Power Development (1980–90) – March 1980" by WAPDA.
3) Capability Margin: The difference between net system generating capability and system maximum demand.
4) Figures of "Capacity of the Largest Unit" show power at sending end.

CHAPTER 4 SELECTION OF MOST SUITABLE SITE FOR COAL-FIRED THERMAL POWER STATION

The JICA Survey Team conducted site surveys to select the most appropriate site for the coal-fired thermal power station including water intake facilities from among the three possible sites. The JICA Survey Team visited the Irrigation Department, Municipal Corporation, Indus Gas Company, Sind University, Liaquat Medical College and other governmental agencies to collect and gather necessary information for this purpose. Also, the first-hand information was collected through interviewing inhabitants living in these three sites. After their return home to Tokyo, the JICA Survey Team devoted themselves to analysis of data and information thus collected and selected the most desirable site on the basis of the criteria of site selection described in 4-1 attached hereto.

4-1 Criteria of Site Selection

In order to select the most suitable site from among the three possible sites, it is necessary to study various conditions and requirements. As criteria of site selection, the following points were mainly taken into account:

(1) The site is to be located near load centers. Taking in and taking out of transmission lines are to be easily made, and transmission line routes should be favorable in respect of constructing and operating them.

(2) Fuel is easily available.

(3) Ash disposal area can be found in suitable places near the proposed power plant site.

(4) A sufficient amount of cooling water for steam condensers is to be available.

(5) Industrial water is to be available.

(6) The site should have ample space for coal storage.

(7) Land for the power station can be obtainable in low price for future expansion.

(8) Land can be acquired easily.

(9) Land development is easy.

(10) The site is hardly affected by typhoons, floods and downpours.

(11) The operation of the power station will hardly influence on the environment.

(12) Access to the site is to be easily made and well prepared.

(13) The living conditions at and in the neighborhood of the site are well arranged.

(14) Ample good-qualitied manpower for construction, operation and maintenance of the power station is to be easily available.

4-2 Conditions of Possible Sites

4-2-1 Jamshoro

(1) Conditions of Site in Jamshoro

1) Location

The Jamshoro area is located on the right-hand bank of the Indus River. It is about 170 kilometers to the east-northeast of Karachi City, the greatest city in Pakistan. The city nearest to the Jamshoro area is Hyderabad City located on the left-hand bank of the Indus River and is at a distance of about 18 kilometers to the south of the Jamshoro area.

The site of water intake for the power plant condensers is located at Bada Village on the Indus River and is about 3.7 kilometers to the east of the power station site.

Near the would-be site of the power station, situated are the 132 kV Jamshoro Grid Station, Sind University Railway Station, Sind University, Mehran Engineering and Technological University and Liaquat Medical College.

2) Access

Access is made to the power station site by passing the Super Highway, National Highway and National Road (New Petaro Road).

There is an existing railway between Karachi City and Dadu. Therefore, access to the power station site is easily made by utilizing the Sind University Railway Station on the National Highway near the site.

Airline service is also available between the Karachi Airport and the Hyderabad Airport to the southwest of Hyderabad City.

3) Weather

Summer (from March to October) in the Hyderabad area is a rainy season. However, the rainfall in that season is not so much and temperature is very high. In winter (from November to February), it rarely rains and temperature is mild.

According to the statistics for the nineteen years from 1961 to 1979, the average of the yearly maximum of monthly rainfall was 90.3 mm and the highest temperature was 48°C (in May 1976). The average of monthly maximum temperature in summer was 45°C. The average of yearly minimum of monthly rainfall in the same period was as small as 4.3 mm. The lowest temperature was minus 2.2°C (in June 1967) and the average of monthly minimum temperature was 10.8°C (in Jan.). The highest value and lowest value of monthly average humidity were 81.3% and 24.0%, respectively.

In summer, wind blows from the southwest. Maximum wind velocity is 27.3 m/sec. Sometimes, there come severe sand storms. In winter, wind blows from the northwest at an average wind velocity of 1.4 m/sec.

4) Topography

The site in the Jamshoro area is a slope descending slowly to the east or southeast. Although there are some hills, the site has relatively gentle relief. The site is about ten meters higher than the flood level of the Indus River so that safety is assured even when a flood is caused by a heavy rainfall in the rainy season. The site of the water intake facilities is a low plain which is inundated upon occurrence of floods.

5) Geology

The site in the Jamshoro area is covered with the Laki limestone layer containing various marls and shales. The earth surface of the site for the cooling water intake facilities consists of the silt layer supposed to be formed by floods.

6) Land

It is estimated that the construction of the thermal power station will require an area of about 2.5 Km^2. The site in the Jamshoro area has a sufficient area for that purpose.

7) Water

The site for condenser cooling water intake facilities is located at Bada Village about 4.4 kilometers upstream from the Kotori Barrage. Cooling water will be taken from the Indus River. According to the data in the past five years (1975 to 1979), the minimum inflow into the Kotori Barrage is 20.5 m^3/sec. Therefore, the amount of water required for cooling of condensers can be secured. When the gates for the Kotori Barrage are overhauled, the water depth of the Indus River decreases to about 3.3 meters. To meet this, some proper measures must be taken. Because industrial water can not be obtained directly from external facilities, an industrial water production equipment utilizing water from the Indus River must be installed within the premises of the power station. Water in the Indus River is very muddy. According to the data gathered so far, turbidity (SS) is 680 ppm minimum and 3,500 ppm maximum. Some means of purifying the river water must be adopted to produce industrial water.

8) Fuel

As fuel, lignite to be produced at the Lakhra Coal Mine located at a distance of about 30 kilometers from the site for the power plant in the Jamshoro area will be used.

The Pakistani Government has recently decided that the use of natural gas should not be allowed to use natural gas for newly constructed power plants. Nevertheless only small amount of natural gas will be used in the power plant for ignition of coal burners, and it will be essential that natural gas be procured by WAPDA on its own responsibility. The gas pipeline spreads up to a point of about 3.5 kilometers from the power plant site.

9) Manpower

The manpower required for construction, operation and maintenance of the thermal power plant will be available within the Hyderabad Division. Also, professional manpower will be secured because there are Sind University and Mehran Engineering and Technological University in the Jamshoro area.

10) Transporation

Coal will be carried from the coal mine to Khanot Railway Station by the railway newly installed, therefrom to the vicinity of Petaro on the existing railway. Then, it will be transported through the sidetrack which will be newly laid and will be unloaded at the Coal Storage Yard in the power station. Materials, equipment and facilities necessary for the construction, operation and maintenance of the power station can be transported through the following two routes:

a) The materials, equipment and facilities will be transported by railway from Karachi to Sind University Railway Station. Trucks or trailers will carry them from Sind University Railway Station to the site along the National Highway and National Road.

b) The materials, equipment and facilities will be transported by trucks and trailers by utilizing the Super Highway, National Highway and National Road.

11) Power transmission lines
The site for the proposed power station is adjacent to the site for the 500 kV Jamshoro Substation whose construction is planned by WAPDA. If the proposed power station is connected to the said Substation, no transmission line will be required, depending on the layout.

12) Living conditions
The Jamshoro area has one of the largest general hospitals in the Hyderabad Division and twenty clinics. There are primary schools, secondary schools, colleges and universities. There are stores selling daily necessities, police station, post office and other governmental organizations.

13) Influence on environment
One of the greatest influences of the thermal power plant on the environment is air pollution. Hyderabad City is located to the southeast of the power plant site. The university, colleges and schools are situated to the south. In winter, wind generally blows from the northwest although wind velocity is low. It will be necessary to take some measure against air pollution.

4-2-2 Khanot

(1) Conditions of Site

1) Location
The Khanot site is located to the east-northeast of Karachi City and at a distance of about 200 kilometers from Karachi City. It is adjacent to the east and end of the Khanot Railway Station. The site lies on the right-hand bank of the Indus River. The city nearest to the Khanot area is Hyderabad City, which is situated to the south and at a distance of about 43 kilometers.

The site for the condenser cooling water intake facilities lies in the Sahara area at a distance of about 2.5 kilometers northeast of the site for the power station. The Sahara area lies on the right-hand bank of the Indus River. There are Khanot Railway Station and the existing 132 kV Lakhra Substation near the would-be site for the power station.

2) Access
The National Highway between Petaro and Mayhand runs in the west of the power station site. The National Highway is connected to New Petaro Road going to Hyderabad so that access can be easily made to the site by utilizing the National Highway.

The railway leading to Dadu runs in the west of the site so that access by railway is also easy because the site is adjacent to Khanot Railway Station.

3) Weather
Almost same as the Hyderabad Area.

4) Topography
The site in Khanot is a plane higher than the flood level of the Indus River and it slowly descends eastward to the Indus River.

At the site for the condenser cooling water intake facilities, the Indus River meanders and the center of water flow changes every time when a flood is caused.

5) Geology
Almost same as the site in the Jamshoro Area.

6) Land
As in the site in the Jamshoro Area, ample area is available.

7) Water
It will be difficult to determine the point of water intake and it will be impossible to take a large quantity of water because the center of water flow in the Sahara area, in which the site for water intake facilities lies, changes whenever a flood is caused. Therefore, only a small amount of water will be taken from the river by the floating pontoon method, and the condensers will have to be cooled in the closed cycle. As for industrial water, some measures of cleaning muddy water will have to be adopted as in the Jamshoro site.

8) Fuel
As fuel, coal to be produced at the Lakhra coal mine about 18 kilometers westward will be used.

The natural gas pipeline is located about 30 kilometers apart from the Khanot site. Because the consumption of natural gas will be small, it is not economical to lay a gas pipeline. As auxiliary fuel, heavy oil and light oil which will be transported from Karachi will be used.

9) Manpower
Almost same as the Jamshoro site.

10) Transportation
Coal will be carried by trucks from the coal mine to the site.

Materials, equipment and facilities required for the construction, operation and maintenance of the thermal power station will be transported through the following two routes:

a) The materials, equipment and facilities will be transported to Khanot Railway Station by Railway. Trailers and/or trucks will be used for transportation of such goods from Khanot Railway Station to the site.

b) The materials, equipment and facilities will be transported from Karachi to the site on the Super Highway, National Highway and New Petaro Road.

11) Power transmission lines
The substation nearest to the Khanot site is the 132 kV Lakhra Substation. However, the power transmission lines leading from this substation do not have sufficient capacity, and the thermal power plant can not be connected to this substation.

The thermal power plant will have to be connected to the 500 kV Jamshoro Substation through 220 kV two-circuit line having a total length of about 35 kilometers.

The power received by the 500 kV Jamshoro Substation from the thermal power plant will be sent to Punjab Province as well as Sind Province including Karachi City.

12) Living conditions
The living conditions in the Khanot area are not adequately met for the daily life. The Khanot site is at a distance of about 40 kilometers from the Jamshoro area so that the existing facilities will hardly be utilized by power station personnel. It is necessary to construct a colony in time to provide necessary living conditions for power station personnel.

13) Influence on environment
No special consideration is needed to be given to air pollution because the Khanot area is hardly inhabited.

4-2-3 Lakhra

(1) Conditions of Site in Lakhra

1) Location
The site is situated about 160 kilometers northeast of Karachi City, which is the greatest city in Pakistan, and lies in the Lakhra area on the right-hand bank of the Indus River.

The city nearest to the site is Hyderabad at a distance of about 35 kilometers south-southeast. The west side of this site is adjacent to the proposed coal mine at Lakhra. The site for water intake facilities for the power plant is located in the Sahara area about 15 kilometers eastward. (The same site as the Khanot plan is proposed.)

2) Access
Access can be made to Khanot by utilizing roads and railways as described in 4-2-2 2). Access will be made from Khanot to the site by utilizing rugged narrow roads. The Lakhra plateau has not road but automobiles can run anywhere because the earth is solid and even.

3) Weather
Rainfall and temperature are supposed to be almost same as the Hyderabad area. However, higher wind velocity and severer sand storm are expected because the Lakhra area is a barren land about 450 feet (137 m) higher than the Jamshoro area.

4) Topography
The Lakhra site is located on an even and plane plateau. The plateau is about 550 feet (168 m) high above the sea level and is about 450 feet (137 m) higher than the Indus River.

5) Geology
Almost same as the other two would-be sites in Jamshoro and Khanot.

6) Land
Land having a sufficient area is available as in Jamshoro and Khanot.

7) Water
Because the site is about 450 feet (137 m) higher than the Indus River, a closed cycle system will be used for cooling of condensers. The required amount of water can be taken from the Indus River at a point near the Sahara Pumping Station in Khanot.

As for industrial water, some means of cleaning the muddy water will have to be taken.

8) Fuel
Coal to be produced at the Lakhra Coal Mine adjacent to the Lakhra site will be used as fuel.

As for natural gas and auxiliary fuel, the conditions are almost same as the Khanot site.

9) Manpower
Same as the Jamshoro site and Khanot site.

10) Transportation
Coal will be transported by trucks directly from the adjacent Lakhra Coal Mine. Materials, equipment and supplies necessary for the construction, operation and maintenance of the power plant will be transported by the following two means:

a) The materials, equipment and facilities will be transported by railway from Karachi to Khanot Railway Station near the site. They will be carried by trailers and trucks from Khanot Railway Station to the site by utilizing a road which will be newly constructed.

b) The materials, equipment and facilities will be transported by trailers and trucks from Karachi to the site along the Super Highway, National Highway, National Road and a new road.

11) Power transmission lines
The substation nearest to the Lakhra site is the 132 kV Lakhra Substation at a distance of about 14 kilometers. However, the capacity of the power transmission lines for this Substation is insufficient so that a 220 kV two-circuit power transmission line will have to be constructed from the thermal power plant to the 500 kV Jamshoro Transformer Substation. If the transmission line should be spanned along the road leading from the Lakhra site to Khanot which will be newly constructed, the length of the transmission line will total about 48 kilometers.

The 500 kV Jamshoro Substation will receive electric power to be generated by the thermal power plant, and will be capable of sending it to Panjab Province as well as Sind Province including Karachi.

12) Living conditions
Almost same as the Khanot site.

13) Influence on environment
Because the Lakhra site is a hardly inhabited vast barren land, no special consideration will be required to be given to air pollution.

4-3 Overall Evaluation of Sites

As the possible sites for the thermal power station; the Jamshoro, Khanot and Lakhra sites were selected. As a result of comparisons of physical conditions of each site, possibility of condenser cooling water intake, transport of fuel, materials, equipment and facilities, necessity of power transmission lines, and approximate construction cost, it has been estimated that the Jamshoro site is most suitable. Table 4-1 Comparison among Possible Sites for Thermal Power Station shows the summary of such comparison.

4-3-1 Jamshoro Site

Weather, topography, geology, availability of land and mobilization of manpower are almost the same for each of these three possible sites. One of the disadvantageous conditions of the Jamshoro site is that the said site is located at a distance of about 30 kilometers from the Lakhra Coal Mine so that lignite will have to be carried for the longest distance, resulting in raised transportation cost. Another disadvantage is that a special measure against air pollution due to sulfur dioxide yielded by combustion of coal with high sulfur content will have to be adopted to eliminate contamination which will be experienced by inhabitants. However, access to this site will be easily made from Karachi by utilizing the railways, roads and airlines. Materials, equipment and facilities necessary for the construction, operation and maintenance of the power station can be transported by means of railways and roads. The Jamshoro area has educational facilities, hospitals, governmental offices and other facilities necessary for maintenance of daily life. Besides, there is a natural gas pipeline stretching up to a distance of about 3.5 kilometer from the site. Natural gas necessary for ignition of coal burners will be easily supplied by extending the pipeline. On the other hand, one of the greatest advantages is that cooling water for condensers can be pumped up from the Indus River all the year around and that there will be no need of constructing new transmission lines in the event the thermal power plant is constructed directly adjacent to the 500 kV Jamshoro Substation. The approximate cost for construction of the proposed power station at the Jamshoro site is estimated at 6,225 Rs. in million as calculated based on the prices prevailing in Japan as of June, 1980. The construction cost for the Jamshoro site has proved to be the lowest.

4-3-2 Khanot Site

Because the Khanot area is scarecely inhabited, there will be no need of giving any consideration to air pollution. As for the access and transport of materials, equipment and facilities, the railways and roads leading from Karachi can be utilized. The Khanot site is located at a distance of about 18 kilometers from the Coal Mine so that lignite will have to be carried by trucks on a road which will be newly constructed for this purpose. The Khanot area is hardly equipped with facilities of living and it will be impossible to utilize the existing facilities in the Jamshoro area. For this reason, a colony for the power station personnel will have to be constructed in time to secure better living conditions. Further, it will be difficult to determine the point of intake of condenser cooling water because the center of water flow in the Indus River changes from time to time so that a large amount of water required for cooling of condensers will not be available all the year round. As a result, a closed cycle system will have to be adopted for cooling, resulting in increased construction costs and poor thermal efficiency. Because the capacity of the existing power transmission lines for the 132 kV Lakhra Substation is insufficient, a 220 kV two-circuit power transmission line with a total length of about 35 kilometers will have to be extended to the Jamshoro Substation.

The approximate cost for construction of the power station and transmission lines has been calculated as 6,270 Rs. in million.

4-3-3 Lakhra Site

One of the greatest advantages is that the cost of fuel transportation will be the lowest because coal can be directly carried by trucks from the adjacent Lakhra Coal Mine. Because the Lakhra Area is a scarecely inhabited barren plateau, there will be no need of giving considerations to air pollution. This area has poor living conditions so that a colony will have to be constructed in time. For the access and transportation of materials and machines up to Khanot, the means described in 4-3-2 can be utilized. However, a new road will have to be constructed for transport and access from Khanot to the Lakhra site. One of the greatest disadvantages lies in that it will be difficult to secure a sufficient amount of cooling water for the same reasons as the Khanot site. Besides, it will be necessary to pump up cooling water for a distance of 15 kilometers and to a height of about 140 meters. As is the case with the Khanot site, a 220 kV two-circuit power transmission line with a total length of about 48 kilometers will have to be extended from the Lakhra site to the 500 kV Jamshoro Substation.

The approximate cost for construction of the power plant and relevant transmission line has been calculated as 6,530 Rs. in million. The cost for the Lakhra site has been proved to be the highest.

Table 4-1 Comparison among Three Possible Sites for Thermal Power Station

Note: AA Most suitable B Fairly suitable
A Suitable C Unsuitable
D Most unsuitable

No.	Item \ Site	Jamshoro		Khanot		Lakhra	
		Estimation	Description	Estimation	Description	Estimation	Description
1	Access	A	Railway, airline and Super Highway between Karachi and Hyderabad can be utilized.	A	Almost same as Jamshoro site.	C	There is no maintained road from Khanot to Lakhara.
2	Weather	C	The highest temperature is 48° and the lowest temperature is minus 2.2°C. Sand storm is sometimes caused in summer.	C	Same as the Jamshoro site	C	Almost same as the Jamshoro site. Wind is harder because of the higher altitude.
3	Topography	A	A plane proceeding gentle relief located at a higher level than the flood level of the Indus.	A	Almost same as the Jamshoro site.	A	Flat plateau with high altitude.
4	Geology	A	Covered with the Eocene Laki limestone.	A	Same as the Jamshoro site	A	Same as the Jamshoro site
5	Land available	A	Sufficient land is available.	A	Same as the Jamshoro site	A	Same as the Jamshoro site
6	Water	B	Water is available all the year round.	C d	It is difficult to determine the point of water intake because the center of water flow of the Indus River changes from time to time.	D	Almost same as the Khanot site. Besides, water must be pumped up for a distance of about 15 kilometers to Lakhra and to a height of about 140 meters.

No.	Item \ Site	Jamshoro		Khanot		Lakhra	
		Estimation	Description	Estimation	Description	Estimation	Description
7	Fuel • Coal	B	Lakhra lignite will be used.	C	Same as the Jamshoro site	C	Same as the Jamshoro site
	• Auxiliary fuels		Natural gas will be used. A nearest to the existing natural gas pipeline.		Furnace oil and light oil are to be used since natural gas pipeline will have to be extended to Khanot.		A natural gas pipeline will have to be extended Lakhra because furnace oil and light oil are to be used.
8	Manpower	B	Laborers, profesional workers, etc. can be easily employed because the site is near Hyderabad.	B	Almost same as the Jamshoro site	B	Almost same as the Jamshoro site
9	Transportation (1) Coal	C	The site is the farthest from the Lakhra Coal Mine so that the transportation cost will be the highest.	C	Transportation cost is higher than the Lakhara site but lower than the Jamshoro site.	AA	The distance of transportation is the shortest and the transportation cost is lowest.
	(2) Materials and machines	A	Railway and Super Highway from Karachi can be utilized.	A	Same as the Jamshoro site.	C	The same means as the other sites can be utilized for transport up to Khanot Railway Station. A new road to the Lakhara site will have to be constructed for transportation.
10	Power transmission line	AA	No transmission line will have to be newly constructed because the 500 kV transformer substation will be constructed within the Jamshoro area.	B	Transmission line to the 500 kV Jamshoro substation will have to be laid.	C	Transmission line to the 500 kV Jamshoro substation will have to be laid. The distance of the transmission line will be longest.

No.	Site / Item	Jamshoro		Khanot		Lakhra	
		Esti-mation	Description	Esti-mation	Description	Esti-mation	Description
11	Living conditions	B	Daily necessities can be procured and public facilities are available.	C	Daily necessities can not be procured and there are hardly any facilities.	D	Daily necessities can not be procured. No public facilities are available.
12	Influence on environment	C	The site is the nearest to Hyderabad City. Possible air pollution due to the direction of wind in winter will have to be considered.	A	There will be noiinflu-ence because the area is hardly inhabited and is distant from Hyderabad City.	A	Same as the Khanot site
13	Approximate construction cost Power station Including transmission facilities		6,225 Rs. in million		6,270 Rs. in million		6,530 Rs. in million
14	Overall evaluation		The Jamshoro site is the most suitable when over-all evaluation is made in connection with the a above items 1 through 13.		Overall evaluation proves that the Khanot site is less suitable than the Jamshoro site and more suitable than the Lakhara site.		Overall evaluation proves that the Lakhra site is most unsuitable among the three candidate sites.

CHAPTER 5 THE OUTLINE OF EQUIPMENT FOR COAL-FIRED THERMAL POWER STATION

5-1 Locational Conditions of the Proposed Site

5-1-1 Location

The proposed site of the coal-fired thermal power station is situated at the Jamshoro area on the right bank of the Indus River at a latitude of 25°29' N. and a longitude of 68°16' E.

The city nearest to the proposed site is Hyderabad City, which spreads out on the left bank of the Indus. The distance between the proposed site and the center (zero point) of the city is approximately 18 km. Karachi City, the largest city in the Islamic Republic of Pakistan is located approximately 150 km west-south-west of Hyderabad City.

A railway running from Karachi City to Dadu City lies approximately 1 km east of the proposed site of the coal-fired thermal power station. From Karachi City, a superhighway extends to a certain point close to the Sind University Railway Station and is connected with a national highway which leads to Dadu City. A national road (New Petaro Road) branches off from this national highway and runs northward along the east side of the proposed site.

In the vicinity of the proposed site, there are the Jamshoro 132 kV Grid Station about 2.5 km to the south, Liaquat Medical College about 5.5 km to the south, Sind University and Mehram Engineering & Technology College about 7 km to the south, Sind University Railway Station about 6.5 km to the south, Kotri Gas Turbine Power Station about 15 km to the south, and Hyderabad Thermal Power Station about 20 km to the southeast.

The proposed water-intake site, which is to be used as a source of condenser cooling water for the coal-fired thermal power station, is located at Bada Village on the right bank of the Indus, about 3.7 km east of the power plant and about 4.4 km upstream of the Kotri Barrage.

5-1-2 Access

(1) Roads

It is possible to readily approach the proposed site by means of the super and national highways connecting Karachi with the Jamshoro area and then New Petaro Road, which branches off from the national highway at a point near Liaquat Medical College in that area and extends toward Khanot.

It is also possible to readily approach the proposed site from Hyderabad City via the Kotri Barrage by taking the national highway and New Petaro Road mentioned above.

(2) Railways

It is possible to readily approach the proposed site by taking the existing railway extending from Karachi City toward Dadu City and by making use of Sind University Railway Station, which stands about 5.5 km south of the proposed site and faces the national highway.

(3) Airport

Hyderabad Airport is situated about 7 km southwest of the center of Hyderabad City and about 18 km distant from the proposed site when measured on the road there.

The road connecting Hyderabad City with Hyderabad Airport is narrow and in need of repair and further improvement.

Two flights are currently operated between Hyderabad Airport and Karachi Airport per week (every Thursday and Friday).

5-1-3 Meteorology

According to the meteorological data from the weather station in Hyderabad (Table 5-1, Meteorological Data, 1961 – 1979), summer in the Hyderabad area (March through October) is the rainy season. During this season, however, the total rainfall is not necessarily heavy but the atmospheric temperatures are extremely high. On the other hand, the climate in winter is dry and mild.

In summer, the total rainfall is not necessarily heavy but it rains, heavily in June through August. The average of the yearly maximum precipitation is 90.3 mm per month, the highest atmospheric temperature is 48°C in May 1976, and the highest monthly average atmospheric temperature is 45°C.

In winter, the lowest monthly average precipitation is about 4.3 mm per month, the lowest atmospheric temperature is minus 2.2°C (June, 1967), and the minimum monthly average atmospheric temperature is 10.8°C.

In summer, the highest monthly average humidity is 81.3 percent; in winter, the lowest monthly average value humidity is 24 percent.

In summer, the wind usually blows from the southwest. The maximum wind velocity recorded so far is 27.3 meters per second. During this season, heavy sandstorms frequently occur.

In winter, the wind usually is from the northwest, with an average wind velocity of 1.4 meters per second.

5-1-4 Topography

The proposed site of the coal-fired thermal power station is situated at the east end of Lakhra, generally sinking sloping gradually eastward but sloping southeastward in some places. The soil at the proposed site has gradually been eroded during the rainy season.

There exist some hillocks having heights of 10 to 20 meters approximately 1 km to the west of New Petaro Road. The land in the proposed site is flat on the whole, vast, barren and almost uninhabited.

This land is about 10 meters higher than the flood level of the Indus River which makes it safe from any torrential flooding during the rainy season.

The land to the east of the New Petaro Road falls away gently approximately 1 km to the east to the railway, east of which is the Indus.

There is a rather flat lowland extending approximately 2.7 km eastward from the railway to the proposed water-intake site at Bada Village, which will be used as a source for condenser cooling water for the power station.

The railway bed has been conducted by building up the ground level by about two meters. According to all accounts from the personnel of WAPDA and from local inhabitants, however, the railway bed is covered with rain water during flooding and the train service is disrupted for from 10 to 14 days.

5-1-5 Geology

Forming the east side of the Lakhra anticline, the Jamshoro area is covered with a layer of the Eocene Laki limestone, which contains quantities of marlstone and shale.

Stratigraphically, the area falls towards the east and is covered with alluvial soil near the Khanot railway station.

The layer of exposed limestone at the surface of the proposed site is solid and hard, with a chalky consistency. In this area, no faulting which could cause seismic problems in case of an earthquake has been detected.

5-1-6 Land

(1) Size of Site Required

The size of the site required for the construction of the coal-fired thermal power station (not including the lot allocated to the construction of the intake, intake channel, and discharge channel for condenser cooling water) has been estimated as follows, with a consideration given to the future construction of the 300 MW plant and an additional construction of another 300 MW plant.

1) The size of the lot for the power station itself (including the coal yard): about 397×10^3 m^2

2) The size of the area for ash disposal (the estimate has been made on the assumption that all the ash produced is dumped at this location): about $1{,}600 \times 10^3$ m^2

3) The size of the area allocated to the construction of a colony for WAPDA's personnel: about 378×10^3 m^2

Total: about 2.38×10^6 m^2

(2) Rough Survey of the Proposed Site

The roughly-conducted survey of the proposed site has revealed that a ground area of 2.5 km could be prepared although the site is dotted with small hills.

(3) Acquisition of the Site

The site required for the construction of the power plant could be acquired without any particular difficulty since:

1) There will be no serious problems in connection with the acquisition of the site by WAPDA, because the proposed site is the property of the Sind Government.

2) There will be no serious problems in connection with the acquisition of the site by WAPDA, because a majority of local inhabitants in the Jamshoro area are Sindhi and the people of other tribes are limited in number, although the area at Bada Village, set aside for the construction of the intake, intake channel, and discharge channel, is owned partly by the Sind Government and partly by private citizens.

5-1-7 Waters

Various types of water are required for the construction, operation and maintenance of the coal-fired thermal power station, including; river water for cooling condensers, pure water for use in boilers, water for cooling bearings, etc. of machines and equipment, water for fire-fighting purposes, water for washing machines and equipment, roughly treated water ("industrial water" obtained by simply settling and filtering river water) for use in lavatories and the like, water for ablutions, and potable water.

(1) Condenser Cooling Water

Water used for cooling condensers will be obtained from the main course of the Indus at Bada.

1) River conditions

   a) A great deal of sediment consisting of sand, silt, and mud has been found along the banks of the river.

   b) The Indus River is approximately 1,300 meters wide. According to WAPDA personnel, domestic animals, including poultry, wild pigs, daily necessities such as furniture and clothes, and so forth have been carried down by the flooded river in the past. The scale of flooding along the river can be readily imagined.

2) The minimum quantity of flowing water in the river
The proposed water-intake site is located about 4.4 km upstream of the Kotri Barrage.

According to Table 5-2 furnished by WAPDA (Monthly Water Level and Runoff of Indus River at Kotri Barrage), the minimum quantity of water flowing into the Kotri Barrage per month over the period of the past five years is 20.5 m^3/sec (April, 1975).

3) Water level and depth of the river

The gates at the Kotri Barrage are raised out of the river every year for checking and overhaul between December 15 and 31. During this period, the water level of the Indus River at the Kotri Barrage drops to the level of the dam crest.

According to Table 5-2 furnished by WAPDA (Monthly Water Level and Runoff of Indus River at Kotri Barrage) and a Hydraulic Survey Report Indus River (For Lakhra Coal), an investigation on the lowest water level of the Indus River at the Kotri Barrage when the gates were raised out of the river and the lowest riverbed level of the Indus at the proposed Bada water-intake site has revealed:

Minimum water depth of the Indus = the lowest water level of the Indus at the Kotri Barrage (48.77 ft recorded in December, 1975) – the lowest riverbed level of the Indus at the proposed Bada water-intake site (37.88 ft) = 48.77 ft (14.87 m) – 38.88 ft (11.35 m) = 9.89 ft (3.32 m)

For this Project, it will be necessary to make special provision when a large quantity of water is pumped from the river at a minimum water depth of 3.32 meters.

4) Turbidity of the river

The water of the river usually is a light brown color and contains a large quantity of microscopic silt. An analysis of Indus water furnished by WAPDA (Data on Analysis of Water from the Indus River) discloses that its turbidity (ss) ranges from 680 ppm (min) to 3,500 ppm (max).

The turbidity tends to become lower from December through February and higher from March through October.

5) River water temperature

According to the measurement data of the temperatures of Indus Water (the periods of June 1980 to Sept. 1980) offered by WAPDA, the temperature of Indus water in the vicinity of the proposed cooling water-intake site, the lowest is 27°C and the highest is 29°C.

(2) Water other than Condenser Cooling Water

It might be convenient for the power plant to procure a constant supply of water except condenser cooling water from an existing source (e.g. city water) without installing special water-making equipment.

The JICA Survey Team conducted investigations on the present status of the city water supply system and related matters at Hyderabad City and in the Jamshoro area through discussions with the representatives of the Hyderabad Development Authority, Sind University and others.

According to their briefings on this matter, it is hardly anticipated that the power plant will hardly obtain water requirements from the city water supply system for the following reasons:

1) The service area of the Hyderabad Development Authority is restricted to Hyderabad City. In other words, the Jamshoro area is outside the jurisdiction of the Authority.

2) Sind University has its own water treatment facilities to supply water to itself and to Mehran Engineering & Technology College. The water supply capacity of the facilities is 6,000 gallons (27.3 m^3) per day, but it is not presently large enough to satisfy the entire current needs of the population of 15,000.

3) The Public Health Engineering Department has formulated a plan for supplying the Jamshoro area with drinking water, but the plan itself is still at a premature stage. For the time being, therefore, it can not be expected that the power plant can obtain water under this plan.

Consequently, the coal-fired thermal power station must have its own water-making facilities.

5-1-8 Fuel

It is necessary that this coal-fired thermal power plant be supplied not only with coal, the main fuel for the power plant but also with gas which will be used for igniting the coal burners in the power plant or stabilizing the flames of the burners when the load is not heavy enough or to be used as an emergency fuel.

(1) Coal

Only lignite produced at the proposed coal mine at Lakhra approximately 30 km away from the proposed site will be used as the main fuel for the power plant. No other coal will be used.

(2) Natural Gas

1) In the Islamic Republic of Pakistan, the Sui Gas Company has a gas supply system that supplies natural gas from a gas field in Sui, to consumers through the Indus Gas Company. At present, two pipelines, one 16 inches and the other 18 inches in diameter, are laid between the Sui gas field and Karachi, and the last point of the existing gas pipeline is existent at a place approximately 6 km away from the proposed site of the power station.

Gas produced in the Sui gas field, called "Sui gas" is currently supplied to the Kotri gas turbine power station and other consumers. In addition, Sui gas will be supplied as fuel to the proposed Korangi gas-fired thermal power station (200 MW) under a contract recently concluded between KESC and Indus Gas Company. Consequently, the excess gas supply capacity of the company will reach its limit from 1983 to 1984 when the Korangi power station is scheduled to be commissioned.

Judging from the above, it seems practically impossible to expect supplies of gas from the company to fill latent needs for industrial gas.

2) In order to cope with the above-mentioned situation, the Government and relevant organizations are planning to develop a new gas field at Pirkoh and connect it to a Sui Gas Company pipeline. However, nothing definite is known to the JICA Survey Team about when the plan will be started.

3) In the Pakistan Times for July 3, 1980, E.C.C. (Economic Coordination Committee of the Cabinet) expressed its views in a definite manner as follows:

"The Economic Co-ordination Committee of the Cabinet which met here today under the chairmanship of Mr. Ghulam Ishaq Khan, Minister for Finance, Planning Commerce, and Co-ordination carried out an exhaustive review of the development of gas and other energy resources in the country.

Taking into account energy requirements for next 10 years, the committee decided that in order to bring the projected gap between availability and demand of energy, the country had no alternative but to opt for nuclear power generating capacity by 1988, which may be in the order of 600 MW. It is expected that the project study which has already been undertaken would be completed by the end of this year and by early 1981 tenders would be issued. The committee also decided that for conservation of gas, which is a precious product its future use for generation of electricity would not be allowed in the new projects. A review of alternatives available for conversion of the existing gas thermal power station of WAPDA would be carried out in order to ascertain if economically and technically it was feasible to convert them to furnace oil which is available within the country.

The committee also directed the Ministry of Petroleum to immediately undertake development of gas fields at Pirkoh in Baluchistan. Not only more wells would be dug but these should be linked with the Sui system. It further redecided that availability of gas for manufacture of fertilizer in order to meet the national requirements should be ensured so that dependence on imports is reduced."

Judging from the above, it seems extremely difficult to use Sui gas for this Project. However, the use of gas for igniting the coal burners in the coal-fired thermal power plant is fairly economical and the quantity of gas used for this purpose is very small. It will be possible to arrange for proper allocation of such gas among respective power stations owned by WAPDA.

5-1-9 Manpower

The total population of Sind Province in 1980 is estimated at 17,947,000, a figure calculated by multiplying the 1973 population census figure by the population growth rate of 3 percent. The segment of the male population falls within the working age range of 20 to 59 years old is said to be between 22 and 23 percent of the total population or 3,948 to 4,128 in number. On the other hand, the number of unemployed persons is estimated at 305,000.

As regards the manpower situation of Hyderabad Division, a part of Sind Province, according to the November 1979 issue of the "Basic Statistics, Hyderabad Division", the total population of this Division as of 1979 is 7,482,000. Consequently, the male population which falls in the working age range of 20 to 59 years old can be estimated at 1,721,000 when calculated using a nation-wide average. In the same manner, the number of unemployed persons can be estimated at 127,000 by multiplying the total population by the unemployment rate of 1.7 percent. Judging from the social conditions of the Islamic Republic of Pakistan, nearly all these unemployed persons are males.

It is generally said there that local contractors are capable of mobilizing labor on a nation-wide scale when they advance the construction of a coal-fired thermal power station or the like. Judging from this and the above-mentioned manpower situation, it is considered quite possible that labor required for carrying out this Project can be drawn from in and around the Hyderabad area in sufficient numbers.

It may also be possible to acquire and utilize professional manpower of high quality from in and around this area, since there are Sind University and Mehran Engineering & Technology College, which have a fairly long, proud history and maintain a high level of education respectively, and are situated in the Jamshoro area adjacent to Hyderabad.

This Project will make important contributions to increase in opportunities for employment in the Hyderabad area by drawing on the manpower there, according to the types of the construction, operation, and maintenance of the power plant.

5-1-10 Transportation

(1) Coal

Coal will be carried from the coal mine to Khanot Railway Station by the railway newly installed, therefrom to the vicinity of Petaro on the existing railway. Then, it will be transported through the sidetrack which will be newly laid and will be unloaded at the coal storage yard in the power station.

(2) Materials, Equipment and Supplies for the Coal-fired Thermal Power Station and Construction Tools, Equipment and Materials

1) The railway between Karachi City and Dadu City runs near the proposed power station site. This railway was used for transporting heavy machines and equipment during the period from 1964 to 1979 when the Guddu Thermal Power Station, the Mangla Hydroelectric Power Station, and the Tarbela Hydroelectric Power Station respectively were being constructed.

   At present, improvement of this railway is in progress on the "Five-year Development Program" conducted by the Pakistani Government, so that the railway can be fully utilized for transportation of materials, equipment and supplies for this Project.

2) Sind University Railway Station is located nearby the proposed site of the power plant, so that heavy loads can be carried from the station to the proposed power plant side using trailers.

3) As mentioned in "5-1-2 Access", the superhighway and the national highway, both of which are wide enough for heavy-load transportation, run from Karachi and Hyderabad to the proposed power plant site, so that materials, equipment and supplies can be transported along these routes.

5-1-11 Transmission Lines

The proposed power station site is situated approximately 2.5 km north of the existing 132 kV Jamshoro Grid Station and adjacent to the 500 kV Jamshoro Substation located at the south end of the 500 kV Guddu – Jamshoro line, which is now being planned by WAPDA. If the power plant is connected with this 500 kV Jamshoro Substation, the construction of a new transmission line will become unnecessary, depending on the layout of the power plant and the Substation.

The 500 kV Jamshoro substation is to be connected also with the KESC system through a 220 kV transmission line, so that the power to be generated at the power plant could be supplied not only to Sind Province including Karachi City, but also to Punjab Province.

5-1-12 Living Environment

In the Jamshoro area with approximately 15,000 inhabitants, there are 20 clinics and a general hospital affiliated with Liaquat Medical College. This general hospital is the largest in the Hyderabad Division with 30 doctors and 600 beds.

As regards educational facilities, there are two primary schools, two secondary schools, Liaguat Medical College mentioned above, Mehran Engineering & Technology College, and Sind University, all in the vicinity of the proposed power plant site. At some distance from this site, Cadet College is located in the neighborhood of the Petaro area.

Thus, there will be no problems in connection with education to children of the power plant employees.

The employees will not have to go shopping as far as the downtown of Hyderabad for their daily necessities, such as meat, vegetables, fruits, etc. since the Jamshoro area will provide all their ordinary needs.

The Jamshoro area is fully equipped not only with public service facilities, such as a police station, post office, telegraph office, bank, waterworks office, the offices of the gas company and WAPDA, filling stations, and so on but also with mosques and recreation facilities, such as a playground, swimming pool, etc.

5-1-13 Influences on Environment

One of the rather unfavorable effects of the coal-fired power plant on environment could be air pollution.

In the vicinity of the proposed power plant, there are Liaquat Medical College about 5.5 km to the south, a small village about 2 km to the east, and Hyderabad City about 18 km to the southeast. In winter, the slight wind is in the northwest. So, it is believed essential that some countermeasures be taken against the possible air contamination.

Table 5-1 Meteorological Data (Year 1961 ~ 79)

Month	Atmospheric pressure (mb)			Temperature (°C)			Relative Humidity (mm)			Rainfall (mm)		Wind velocity (m/s)		
	5:00 (mean)	8:00 (mean)	17:00 (mean)	Min. (mean)	Max. (mean)	Max. highest (24 hrs.)	5:00 (mean)	8:00 (mean)	17:00 (mean)	Total rainfall during the month	Greatest rainfall in a day	8:00 (mean)	17:00 (mean)	Average speed past 24 hrs.
Jan.	1,016.0	1,018.1	1,015.4	10.8	24.8	33.3	62.7	63.1	31.1	4.6	7.9	1.3	1.6	1.4
Feb.	1,014.3	1,015.8	1,012.8	13.6	28.1	36.6	62.5	61.8	27.6	6.1	11.7	1.1	1.6	1.4
Mar.	1,013.1	1,012.3	1,009.1	14.5	34.1	42.0	63.9	59.6	24.1	13.7	24.4	1.1	2.0	1.6
Apr.	1,006.5	1,007.9	1,004.8	22.9	38.8	46.0	66.2	58.7	24.0	2.9	46.7	1.5	2.7	2.2
May	1,002.2	1,003.8	1,000.1	26.1	41.6	48.0	74.4	63.6	28.6	12.8	47.4	2.8	3.6	3.3
June	997.8	999.0	997.2	26.5	40.0	47.2	78.5	69.8	42.7	34.6	113.3	3.8	4.0	4.2
July	996.2	997.7	995.0	27.8	37.4	44.0	80.3	74.2	53.3	64.2	106.6	3.5	4.0	4.1
Aug.	998.6	999.8	996.7	27.4	36.6	43.9	80.3	74.9	53.7	65.0	108.0	3.3	3.7	3.6
Sept.	1,003.5	1,004.9	1,002.2	25.3	37.0	45.0	81.3	74.7	47.9	19.8	250.7	2.2	3.1	2.7
Oct.	1,009.6	1,011.0	1,008.3	22.2	37.3	43.9	69.6	64.4	30.9	9.8	16.0	1.0	1.8	1.5
Nov.	1,014.0	1,015.2	1,013.0	17.1	31.6	41.0	63.7	60.0	30.2	6.9	20.1	1.1	1.4	1.3
Dec.	1,016.5	1,018.2	1,015.5	12.4	23.6	35.6	63.5	62.8	33.7	6.2	22.6	1.4	1.5	1.5
Year	1,007.3	1,008.6	1,005.8	20.6	34.2	48.0	70.6	65.6	35.7	13.0	250.7	2.0	2.6	2.4

Average Max. 45°C
Average Min. 10.8°C
Maximum Wind Velocity (recorded) 27.3 m/s

Table 5-2 Monthly Water Level and Runoff of Indus River at Kotri Barrage

Items \ Month	January	February	March	April	May	June	July	August	September	October	November	December
	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.
Year	1975											
Water Level (m)												
L.W.L.	18.46	18.52	18.44	18.27	18.49	20.12	20.88	20.64	20.73	20.51	18.88	14.84
Nor. H.W.L.	20.59	19.32	18.55	19.71	20.42	20.94	21.03	21.00	21.03	20.73	20.73	19.99
Runoff (m^3/s)												
Max.	329.55	69.09	31.74	58.96	431.64	2,827.06	7,367.49	10,908.30	13,889.43	3,223.04	207.48	144.16
Min.	23.05	31.38	25.34	20.47	50.18	324.74	1,718.42	1,867.19	3,428.34	166.33	71.78	35.14
Average	204.45	51.54	27.67	26.73	254.23	1,335.91	3,479.31	7,053.85	8,745.85	1,031.16	150.28	82.54
Year	1976											
Water Level (m)												
L.W.L.	18.26	19.20	19.32	19.87	20.73	20.73	20.18	20.73	20.73	20.73	20.73	15.04
Nor. H.W.L.	20.12	20.12	19.87	20.73	20.73	20.91	20.91	22.83	21.70	20.73	20.73	20.73
Runoff (m^3/s)												
Max.	382.99	152.63	173.53	444.78	1,700.83	4,746.67	7,962.34	22,426.84	16,300.60	2,904.62	735.00	576.08
Min.	41.12	47.06	49.30	162.94	406.24	905.15	738.65	8,305.80	4,312.51	595.79	396.13	270.99
Average	242.59	110.32	100.70	395.90	1,195.88	2,226.40	3,568.48	14,815.37	10,647.96	1,372.89	543.66	398.82
Year	1977											
Water Level (m)												
L.W.L.	17.04	20.57	20.21	20.73	20.15	19.43	20.73	20.73	20.73	20.73	19.95	14.87
Nor. H.W.L.	20.73	20.73	20.73	20.73	20.73	20.91	20.73	20.88	20.73	20.73	20.73	20.15
Runoff (m^3/s)												
Max.	863.16	823.03	418.98	663.78	626.43	1,553.58	8,966.75	9,897.70	5,909.28	1,846.83	640.79	244.15
Min.	76.94	163.96	141.44	269.72	278.55	203.68	550.45	4,435.26	1,092.10	570.59	221.24	28.43
Average	573.36	504.10	218.86	365.01	404.08	835.35	4,042.17	7,442.47	3,006.27	921.72	329.38	161.04

Items \ Month	January	February	March	April	May	June	July	August	September	October	November	December
	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.
Year	1978											
Water Level (m)												
L.W.L.	14.87	19.19	19.51	20.12	20.48	20.73	20.73	20.85	20.73	20.73	20.54	15.00
Nor. H.W.L.	20.63	20.09	20.73	20.73	20.73	20.73	21.00	22.27	21.95	20.73	20.73	20.54
Runoff (m^3/s)												
Max.	378.99	145.66	1,106.54	1,111.36	2,487.76	5,547.44	13,568.32	20,442.75	16,558.71	1,685.65	1,259.23	258.96
Min.	24.44	83.34	90.30	130.09	200.99	2,117.55	2,476.60	13,668.47	1,855.16	728.37	212.41	119.89
Average	208.13	104.21	212.29	301.58	1,007.83	3,409.08	8,311.12	17,661.51	6,886.52	1,199.65	475.95	212.38
Year	1979											
Water Level (m)												
L.W.L.	15.00	19.25	20.73	20.73	20.73	19.99	20.82	20.73	20.07	20.51	19.16	15.06
Nor. H.W.L.	20.51	20.73	20.73	20.73	20.73	20.85	20.85	20.85	20.73	20.73	20.51	16.15
Runoff (m^3/s)												
Max.	400.91	339.41	3,018.20	1,861.62	3,144.89	2,658.40	6,302.12	8,517.67	5,440.57	1,075.51	274.79	226.05
Min.	109.05	157.24	451.74	906.03	725.62	388.28	2,354.45	3,060.19	512.14	259.38	162.31	32.05
Average	229.00	216.20	1,585.19	1,445.07	2,001.62	1,343.81	4,212.24	6,673.67	1,273.76	589.22	233.98	148.13

U.S.; upstream 1F = 0.3048 m
1 cusec = 1 F^3/s = 0.028317 m^3/s

5-2 Basic Concept of Design

5-2-1 Power Station Scale and Unit Size

It is quite natural that the scale of Lakhra Coal-fired Thermal Power Station should be determined according to annual production of coal from the possible mine site at Lakhra. The study of mine development has proved that lignite production of one million tons per annum will be possible on an air dry basis consecutively for thirty years. On the assumption that the annual production of lignite is to reach one million tons as stated above, it is possible to determine the scale of this power station as 300 MW in consideration of annual plant factor and thermal efficiency, etc.

There are two alternatives such as employment of a single unit of 300 MW and of two units of 150 MW each. It is advisable to employ the former for the reasons listed below.

(1) In case comparisons are made on capital costs of the alternative of 300 MW x 1 unit and that of 150 x 2 units, the former will be cheaper than the latter by around 10%. The former is also more advantageous in respect of operating costs in view of decrease in lignite consumption because of improvement of thermal efficiency. In other words, the alternative of employment of a single unit of 300 MW will provide scale-merit and is considered to be economically favourable.

(2) According to WAPDA, Tarbela with a capacity of 406 MW x 5 units and Mid Country with a capacity of 400 MW will have already been commissioned in WAPDA System prior to the commissioning of 300 MW Lakhra Thermal Power Station.

The criteria and conditions for preliminary design are described below, provided that the regional characteristics of the Islamic Republic of Pakistan are taken into consideration in design, for example, design wind velocity, ambient temperature, seismic coefficient, etc., are to be obtained from the results of field investigations.

5-2-2 Design Criteria

The materials and standards to be used in design of equipment and structures are the Japanese domestic standards and criteria listed below.

(1) Japanese Industrial Standards (JIS)

(2) Standards of the Japanese Electrotechnical Committee (JEC)

(3) The Japan Electric Machine Industry Association Standards (JEM)

(4) Japanese Electric Wire & Cable Makers' Association Standards (JCS)

(5) Japan Society of Civil Engineers (JSCE) Standard Specifications for Concrete

(6) Architectural Institute of Japan Standards (AIJS)

(7) In addition to the above, standards of Individual equipment manufacturers

5-2-3 Design Conditions for Equipment and Structures

(1) Atmospheric Temperature	
Average maximum (summer)	45°C
Average minimum (winter)	10.8°C
(2) Electrical Equipment Design Temperature	45°C
(3) Seismic Coefficient	0.1 G
(4) Maximum Wind Velocity	
Mechanical and electrical design	45 m/sec
Building design	160 kg/m^2 (velocity pressure)
(5) River Water Temperature	
Design temperature	28°C
Maximum temperature	35°C

Note: Design temperature of condenser cooling water is to be planned for 28°C referring to the Indus River water temperature records (June 1980 – September 1980) furnished by WAPDA.
(See Table 5-3 River Indus Temperature near Lakhra for Coal-fired Power Station.)

(6) Humidity	
Mean maximum value	81.3%
Mechanical and electrical design	80%

Table 5-3 River Indus Water Temperature near Lakhra for Coal-fired Thermal Power Station

Date	Ambient Temp. (°C)	River Temp. at Surface (°C)	River Temp. Deep (8' to 10') (°C)
22.6.1980	39	37	29
28.6.1980	38	36	29
03.7.1980	41	39	29
09.7.1980	37	36	28
14.7.1980	34	32	28
16.7.1980	36	34	29
21.7.1980	37	34	28
23.7.1980	35	34	28
26.7.1980	40	38	29
29.7.1980	37	36	29
02.8.1980	35	33	28
05.8.1980	33	32	28
09.8.1980	35	33	28
16.8.1980	36	32	28
20.8.1980	37	32	28
24.8.1980	38	33	29
28.8.1980	36	32	28
01.9.1980	36	32	28
04.9.1980	36	31	28
09.9.1980	36	28	27

5-2-4 Items to be Especially Considered in Basic Design

(1) The main fuel of this thermal power station is to be coal to be produced at the proposed Lakhra Coal Mine with supplementary fuel being natural gas which is to be used only for igniting burners, start-up of the boiler and stabilization of burner flame in the low load operation of the boiler.

(2) Since this thermal power station is to be operated as a base load thermal power station, an automatic control system is to be adopted in consideration of reliability and safety from the aspect of operation.

Boiler steam temperature control is to be such that operation can be done in a constant manner with load in a range of 60 to 100%.

(3) In selection of steam conditions, planning was done as indicated below for maximum economy considering unit capacity, fuel cost, construction cost and other matters.

	300 MW	150 MW (Alternative)
Steam pressure (at main stop valve inlet)	169 kg/cm²	127 kg/cm²
Steam temperature (at main stop valve inlet)	538°C	538°C

(4) Unit Capability

Planning is to be done in accordance with the following principles:

1) Power generation of 300 MW possible with condenser cooling water temperature of 35°C

2) Overloading of 5% possible with condenser cooling water temperature of 28°C

(5) Adoption of Central Control System

This thermal power station is a coal-fired power station burning lignite for power generation, and compared with furnace oil and gas thermal stations, there is more auxiliary equipment and controlling is more complex.

Consequently, a central control room is to be provided in the main building of the power station, where major monitoring instruments, operating switches, etc. are concentrated in one place so that plant starting and stopping operations, monitoring and managing, and emergency measures during faulting can be carried out there while aiming to achieve prevention of erroneous operation and improvement in plant reliability.

For these objectives, automatic control according to function and sequence control are to be adopted as much as possible with regard to control, and rational planning is to be done aiming to save labor in operation and in monitoring as a whole.

(6) Adoption of Remote-controlled Operation System

Equipment, principal valves, gas burners required to be operated in starting and stopping the plants and when increasing and decreasing load are to be made centrally remote-controlled as much as possible aiming to preclude errors from on-site operation and to save manpower.

Large-size valves requiring physical exertion to operate are to be made electrically driven. Further, the design is to be such that manual operation can be done at the site when necessary.

(7) Prevention of Boiler Corrosion Accompanying Combustion of High-Sulfer Lignite

According to the results of scrutiny of data on the coal scheduled to be used at Lakhra Coal-fired Thermal Power Station, the sulfur content of the coal is an average of 7.1%, which is an extremely high value.

In general, when a comparison is made of the trends of corrosion of equipment due to sulfur content in the cases of pulverized coal firing and oil firing, it may be said for the reasons below, that the degree of corrosion of equipment due to sulfur content at the time of firing of coal is extremely low compared with that during firing of heavy oil.

That is, it is said to be because in the case of firing pulverized coal, since the SO_3 produced by the combustion reacts with Al_2O_3, MgO, CaO, etc. which are components of the ash produced, the SO_3 in the exhaust gas is reduced.

A case of corrosion having been greatly alleviated by the mixed firing of pulverized coal of about 5% at a oil-firing boiler taking advantage of this characteristic has been reported.

However, not all of the SO_3 produced reacts with the components of ash, while since the sulfur content of the coal used for this Project is of an an unusually high level as mentioned above, there is a risk of corrosion and clogging occurring in the equipment depending on the temperature conditions of use.

In effect, SO_3 exhaust gas produces sulfuric acid at the dewpoint temperature of the acid, and the metal where this occurs is corroded.

Further, ash is apt to adhere to the sulfuric acid produced, and in case this occurs in a confined space, there is risk of clogging being produced depending on the state of progress of the adherence.

1) The kinds of equipment with which there are possibilities of metal temperatures coming close to acid dewpoint during operation of the boiler, and the conditions of damage which can be anticipated in such cases are the following:

   a) Regenerative Air Preheater

      - Corrosion of low-temperature elements
      - Clogging of low-temperature elements

   b) Low-temperature Flue

      - Corrosion of inner surface of flue

   c) Electrostatic Precipitator

      - Ash adherence on discharge wire results in thickening of the discharge wire to weaken corona discharge, produce sparking, and as a result dust collecting efficiency is lowered and dust is scattered about.
      - Ash adheres to dust collecting electrodes to lower dust collecting efficiency.
      - Various parts of the interior of the precipitator are corroded.

   d) Stack

      - The lining at the linner surface of the stack is corroded.
      - In case ash adheres to sulfuric acid produced at the inner surface of the stack

and grows thick, it can be spalled off by temperature changes caused by starting or stopping of the unit to fall in the form of relatively large slabs of ash (acid smut) in the power station grounds and the vicinity to produce damage such as corrosion of metals.

2) Measures for Preventing Low-temperature Corrosion and Clogging of Equipment

In general, the dewpoint temperature of acid is governed by the sulfur content of coal and the ratio of excess air to the fuel. The critical temperatures at cold ends at which there are possibilities for corrosion and clogging to occur due to the sulfur contents in fuels and the air-fuel ratios in heavy oil firing and coal firing are indicated in Fig. 5-39.

In case lignite with a 7% sulfur content is fired at an air-fuel ratio of 1.3, since the sulfur content of 7% is not much different from the 6% indicated in Fig. 5–39, the average temperature of the heating surface will be about 85°C. Generally speaking, the temperature range in which corrosion of metal by sulfuric acid is at a maximum is 10°C to 20°C lower than the average temperature of the heating surface.

In view of the above characteristics, the measures for prevention of low-temperature corrosion and clogging of equipment will be the following:

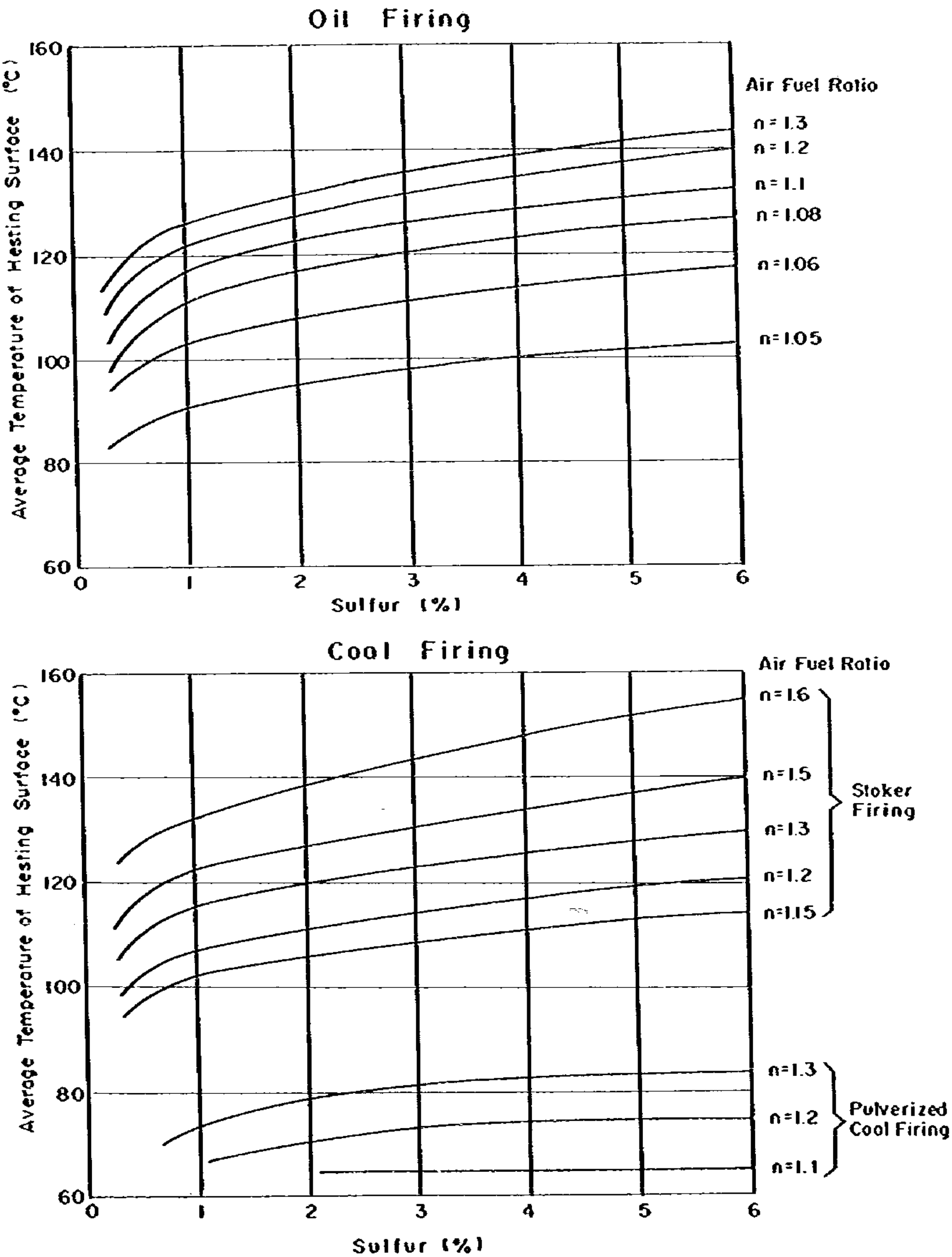
a) Measures for Preventing Corrosion and Clogging of Air Preheater Low-temperature Elements

- The air preheater outlet gas temperature is designed to be 120°C and the inlet air temperature 45°C in order that the metal temperature at the cold end of the air heater will be 85°C or higher.
- In the winter time and during hours of low load, it is to be made possible for inlet air temperature to be raised to 70°C, using a steam air heater.
- Further, a ceramic which is an acid-resisting material is to be used for the low-temperature elements.
- A air preheater bypass line for cold air is to be provided as a measure to prevent clogging of the air heater elements so that cold air will not be passed through the air heater, and by raising the temperatures of the elements and drying them, clogging is to be prevented.
- In case ash or other matters should adhere to the air preheater elements, it is to be removed periodically by steam soot blower to prevent clogging.
- In case the air preheater elements should unfortunately become clogged, they are to be cleared employing the element washing apparatus using warm water heated by auxiliary steam.

b) Low-temperature Flue

Measures for reducing corrosion such as using acid-resistant steel plates can be provided for the low-temperature flue downstream of the electrostatic precipitator. Nevertheless, since they are so costly, the following methods are to be adopted.

FIG. 5-39 CRITICAL TEMPERATURE OF COLDEND



- Insulation of the outer surface is to be made complete to reduce diffusion of heat thereby preventing metal temperature from falling to the vicinity of dewpoint.
- Steel with thickness considering corrosion is to be used.
- The interior of the flue is to be cleaned, inspected and repaired each time the unit is shut down.

c) Electrostatic Precipitator

- A powerful hammering system is to be selected to prevent adherence of ash to discharge wires and dust collecting electeodes.
- The interior of the precipitator is to be washed with an alkaline water solution each time the unit is shut down.
- After washing of the interior, inspection and repairing is to be done.

d) Stack

- The lining material for the inner surface of the stack is to be acid-resistant brick.
- The inner surface of the stack is to be cleaned with water each time the unit undergoes periodic repairs.

3) Reduction of Excess Air

Fig. 5-39, Critical Temperature at cold end, shows that there is a tendency for dewpoint temperature of acid to be higher in correspondence with the ratio of excess air to fuel (air-fuel ratio).

On the other hand, the more that the ratio of excess air for combustion is lowered, the more will the temperature at which low-temperature corrosion occurs be lowered, and this will be of help to preventing low-temperature corrosion.

However, combustion of pulverized coal requires more excess air compared with combustion of heavy oil, and when excess air is reduced below the necessary level, uncombusted carbon will be produced to be a factor in lowering of efficiency, and therefore, it will be desirable for excess air to be reduced, depending upon the condition of combustion.

5-3-1 Civil Works

	(300 MW x 1)	(150 MW x 2)
(1) Site Preparation (exclude ash disposal area and colony area)		
Site Area:	378,000 m²	386,000 m²
Site Formation Level:	EL. 33.50 m	EL. 33.50 m

(2) Circulating Water System
Intake Open Channel

		(300 MW x 1)	(150 MW x 2)
Type:		Open Channel	Open Channel
Dimension	(Width) :	99.20 m	99.20 m
	(Height) :	13.20 m ~ 14.60 m	13.20 m ~ 14.60 m
	(Length):	2,592.00 m	2,592.00 m
Intake			
Type:		Reinforced concrete structure	Reinforced concrete structure
Dimension	(Width) :	50.00 m	50.00 m
	(Height) :	15.90 m	15.90 m
	(Length):	25.00 m	25.00 m
Waterway			
Type:		Reinforced concrete structure	Reinforced concrete structure
Dimension	(Width) :	3.80 m	3.80 m
	(Height) :	3.90 m	3.90 m
	(Length):	250.00 m	250.00 m
Pump Pit			
Type:		Reinforced concrete structure	Reinforced concrete structure
Dimension	(Width) :	37.00 m	31.00 m
	(Height) :	19.40 m	18.40 m
	(Length):	41.00 m	41.00 m
Circulation Water Pipe			
Type:		Underground steel pipe	Underground steel pipe
Dimension	(Inner diameter):	2.20 m	1.60 m
	(Length-mean):	1,600 m x 2 lines	1,600 m x 4 lines
Discharge Pit			
Type:		Reinforced concrete structure	Reinforced concrete Structure
Dimension	(Width) :	14.80 m	14.80 m
	(Height) :	6.40 m	6.40 m
	(Length):	26.00 m	26.00 m
Tailrace			
Type:		Reinforced concrete structure	Reinforced concrete structure
Dimension	(Width) :	4.70 m	4.70 m
	(Height) :	4.80 m	4.80 m
	(Length):	4,151.00 m	4,151.00 m
Outlet			
Type:		Reinforced concrete structure	Reinforced concrete structure
Dimension	(Width) :	13.00 m	13.00 m
	(Height) :	10.00 m	10.00 m
	(Length):	17.00 m	17.00 m

	(300 MW x 1)	(150 MW x 2)
(3) Coal Storage Yard and Coal Draw-out Culvert		
Coal Storage Yard		
Dimension:	220 m x 220 m	220 m x 220 m
Area:	48,400 m^2	48,400 m^2
Coal Draw-out Culvert		
Type:	Reinforced concrete structure	Reinforced concrete structure
Dimension (Width) :	1.80 m	1.80 m
(Height) :	2.50 m	2.50 m
(Length):	231.50 m x 2 lines	231.50 m x 2 lines
(4) Ash Settling Pond		
Type:	Reinforced concrete structure	Reinforced concrete structure
Dimension (Width) :	9.00 m	9.00 m
(Height) :	4.60 m	4.60 m
(Length):	63.70 m x 2 lines	63.70 m x 2 lines
(5) Road in Site Area		
Type:	Asphalt pavement	Asphalt pavement
Dimension (Width) :	10.00 m, 6.00 m	10.00 m, 6.00 m
(Length):	4,000 m	4,000 m
(6) Ash Disposal Area		
Area:	1,640,000 m^2	1,640,000 m^2
Capacity:	4,120,000 m^3	4,120,000 m^3

5-3-2 Buildings

(1) Powerhouse

1) Foundation
Reinforced concrete mat foundation (incl. for boiler, bunker)

2) Structure
Steel construction
Roof, asphalt-waterproofed
Exterior wall, reinforced concrete for dado and steel (with insulation material substrate) for upper part Floor, reinforced concrete, partly steel grating

3) Building Scale

Unit	300 MW x 1	150 MW x 2
Building area	3,670 m²	4,410 m²
Floor area	11,880 m²	13,230 m²
Building volume	87,610 m³	100,800 m³
Building height		
Turbine house	28.4 m (3-story)	26 m (3-story)
Control house	21 m (4-story)	15 m (3-story)
Boiler and bunker mat area	2,700 m²	3,430 m²

4) Equipment & Facilities
Air-conditioning system
Lighting system
Water supply & drainage system
Sanitation system
Fire extinguishing system
Fire alarm system
Ventilating system

(2) Administrative Building

1) Foundation
Reinforced concrete foundation

2) Structure
Reinforced concrete construction, 3-story

3) Scale
Building area, 1,410 m²
Floor area, 4,230 m²

4) Rooms Provided
1F Entrance hall, fuel testing & water analysis laboratory, security section office, storeroom, locker room, clinic, air-conditioning machine room, kitchen, lavatory

2F Maintenance section office, accounting section office, drafting section office, administration section office, government labor supervisor office, training & coordination officer room, locker room, kitchen, lavatory

3F Telephone exchange room, data storage room, operation section office (2 rooms), conference room (3 rooms), plant manager's office, deputy manager's office, locker room, kitchen, lavatory

5) Equipment & Facilities
Air-conditioning system
Lighting system
Water supply & drainage system
Fire alarm system
Fire extinguishing system
Sanitation system
Ventilation system

(3) Scales of Appurtenant Buildings

1) Coal Transport Control Building
Steel construction, 2-story, 1,200 m^2

2) Repair Shop
Steel construction, 1-story, 1,800 m^2

3) Water Treatment Plant
Reinforced concrete construction, 1-story, 300 m^2

4) Hydrogen Generation Apparatus House
Reinforced concrete construction, 1-story, 150 m^2

5) Bulldozer Garage
Steel construction, 1-story, 300 m^2

6) Garage
Steel construction, 1-story, 280 m^2

7) Hazardous Materials Storehouse
Reinforced concrete construction, 1-story, 2 buildings, 380 m^2

8) Storehouse
Steel construction, 1-story, 4 buildings, 6,900 m^2

9) Guardhouse
Reinforced concrete construction, 1-story, 150 m^2

10) Gypsum Storage
Steel construction, 1-story, 2 buildings, 3,000 m^2

(4) Derrick Type Steel Stack

Unit	300 MW x 1	150 MW x 2
Supporting Steel Structure	Height 140 m	Height 140 m
Chinmey Shell	1 ea Top diameter 4.9 m Bottom diameter 5.4 m Height 150 m	2 ea Top diameter 5.0 m Bottom diameter 3.5 m Height 150 m
Lining	Porcelain brick	Porcelain brick
Foundation	Reinforced concrete foundation	Reinforced concrete foundation

5-3-3 Mechanical Equipment

Item	Unit	300 MW x 1 Unit	150 MW x 2 Untis
(1) Boiler Equipment			
1) Boiler			
a) Type			
Natural circulation, single drum, outdoor type (Burner, coal bunker will be covered.)			
b) Number	set	1	1 x 2
c) Evaporation			
Maximum continuous rating (MCR)	t/h	980	500
d) Steam pressure			
Superheater outlet (MCR)	kg/cm^2g	173	131
Reheater outlet (MCR)	kg/cm^2g	36	34
e) Steam temperature			
Superheater outlet (MCR)	°C	541	541
Reheater outlet (MCR)	°C	541	541
f) Feed water temperature (MCR)	°C	240	240
g) Draft system			
Balanced draft system			
h) Burner arrangement			
Front type			
i) Operation type of gas burner			
Remote operation type			
j) Fuel			
Main fuel: Lignite			
Supplementary fuel: Natural gas			
2) Economizer			
a) Type			
Horizontal bare tube type			
b) Number	set	1	1 x 2
3) Air Pre-heater			
a) Type			
Rotary regenerative type			
b) Number	set	2	2 x 2
4) Steam Air Pre-heater			
a) Type			
CU-fined steel pipe type			
b) Number	set	2	2 x 2
5) Soot Blower			
a) Type			
Steam blowing type with electric motor drives			
b) Number			
Necessary quantities			

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
6) Automatic Boiler Controls			
a) Combustion control			
Element : Boiler master control			
: Fuel flow control			
: Combustion air flow control			
: Furnace pressure control			
b) Feed water flow control			
Element : Steam flow control			
: Feed water flow control			
: Drum water level control			
c) Steam temperature control			
Element : Superheater steam temperature control			
: Reheater steam temperature control			
7) Monitor Television			
a) Drum level	set	1	1 x 2
b) Furnace	set	1	1 x 2
c) Stack	set	1	1 x 2
(2) Draft Equipment			
1) Induced Draft Fans			
a) Type			
Double suction type			
b) Number	set	2	2 x 2
2) Forced Draft Fans			
a) Type			
Double suction type			
b) Number	set	2	2 x 2
(3) Fuel Firing, Handling and Storage Equipment			
1) Coal Bunker			
a) Type			
Steel plate type			
b) Capacity x number	m^3 x set	950 x 5	650 x 4 x 2
2) Coal Feeder			
a) Type			
Belt type			
b) Capacity x number	t/h x set	55 x 5	38 x 4 x 2
3) Coal Pulverizer			
a) Type			
Vertical, roller type			
b) Capacity x number	t/h	55 x 5	38 x 4 x 2

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
4) Primary Fan			
a) Type			
Double suction turbo fan			
b) Number	set	5	4 x 2
5) Pulverizer Seal Fan			
a) Type			
Single suction turbo fan			
b) Number	set	5	4 x 2
6) Coal Burner			
a) Type			
Intervane type			
b) Capacity x number	t/h x set	12 x 20	8 x 16 x 2
7) Gas Ignitor			
a) Number	set	20	16 x 2
8) Gas Burner			
a) Capacity/set	Nm^3/h	2,000	2,300
b) Number	set	20	16 x 2
9) Light Oil Tank (for emergency diesel engine)			
a) Capacity	kℓ	5	5
b) Number	set	1	1
10) Truck Hopper			
a) Capacity x Nos. x line		60t x 15 sets x 2 lines	
b) Total capacity	t	1,800	1,800
11) Coal Yard Supply Conveyor			
a) Capacity	t/h	500	500
b) Number	set	2	1 x 2
12) Coal Bunker Supply Conveyor			
a) Capacity	t/h	350	350
b) Number	set	2	1 x 2
13) Magnet Separator			
a) Number	set	2	1 x 2
14) Crusher			
a) Number	set	2	1 x 2
15) Bulldozer			
a) Weight	t	35	35
b) Number	set	4	4
(4) Ash Handling Equipment			
1) Clinker Hopper			
a) Capacity	m^3	90	100
b) Number	set	2	1 x 2
2) Clinker Crusher			
a) Capacity	t/h	50	30
b) Number	set	2	2 x 2

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
3) Jet Pulsion Pump			
a) Capacity	t/h	50	30
b) Number	set	2	2 x 2
4) Ash Slucing Pump			
a) Type			
Volute			
b) Capacity	m^3/h	500	650
c) Number	set	3	3
5) Dewatering Bin			
a) Capacity	m^3	450	500
b) Number	set	2	1 x 2
6) Coarse Ash Tank			
a) Capacity	m^3	800	800
b) Number	set	2	1 x 2
7) Fly Ash Tank			
a) Capacity	m^3	1,500	1,500
b) Number	set	2	1 x 2
(5) Dust Collecting Equipment			
1) Electrostatic Precipitator			
a) Collection Efficiency	%	90	90
b) Number	set	2	2 x 2
(6) Steam Turbine Equipment			
1) Turbine			
a) Type			
Tandem compound, two-cylinder double flow reheat turbine			
b) Number	set	1	1 x 2
c) Rated output (at generator terminal)	MW	300	150
d) Steam pressure			
At main stop valve inlet	kg/cm^2g	169	127
At reheat stop valve inlet	kg/cm^2g	33	30
e) Steam temperature			
At main stop valve inlet	°C	538	538
At reheat stop valve inlet	°C	538	538
f) Number of extractions	stage	7	6
g) Exhaust pressure	mmHg Vac.	700	700
h) Design gross thermal efficiency	%	37	36
2) Governing Equipment			
a) Type			
Mechanical oil pressure type			
b) Number	set	1	1 x 2
3) Automatic Speed Control Device			
a) Number	set	1	1 x 2

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
4) Turning Device			
1) Number	set	1	1 x 2
5) Auxiliary Oil Pump			
a) Type Vertical centrifugal type			
b) Number	set	1	1 x 2
6) Emergency Oil Pump			
a) Number	set	1	1 x 2
7) Main Oil Tank			
a) Number	set	1	1 x 2
8) Oil Cooler			
a) Number	set	2	2 x 2
9) Vapour Extractor			
a) Number	set	1	1 x 2
10) Oil Purifier			
a) Number	set	1	1 x 2
11) Oil Storage Tank			
a) Number	set	1	1
12) Gland Steam Seal Regulator			
a) Number	set	1	1 x 2
13) Gland Steam Condenser			
a) Number	set	1	1 x 2
(7) Condenser and Feed Water Equipment			
1) Condenser			
a) Type Double pass, divided water box type, surface condenser			
b) Number	set	1	1 x 2
c) Circulating water inlet temperature (Design)	°C	28	28
d) Circulating water quantity	m^3/h	35,600	18,900 x 2
e) Material of tube Aluminum brass			
2) Circulating Water Pump			
a) Type Vertical diagonal flow type			
b) Capacity	$m^3/sec.$	5.6	3.0
c) Number	set	3	5
3) Reversing Value			
a) Type Butterfly, motor drive			
b) Number	set	2	2 x 2

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
4) Main Air Ejector			
a) Type			
Twin elements, two stages, steam jet type			
b) Number	set	1	1 x 2
5) Starting Ejector			
a) Type			
Single stage steam jet type			
b) Number	set	1	1 x 2
6) Condensate Pump			
a) Type			
Vertical type			
b) Capacity	m^3/h	340	190
c) Number	set	3	3
7) Bar Screen			
a) Number	set	2	4
8) Rotary Screen			
a) Number	set	3	5
9) Mesh Screen			
a) Number	set	3	5
10) Intake Crane			
a) Type	t	25	15
Gantry			
b) Capacity	t	25	15
c) Number	set	1	1
11) Low Pressure Feed Water Heater (with heater by-pass)			
a) Type			
Horizontal U-tube type			
b) Number	set	4	3 x 2
12) Deaerator			
a) Type			
Horizontal, tray type			
b) Number	set	1	1 x 2
13) High Pressure Feed Water Heater (with heater by-pass)			
a) Type			
Horizontal U-tube type with drain cooling zone and desuperheating zone			
b) Number	set	2	2 x 2
14) Deaerator Recirculating Pump			
a) Type			
Horizontal centrifugal type			
b) Number	set	1	1 x 2

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
15) Boiler Feed Water Pump			
a) Type			
Motor driven, horizontal, multi-stage volute with booster pump			
b) Capacity	t/h	540	270
c) Number	set	3	3
(8) Miscellaneous Equipment			
1) Raw Water Supply Pump			
a) Capacity	m^3/h	70	70
b) Number	set	2	2
2) River Water Clarifier			
a) Type			
Siphon type			
b) Capacity	m^3/h	50	50
c) Number	set	1	1
3) Filter			
a) Capacity	m^3/h	50	50
b) Number	set	2	2
4) Filtrate Tank			
a) Type			
Concrete			
b) Capacity	m^3	200	200
c) Number	set	1	1
5) Raw Water Tank			
a) Type			
Steel, cone roof			
b) Capacity	m^3	1,500	1,500
c) Number	set	2	2
6) Raw Water Pump			
a) Type			
Volute			
b) Capacity	m^3/h	70	70
c) Number	set	2	2
7) Fire Extinguishing Pump			
a) Type			
Normal operation: Motor driven Electrical failure: Diesel driven			
b) Number	set	1	1
8) Demineralization Plant			
a) Type			
2 beds, 3 towers type			
b) Capacity	m^3/h	30	30
c) Number	set	2	2

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
9) Demineralized Water Tank			
a) Type			
Cone roof type			
b) Capacity	m^3	1,000	1,000
c) Number	set	2	2
10) Neutralization Tank			
a) Type			
Concrete			
b) Capacity	m^3	200	200
c) Number	set	1	1
11) Make-up Water Tank			
a) Capacity	m^3	300	300
b) Number	set	1	1 x 2
12) Boiler Chemical Injection Equipment			
a) Kinds of chemicals, phosphate, ammonia, hydrazine			
b) Number	set	1	1 x 2
13) Sampling Equipment			
a) Type			
Rack type			
b) Number	set	1	1 x 2
14) Powerhouse Crane			
a) Type			
Overhead travelling crane			
b) Capacity x Number	t	70t/35t x 1	60t/30t x 1 10t/5t x 1
15) Ash Settling Pond Crane			
a) Type			
Gantry			
b) Capacity	t	15	15
c) Number	set	1	1
16) Air Compressor			
a) Instrument air compressor			
Number	set	2	2
b) Miscellaneous use air compressor			
Number	set	1	1 2
c) Dehumidifier			
Number			
17) Raw Water Head Tank			
a) Number	set	1	1 x 2
18) Cooling Water Pump			
a) Type			
Vertical turbine type			
b) Number	set	3	3 x 2

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
19) Cooling Water Cooler			
a) Type			
Horizontal straight tube			
b) Number	set	2	2 x 2
20) Cooling Water Booster Pump			
a) Type			
Horizontal, volute type			
b) Number	set	2	2 x 2
21) Fire Extinguishing Facility			
a) Water extinguisher for outdoor			
Place			
Cool yard and whole outdoor area			
Number	set	1	1
22) House Service Boiler			
a) Type			
Package type			
b) Steam condition	kg/cm^2g	10	10
c) Capacity	t/h	10	10
d) Fuel			
Natural gas			

5.3.4 Electrical Equipment

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
(1) Generator (with Automatic Voltage Regulator, Automatic Load Regulator, Automatic Reactive Power Regulator, Automatic Synchronous Regulator, Surge Absorber, Protection System, Main Circuit Breaker, Grounding Equipment, etc.)			
1) Generator			
Type			
Horizontal, rotation field, closed hydrogen cooled, explosion proof			
Rating			
Output (at rated hydrogen pressure 2.0 kg/cm^2)	kVA	353,000	177,000
Frequency	Hz	50	50
Power Factor	–	0.85 (lag)	0.85 (lag)
Voltage	kV	18	15
Current	A	11,323	6,813
2) Exciter			
Static Excitation Type (Silicon controlled rectifier)			
(2) Busduct			
Type			
Cylindrical aluminum made enclosed			
Rating			
Voltage	kV	23	23
Current	A	12,000	8,000
(3) Transformer			
1) Main Transformer			
Type			
Outdoor, 3 phase, Forced oil, Forced-air-cooled			
Rating			
Capacity	kVA	333,000	165,000
Frequency	Hz	50	50
Primary Voltage	kV	18	15
Secondary Voltage	kV	132 kV ± 10%	132 kV ± 10%
Connection	–	Δ-Y	Δ-Y
Impedance Voltage (based on the rated kVA)	%	10	10

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
Number	set	1	2
2) Starting Transformer (Common)			
Type			
Outdoor, 3 phase, Forced Air Cooled On-load Tap Changer			
Rating			
Capacity	kVA	45,000	22,000
Frequency	Hz	50	50
Primary Voltage	kV	132kV ± 10%	132kV ± 10%
Secondary Voltage	kV	6.9 kV ± 5%	6.9 kV ± 5%
Connection		Y-Y-Δ	Y-Y-Δ
Number of Taps	taps	17	17
Impedance Voltage (based on the rated kVA and rated Voltage)	%	7.5	7.5
Number	set	1	1
3) House Transformer			
Type			
Outdoor, 3 phase, Forced-air-cooled			
Rating			
Capacity	kVA	30,000	15,000
Frequency	Hz	50	50
Primary Voltage	kV	18	15
Secondary	kV	6.9	6.9
Connection		Δ-Y	Δ-Y
Impedance Voltage (based on the rated kVA)	%	7.5	7.5
4) Auxiliary Transformer			
Type			
Indoor, 3 phase, Self-cooled			
Rating			
Capacity	kVA	2,000 1,000	1,000 1,000
Frequency	Hz	50	50
Primary Voltage	V	6,900 460	6,900 460
Secondary Voltage	V	460 220	460 220
Number	set	4 1	6 1
(4) 6.9 kV Switchgear Cubicle			
Type			
Indoor, Metal-clad, Single Bus System, 3 Phase, 3 Wire, Draw-out			
Rating			
Current (Main bus)	A	3,000	2,000

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
(5) Low Voltage Cubicle			
Type			
Indoor, Metal-clad, Single Bus System, 3 Phase, 3 Wire, Draw-out			
Rating Voltage	V	460	460
(6) Emergency Diesel Power Unit			
1) Engine			
Type			
Vertical Type, 4 Cycle, with Turbo-charger, Water Cooled			
Rating (continuous)	HP	600	600
Revolution Speed	r.p.m.	500	500
2) Generator			
Type			
Horizontal Shaft, Self-cooled			
Rating			
Capacity	kVA	500	500
Frequency	Hz	50	50
Voltage	V	460	460
Power Factor		0.8	0.8
Phase	Phase	3	3
Number	Unit	1	1
(7) DC Supply System			
1) Buttery			
Type			
Lead Acid, Plastic Container, Steel Rack			
Voltage	V	110	110
Capacity x Number of Units	AH	2,000 x 1	1,000 x 2
2) Buttery Charger System			
Type			
Silicon Controlled Rectifier Type			
Capacity x Number of Units	A	500 x 1	250 x 2
Voltage	V	460V AC 160V DC	460V AC 160V DC
(8) Digital Computer			
Capacity	k Bit	2,000	2,000
(9) Disconnecting Switch			
Type			
Horizontal, Double Break			
Rating			
Voltage	kV	168	168
Current	kA	2,000	2,000

Item	Unit	300 MW x 1 Unit	150 MW x 2 Units
(10) Tie Line between Lakhra Power Plant and Jamshoro Substation			
Type			
Steel Structures with ACSR Conductor			
Rated Voltage	kV	132	132
Number of Circuit		2	3
(11) Communication Equipment			
1) House Service			
Type			
Automatic-exchange elephone			
Number of Channels	ch	100	200
2) For Load Dispatching			
Type			
Tone Ringer			
Number of Channels	ch	5	5
3). Paging System			
Number of Speakers	set	50	70
Number of Telephones	set	100	130

5.3.5 Flue Gas Desulfurization Plant

Main Equipment	Calcium Base Throw-Away Process	Limestone/Gypsum Recovery Process
(1) Gas Treatment		
1) Flue Gas Boost-up Fan		
Type	Turbo	Turbo
Number	1	1
(2) Prescrubbing		
1) Prescrubber		
Type	Spray Tower	Spray Tower
Number	1	1
2) Prescrubber Recycle Pumps		
Type	Centrifugal	Centrifugal
Number	3	3
3) Mist Eliminator		
Type	Horizontal Flow	Horizontal Flow
Number	3	3
(3) Absorption		
1) Absorber		
Type	Spray Tower	Spray Tower
Number	3	3
2) Absorber Recycle Pump		
Type	Centrifugal	Centrifugal
Number	1	1
3) Feed Water Pump		
Type	Centrifugal	Centrifugal
Number	2	2
(4) Absorbent Make up		
1) Absorbent Silo		
Type	Vertical	Vertical
Number	1	1
2) Absorbent Feeder		
Type	Screw	Screw
Number	1	1
3) Absorbent Make-up Pump		
Type	Centrifugal	Centrifugal
number	2	2
(5) Gypsum Product	This section is not required for throw-away process	
1) Oxidizer with Blower		
Type		Vertical
Number		2

Main Equipment	Calcium Base Throw-Away Process	Limestone/Gypsum Recovery Process
2) PH Controller		
Type		Vertical
Number		1
3) Thickner		
Type		Center Shaft Drive
Number		1
4) Dehydrator		
Type		Basket Bottom Exhaust
Number		9
5) Gyspsum Warehouse		
Number		1
(6) Deheating		
1) Reheating Furnace Type	Vertical gas-firing	Vertical gas-firing
Number	1	1
(7) Blow Down		
1) Absorbing Blow Pit		
Number	1	1
2) Prescrubbing Blow Pit		
Number	1	1
(8) Mother Liquid Treatment		
Number	1 set	1 set
System	Softening Treatment	Same as left
(9) Waste Water Treatment	This section is not required for throw-away process	
Number		1 set

feeding pipes due to surface moisture of coal.

5-4-3 Civil Structures

(1) Circulating Water System

The locations and structures of condenser cooling water facilities should be finalized upon detailed studies at the stage of definite design taking into consideration the results of surveys of the conditions of the Indus River during floods and of the geological conditions of the site.

The locations and structures of the intake and outlet taken up in this study were selected for the reasons below.

A location for intake from the Indus River can be considered in the section 4,300 m to 4,600 m upstream from Kotri Barrage judged from the river profile and cross section furnished by WAPDA (See Fig. 5-3) If within this section, it is considered possible to construct a circulating water way at any location in view of the topographical and geological conditions of this area.

Regarding the outlet, the effects of discharging thermal effluent when the inflow to Kotri Barrage is small has been considered, and the location was set approximately 1,000 m downstream from the intake site.

Several methods are conceivable for the water-conducting system, but in consideration of the topographic features of the site, ease of construction, and economy, a comparison study was made of the two cases below. (See Fig. 5-4)

Case I would consist of locating the intake at the bank of the Indus River with a sedimentation basin and pump pit provided adjacent to the intake, and water would be conveyed from the pump pit to the power plant by steel pipelines.

Case II would consist of conducting water to a point approximately 2,600 m inland from the Indus River by an open channel from where steel pipelines would go to the power plant after the water passes through an intake, intake culvert and pumping station.

The study showed that Case I would be relatively costlier to construct than Case II since a sedimentation basin would be required, while the pump pit would be at a long distance from the power plant, and especially, there would be problems in maintenance of equipment such as screens and pumps. In Case II, the open channel can be expected to function as a sedimentation basin, maintenance will be easier because of nearness to the power plant, and the construction cost will be lower. Accordingly, this was selected as the scheme to be adopted. However, since it is expected of the open channel to function as a sedimentation basin in Case II, it will be necessary for dredging to be done periodically every year.

Outlines of the various facilities are given below.

1) Open Channel
   The minimum water level at the intake site will be EL. 14.63 m during gate repairs at Kotri Barrage. (The depth of the Indus River at this time will be approximately 3 m.) (See Fig. 5-3)

The period of this minimum water level will be short being from the middle to the end of December every year according to data for the 5-year period from 1975 through 1979. It will be necessary for a structural type enabling intake to be accomplished even during this period.

On the other hand, the flood season of the Indus River is in June through October which corresponds to the rainy season and the water level will rise to a maximum of El. 23.73 m. Considering this water level variation, it may be anticipated that there will be effects of sedimentation at the intake site during the flood season. Consequently, since it is desirable for intake facilities to be of such construction that dredging of sediment can be performed with ease in order that intake can be made possible through the year, an open channel was adopted. The period during which sediment in the open channel is to be dredged is to be the low-water season other than the minimum water level period (gate repair period) at Kotri Barrage. Dredging can be accomplished by pump.

The cross section of the open channel need be only enough to enable intake in the low-water season of $Q = 9.80\ m^3/sec$, the water requirement for this Project (300 MW x 1 unit). However, considering the relatively small quantity of excavation to be done additionally for the plant expansion and the effects of sediment and muddy water on the existing open channel during excavation, it will be more advantageous to excavate from the beginning to a cross section which takes into account water passage upon plant expansion. Consequently, the cross section of the open channel is to be that which considers plant expansion.

The height of the open channel levee crest and the slope gradient were selected to be such that there will be safety even during floods. The inlet section of the open channel facing the river is to have training walls of cell-type construction using steel sheet piles to prevent collapsing due to waves.

In carrying out construction, it will be desirable for determinations to be made of the open channel configuration, flow velocity, sedimentation, etc. upon detailed studies conducting hydraulic model experiments.

2) Intake and Intake Culvert

The intake and intake culvert, as shown in Fig. 5-6, are to comprise an integrated structure of reinforced concrete construction having widths of 25.00 m to 34.00 m and heights of 15.9 m to 3.90 m, with the foundations supported by concrete piles. The intake orifice is to be of ample width to reduce flow velocity as a consideration for preventing entrance of large pieces of sediment.

A bar screen is to be provided at the intake as a measure to dispose of trash. Stop logs are to be provided in the intake to make it possible to dewater the inside of the intake during repairs of the bar screen.

The intake waterway was made a culvert for the purpose of crossing roads and railways and to secure the cross-sectional area of the stream during floods of the Indus River.

3) Pump Pit

The pump pit, as shown in Fig. 5-6, is to be of reinforced concrete construction having a width of 37.00 m, heights of 16.90 m to 19.40 m and a length of 35.00 m, and it was surmised that the foundation would be bed-rock.

Regarding the location of the pump pit, although it is conceivable for it to be adjacent to the intake, it was selected at the power plant side to shorten circulating water pipes and to make maintenance during floods easy to perform.

A rotary screen and net screen are to be installed at the pump pit to handle trash.

Stop logs are to be provided in order to make it possible to dewater the pump pit for waterway inspection and screen repairs.

4) Circulating Water Pipes

Circulating water pipes are to be steel pipes of inside diameter of 2.20 m to be buried underground with two lines provided for each unit.

The pipelines are to be directly buried, and since the foundations will be bedrock, bedding sand is to be used for cushioning. Lining of steel pipe is to be tar-epoxy paint on interior surfaces and double layers of coal tar-enamelled glass cloth on exterior surfaces.

5) Tailrace and Tailrace Outlet

The tailrace is to be a waterway starting from the discharge pit to go downstream to the Kotri Barrage regulating pond via the tailrace waterway and tailrace outlet, and is to be a culvert of reinforced concrete construction.

A ground sill is to be provided at the tailrace outlet in order to prevent scouring by flowing water when the water level of the Kotri Barrage regulating pond has dropped.

(2) Site Preparation

Detailed topographic surveying and geological investigations are to be carried out by WAPDA and/or associated organization(s) of Pakistan on the site and its vicinity with the purpose of site preparation for the power station, and decisions on the site should be made based on the results of detailed studies following definite design taking into consideration the results of the said investigations. The locations and structural types of the power plant, coal yard and other facilities have been proposed for the reasons listed below.

As a result of studies of 1/50,000 topographical maps furnished by WAPDA and field surveys, the power plant site was selected at the location indicated in Fig. 5-1 where the necessary area for the power station could be secured and where it would be absolutely safe during floods of the Indus River.

The area required for the power station was made to include the area necessary for future extension. The site is to be planned so that it will be flat, and with excavated rock to be effectively utilized for building levees of the intake waterway (open channel) and as materials for protection of slopes of levees of the ash disposal area.

(3) Coal Storage Yard and Coal Drawout Culverts

The coal storage yard is to be of a size of 220 m x 220 m with 2 coal drawout culvert lines provided at the center.

Water containment walls are to be built around the coal yard to prevent outflow of turbid water during rain.

Evacuation shafts to be used at times of accident which will also serve for ventilation of the coal drawout culverts are to be provided at the ends of the culverts.

(4) Ash Disposal Area

It is desirable for the ash disposal area to be at a place as near as possible to the powerhouse. As a result of the field surveys conducted by the JICA Survey Team a relatively flat depressed area at the northwest side of the powerhouse was planned as the ash disposal area.

Levees are to be provided around the ash disposal area to prevent outflow of ash. The top of a part where ash disposal has been completed is to be covered with soil to prevent ash from being blown away and finished with a slope suitable for drainage.

Dry pitching is to be provided at outer slopes of levees to prevent collapse due to wind and rain. Ditches are to be provided around levees in consideration of drainage from the surface of the ash disposal area and prevention of collapse of levees due to flowing water from outside.

(5) Irrigation Water Intake Facilities

An intake plan for irrigation water has not been decided on at present, but intake facilities for irrigation water with the aim of effective utilization of water discharged from the powerhouse were provided for midway along the tailrace. (See Fig. 5-7)

The quantity of intake cooling water for the condensor will reach 10.2 cubic meters per second while that of discharge water will be 9.9 cubic meters per second. The temperature of said water will rise by about 9°C (the temperature of water at the inlet of the condensor plus approximately 9°C) at the condensor discharge. No chemicals will be used for the condensor cooling water for preventing corrosion of the condensor tubes, and there will be no change in the quality of water. Accordingly, cooling water to be discharged from the condensor can be used for agricultural irrigation purposes.

5-4-4 Water Supply for Power Station

Boiler feed water, bearing cooling water, drinking water, miscellaneous-use water, and fire-extinguishing water are all to be river water which will be treated for use since city water is not available at the site. Refer to Fig. 5-21 for details.

According to the water quality analysis of Indus River water (Table 5-4), the turbidity is extremely high.

Because of this, water supply of power station, river water branched from the pipeline for condenser cooling water is to be boosted up and supplied to a pulsator and filter, cleared by aggregation, settling and filtration, and upon completion of treatment, stored in a raw water tank for the various uses indicated on the next page.

Table 5-4 Data on Analysis of Water from the Indus River

Measuring Item	Unit	Value	Remarks
Temperature	°C	20 to 35°C	The results vary
pH		7.5 to 7.8	from minimum to
Conductivity	Micr-Mho/cm	0.3×10^3 to 0.4×10^3	maximum limits. The water is clearer
Total Solid	ppm	320 to 450	in December to
Turbidity	ppm	680 to 3,500	February and
M-Alkalinity	ppm as $CaCO_3$	100 to 120	turbidity increases
Chloride	ppm as Cl	40 to 80	from March to
Total Hardness	ppm as $CaCO_3$	96 to 120	October.
Calcium Hardness	ppm as $CaCO_3$	80 to 110	
Magnesium Hardness	ppm as $CaCO_3$	25 to 45	
Sulfuric Acid Ion	ppm as SO_4	—	
Total Iron Ion	ppm as Fe	—	
Ammonia Ion	ppm as NH_4	The remaining	
Silica Iron	ppm as SiO_2	results are not	
Langelier Satulation Index	30°C	available.	

(1) Boiler Water

Raw water stored in the raw water tank is to be fed to the demineralization plant by the raw water pump where it is subjected to a sophisticated water treatment process to be made into demineralized water and stored in the demineralized water tank as boiler water.

(2) Bearing Cooling Water

Raw water in the cooling water tank to be installed on the first floor of the turbine room is to be used as bearing cooling water. Refer to Fig. 5-22 for details.

A closed circuit is to be adopted for the bearing cooling water system.

The bearing cooling water is to be cooled with river water by means of the cooling water cooler.

(3) Drinking Water

A drinking water treatment apparatus is to be installed at the rooftop of the administrative building, and with water supplied from the raw water tank, simple filtering and sterilizing is done, upon which the water is to be used as drinking water.

(4) Fire Extinguishing Water

Fire extinguishing water is to be supplied from the raw water tank.

Fire extinguishing pumps are to be both electrically- and engine-driven.

(5) Miscellaneous-use Water

Miscellaneous-use water such as for washing equipment and floors is to be supplied from the pipeline of the raw water pump.

(6) Capacity of Raw Water Tank

The requirement for raw water per day will be the following:

1) Quantity required for boiler make-up water
   (300 MW x 1 unit or 150 MW x 2 units)
   (Boiler evaporation) 500 t/hr x 2 units x 2%
   (Average make-up quantity) x 24 hrs.
   = 1,000 x 0.02 x 24 = 480 t/day

2) Bearing cooling water make-up quantity
   10 t/hr x 24 = 240 t/day

3) Others
   10 t/hr x 24 = 240 t/day
   Total of 1), 2) and 3) 960 t/day ≒ 1,000 t/day

Taking into account washing of equipment for periodic inspection and use of water for works, the maximum requirement is to be:

Average consumption x 1.5 = 1,500 t/day

The tank capacity, taking into consideration repairs of tank interiors, is to be 1,500 t x 2 units.

(7) Capacity of Demineralized Water Tank

In case of silica blowing of a boiler of 300 MW x 1 unit, 1,500 t/day of pure water will be required. Meanwhile, the capacity of the demineralization plant in case of 10-hr operation of two lines of 30 t/hr will be 600 t. Consequently,

Demineralized water requirement for Silica purging
– Capacity of purification plant = Pure water shortfall
= 1,500 t – 600 t = 900 t

The capacity of a single tank is to be made 1,000 t considering dead space of the tank, and taking into account trouble at the demineralization plant and inspections of tank interiors, two 1,000-t demineralized water tanks are to be provided.

5-4-5 Fuel Facilities

(1) Fuel

This Project will use coal to be produced at Lakhra Coal Mine as main fuel, and natural gas produced at Sui as supplementary fuels.

Table 5-5 Specification of Fuel and Ash

1.	Coal	
(1)	Gross Calorific Value	4,613 Kcal/kg (Air Dried Base)
(2)	Proximate Analysis (Air Dried Base)	
	Moisture	9.5%
	Ash	23.7%
	Volatile Matter	34.7%
	Total Sulfur	7.1%
	Fixed Carbon	25.0%
(3)	Ultimate Analysis	
	C	65.2%
	H	5.2%
	O	18.0%
	N	1.1%
	S	10.5%
(4)	Hardgrove Index	72
(5)	Refractoriness of Ash	
	Initial Deformation Point	1,310°C
	Melting Point	1,380°C
	Fluid Point	1,410°C
(6)	Electrical Resistivity of Ash	
	100°C	2.9×10^{13} Ω-cm
	130°C	3.5×10^{13} Ω-cm
	160°C	2.5×10^{13} Ω-cm
(7)	Specific Gravity of Ash	1.54
(8)	Composition of Ash	
	SiO_2	32.7%
	Al_2O_3	20.18%
	Fe_2O_3	30.23%
	CaO	4.55%
	MgO	2.28%
	Na_2O	1.18%
	K_2O	0.62%
	SO_3	6.23%
2.	Natural Gas	
(1)	Calorific Value	878.7 Btu/cu.ft (7,819 Kcal/cu.m)
(2)	Data of Analysis	
	Methane (CH_4)	94.42%
	Ethane (C_2H_6)	1.05%
	Propane (C_3H_8)	–
	Carbon Dioxide (CO_2)	0.02%
	Nitrogen (N_2)	3.89%

The natural gas is to be used for igniting the main burners, start-up of the boiler and stabilization of burner flame in the low load operation of the boiler.

The specifications and analysis results of the fuels are indicated in Table 5-5.

(2) Fuel Consumption
With plant utilization factor as 70% and gross thermal efficiency at generating end as 300 MW: 37% and 150 MW: 36%, the fuel consumption was calculated approximately by the equation below.

$$W = P_G \times 860/\eta_p \times H_h$$

where
- W : fuel consumption (kg/hr, Nm^3/hr)
- P_G : generating end output (MW)
- η_p : gross thermal efficiency at generating end
- H_p : gross calorific value (air dried base) (Kcal/kg), gas ($Kcal/Nm^3$)

1) Coal (Air Dried Base)

300 MW x 1 unit

$$W_C = \frac{300 \text{ MW} \times 860}{4{,}613 \times 0.37} = 151.2 \text{ t/hr}$$

150 MW x 2 units

$$W_C = \frac{150 \text{ MW} \times 2 \text{ unit} \times 860}{4{,}613 \times 0.36} = 155.4 \text{ t/h}$$

2) Natural gas
Natural gas is to be used for igniting coal burners, stabilizing flame of burners, and maintaining the load of the power stations even if the pulverizers are out of order.

Taking into account the capacity of the natural gas, it is necessary that 35% of the rating capacity of the power station could be provided, in case of 300 MW x 1 unit, by the natural gas in order to compensate for a trouble of 1 unit of pulverizer.

As to 150 MW x 1 unit, 30% of the rating capacity should be provided by the natural gas.

The gas consumption per hour for all burners of 300 MW x 1 unit or 150 MW x 2 units will be respectively:

300 MW x 1 unit

$$W_G = \frac{300 \text{ MW} \times 860 \times 0.35}{7{,}819 \times 0.37} = 31{,}213 \text{ Nm}^3/\text{h}$$

150 MW x 2 units

$$W_G = \frac{150 \text{ MW} \times 2 \text{ units} \times 860 \times 0.30}{7{,}819 \times 0.36} = 27{,}497 \text{ Nm}^3/\text{h}$$

(3) Fuel Storage Quantities

1) Coal
Coal storage quantities as received basis, since total moisture is 25.0%, will be:

$$\frac{\text{Coal \% (air dried basis)}}{\text{Coal \% (as received basis)}} \times 100 = \frac{90.5}{75} \times 100 = 120.7\%$$

300 MW x 1 unit	150 MW x 2 units
151.2 t/h x 1.207 = 182.5 t/h	187.6 t/h x 24 h x 14 days = 63,034 t/2 weeks

Considering storage of two-weeks' supply,

300 MW x 1 unit	150 MW x 2 units
182.5 t/h x 24 h x 14 days = 61,320 t/2 weeks	187.6 t/h x 24 h x 14 days = 63,034 t/2 weeks

Therefore, the coal storage capacity in the case of 300 MW x 1 unit or 150 MW x 2 units is to be 63,000 t.

With height of piling of coal as 3 m and the specific gravity of coal as 0.9, the area required will be:

$$\frac{63{,}000\ t}{0.9 \times 3} = 23{,}300\ m^2$$

Considering the efficiency in piling and repiling of coal,

Planned area = Area required x 2 = 23,300 x 2 = 46,600 m^3

Therefore, the dimensions of the coal yard is to be 220 m x 220 m.

2) Natural gas
It is assumed that a stable supply of natural gas can be obtained from the Indus Gas Company and storage facilities will not be provided in the premises.

(4) Coal Handling
Coal to be produced at Lakhra Coal Mine will be delivered to the power station by a special rail line. Refer to Fig. 5-19 for details.

1) Capacity of receiving hopper
The coal consumption per day will be 187.6 t/hr x 24 = 4,502 t. With the quantity received as 5,000 t/day, it is assumed that coal will be received by trains each of thirty of 30-ton cars, and to consider some allowance, the receiving hoppers are to be 900 x 2 units.

2) Coal yard supply conveyor
Assuming that 5,000 t of coal per day is to be supplied to the coal yard in 5 hours, the capacity of conveyors would be 500 t/hr x 2 units.

3) Coal bunker supply conveyor
Consumption of coal will go on 24 hours of the day, while it is assumed supply to the coal bunkers will be for 8.5 hours from 8:30 to 18:00 hrs for storage as of 18:00 hrs the coal required from 18:00 hrs to 08:30 hrs of the following day, and the capacity of one supply conveyor unit will thus be:

300 MW x 1 unit	150 MW x 1 unit
$\frac{182.5 \text{ t/h} \times 24 \text{ h}}{8.5 \text{ h}} = 515 \text{ t/h}$	$\frac{187.6 \text{ t/h}/2 \times 24 \text{ h}}{8.5 \text{ h}} = 265 \text{ t/h}$
515 t/h x 1.2 = 620 t/h	265 t/h x 1.2 = 320 t/h
350 t/h x 2 lines	350 t/h x 1 line/unit

4) Coal bunker capacity

a) 300 MW x 1 unit

Since it will suffice to have storage for 14.5 hours:

14.5 hrs. x 182.5 t/h = 2,646 t

With specific gravity of coal as 0.9 and the actual volume ratio of the hopper as 0.8,

$$\text{Bunker capacity} = 2{,}646 \times \frac{1}{0.9} \times \frac{1}{0.8} = 3{,}675 \text{ m}^3$$

Assuming five bunker hopper units (including one reserve):

$$\text{Volume per bunker} = \frac{3{,}675 \text{ m}^3}{4} = 919 \text{ m}^3$$

950 m^3 x 5/unit

b) 150 MW x 1 unit

Storage for 14.5 hours

14.5 hrs. x 187.6 t/h/2 = 1,360 t

$$\text{Bunker capacity} = 1{,}360 \text{ t} \times \frac{1}{0.9} \times \frac{1}{0.8} = 1{,}889 \text{ m}^3$$

Assuming four bunker hopper units (including one reserve):

$$\text{Volume per bunker} = \frac{1{,}889 \text{ m}^3}{3} = 630 \text{ m}^3$$

650 m^3 x 4/unit

(5) Fuel Firing Equipment

1) Coal

a) Coal Feeder(for coal as received)

The capacity per coal feeder unit is the following:

300 MW unit	150 MW unit
$\frac{182.5 \text{ t/h}}{4} = 45.6$	$\frac{187.6 \text{ t/h}/2}{3} = 31.3 \text{ t/h}$
45.6 t/h x 1.2 ≒ 55 t/h	31.3 t/h x 1.2 = 38 t/h

Therefore,

55 t/h x 5 (incl. 1 reserve)	38 t/h x 4 (incl. 1 reserve)

are to be provided.

b) Coal Pulverizer

300 MW unit	150 MW unit
55 t/h x 5 (incl. 1 reserve)	38 t/h x 4 (incl. 1 reserve)

are to be provided.

c) Pulverized Coal Burner (for coal as received)
hence:

	300 MW unit	150 MW unit
General use burner	16 sets	12 sets
Reserve	4 sets	4 sets

Capacity of each burner is

$$\frac{182.5\ t/h}{16} = 11.4\ t/h \qquad \frac{187.6\ t/h/2\ units}{12} = 7.8\ t/h$$

Therefore,

12 t/h x 20 sets	8 t/h x 16 sets

are to be provided.

2) Natural Gas
hence:

	300 MW unit	150 MW unit
Ignition burner	20 sets (incl. 4 reserves)	16 sets (incl. 4 reserves)
Gas burner	20 sets (incl. 4 reserves)	16 sets (incl. 4 reserves)

Capacity of each burner is

$$\frac{31{,}213\ Nm^3/h}{16} = 1{,}951\ Nm^3/h \qquad \frac{27{,}497\ Nm^3/h/2\ units}{12} = 2{,}291\ Nm^3/h$$

Therefore,

2,000 Nm^3/h x 20 sets	2,300 Nm^3/h x 16 sets

are to be provided.

5-4-6 Ash Handling Equipment

(1) Quantity of Ash Generated

Since the content of ash in the coal is 23.7%, the quantity of ash generated daily per unit will be:

300 MW x 1 unit	150 MW x 2 units
151.2 t/h x 24 h x 0.237 = 860 t/day	155.4 t/h x 24 h x 0.237 = 884 t/day

(2) Proportion of Ash Generated

Assuming the following:

		Specific gravity
Clinker	15%	1.0
Cinder	5%	0.8
Fly ash	80%	0.8

(3) Quantity of Ash Disposal

Assuming that all of the clinker and cinder and 50% of the fly ash are to be disposed of:

1) Ash disposal per day

300 MW x 1 unit	150 MW x 2 units
860 t/day x 0.6 = 516 t/day	884 t/day x 0.6 = 530 t/day

2) Planning the area of the ash disposal site to be sufficient for 30 years, the quantity of ash to be disposed of in 30 years will be:

300 MW x 1 unit	150 MW x 2 units
516 t/day x 365 days x 0.7 x 30 years = 3,955,140 t	530 t/day x 365 days x 0.7 x 30 years = 4,062,450 t

(4) Ash Disposal Site Area Required

Average specific gravity = 0.85

Assuming height of piling of ash to be 3 m:

300 MW x 1 unit

$$\frac{3,955,140 \text{ t}}{0.85 \times 3} \fallingdotseq 1,551,000 \text{ m}^2$$

150 MW x 2 units

$$\frac{4,062,450 \text{ t}}{0.85 \times 3} \fallingdotseq 1,593,000 \text{ m}^2$$

The design area of the ash disposal lot is to be 1,600,000 m² for the case of 300 MW.

(5) Capacities of Ash Handling Equipment

1) Capacity of Clinker Hopper

A capacity sufficient to store a volume of water 2.5 times the quantity of ash is required, and since ash removal is to be done every 10 hours.

300 MW x 1 unit	150 MW x 1 unit
151.2 t/h x 0.237 x 0.15 = 5.4 t/h	$\frac{155.4 \text{ t/h} \times 0.237 \times 0.15}{2}$ = 2.8 t/h
5.4 t/h x 10 h x 2.5 = 135 t 135 t x 1.3 = 176 t (176 m^3) 90 m^3 x 2 sets are to be provided.	2.8 t/h x 10 h x 2.5 = 70 t 70 t x 1.3 = 91 t (91 m^3) 100 m^3 x 1 set

2) Capacity of Jet Pulsion Pump

Assuming that ash in the clinker hopper is to be handled in 40 minutes,

300 MW x 1 unit	150 MW x 1 unit
5.4 t/h x 10 h x 60 min./40 min. = 81 t 81 t/h x 1.3 = 105 t/h	2.8 t/h x 10 h x 60 min./40 min. = 42 t 42 t/h x 1.3 = 55 t/h
Therefore, 50 t/h x 2 sets are to be provided.	30 t/h x 2 sets

3) Capacity of Dewatering Bin (per unit)

A capacity to accommodate the water inside the clinker hopper (volume of pressurized water for jet propulsion pump + volume of hopper jetting water) will be required.

300 MW x 1 unit	150 MW x 1 unit
(90 m^3 x 2) + (420 m^3/h x 40 min./60 min.) x 2 + 100 m^3/h x 40 min./60 min. = 180 m^3 + 560 m^3 + 70 m^3 = 810 m^3	100 m^3 + (250 m^3/h x 40 min./60 min.) x 2 + 100 m^3/h x 40 min./60 min. = 100 m^3 + 330 m^3 + 70 m^3 = 500 m^3
Therefore, 900 m^3 x 1 set are to be provided.	500 m^3 x 1 set

4) Capacity of Ash Sluicing Pump

The capacity is used for the jet pulsion pump and for clinker jetting.

a) Water Requirement for Clinker Handling (per unit)

300 MW x 1 unit	150 MW x 1 unit
Jet pulsion pump water requirement (420 m^3/h x 2 sets) + clinker jetting water (100 m^3/h) + Allowance (20 m^3/h) = 960 m^3/h ≒ 1,000 m^3/h	Jet pulsion pump water requirement (250 m^3/h x 2 sets) + clinker jetting water (100 m^3/h) + Allowance (10 m^3/h) = 610 m^3/h ≒ 650 m^3/h

b) Capacity of an Ash Sluicing Pump

300 MW x 1 unit	150 MW x 2 units
500 m^3/h x 3 sets (incl. 1 reserve)	650 m^3/h x 3 sets (incl. 1 reserve)

5) Capacities of Coarse Ash Tanks and Fly Ash Tanks
With specific gravity of ash 0.8 and volumetric efficiency 0.8, and with holding of a 3-day volume considered, in case of 300 MW x 1 or 150 MW x 2 units.

$$\frac{884 \text{ t/day} \times 0.85 \times 3 \text{ days}}{0.8 \times 0.8} = 3{,}523 \text{ m}^3 \fallingdotseq 4{,}000 \text{ m}^3$$

In case of 300 MW x 1 unit:

$$\frac{860 \text{ t/day} \times 0.85 \times 3 \text{ days}}{0.8 \times 0.8} = 3{,}427 \text{ m}^3 \fallingdotseq 4{,}000 \text{ m}^3$$

Considering the ratio of coarse ash to fly ash to be approximately 1:2,
Coarse Ash Tank Capacity = 1,500 m^3/2 = 750 m^3 ≒ 800 m^3

Therefore, the coarse ash tanks to be provided will be the following:

300 MW x 1 unit	150 MW x 2 units
1,600 m^3 x 1 set	800 m^3 x 2 sets

are to be provided.

Meanwhile,
Fly Ash Tank Capacity = 2,500 m^3/2 = 1,250 m^3 ≒ 1,500 m^3

Therefore, the fly ash tanks to be provided will be the following:

300 MW x 1 unit	150 MW x 2 units
3,000 m^3 x 1 set	1,500 m^3 x 2 sets

are to be provided.

6) Ash Settling Pond
Water from the dewatering bin will flow into the ash settling pond.

The capacity of the pond will be the following:
Capacity of 1 Dewatering Bin (500 m^3) + Ash Sluicing Pump Water Requirement (650 m^3) = 1,150 m^3 ≒ 1,200 m^3
The lines of the above-capacity ponds are to be provided.

5-4-7 Boiler Facilities

(1) Adoption of Natural Circulation Boiler
Boilers may be broadly divided into natural circulation, forced circulation and once-through

types.

Natural circulation boilers are adopted for this Project for the reasons below.

1) Operation and maintenance are relatively easy.
2) Boiler circulation is sure.
3) Damage is limited even when water tubes are harmed.
4) Construction cost is relatively low.

(2) Steam Conditions

The steam conditions used are to be standard type ones which are economical and reliable.

Superheater outlet	300 MW unit	150 MW unit
Steam pressure	173 kg/cm²g	131 kg/cm²g
Steam temperature	541°C	541°C

(3) Adoption of Outdoor Type Boiler

1) There is little dead space in construction and the construction cost can be reduced.
2) The construction period can be shortened.
3) There is more safety in case of fuel leakage.
4) Lighting, wiring and piping are relatively easy to provide.
5) There is little rainfall in the Jamshoro District.

(4) Adoption of Balanced Draft System

1) Sufficient draft can be obtained while maintaining the interior of the furnace at lower pressure than the atmosphere.
2) The system is safe as there is no leakage of combustion gas to the outside.
3) Control of air quantity is easy.

(5) Adoption of Rotating Regenerative Air Preheater

1) There is little clogging by ash.
2) The installation area is small.
3) The heat transmitting efficiency is good.

(6) Adoption of Steam Air Preheater

Since the coal to be used in this Project will have a very high combustible sulfur content in fuel of 7.1%, a steam air preheater is to be provided to prevent corrosion of elements at low-temperature parts of the rotating regenerative air preheater.

(7) Selection of Dust Collector

Electrostatic precipitator are to be adopted for the reasons given below.

1) The dust collection efficiency extremely high.
2) Collection of minute particles is possible.
3) The pressure loss inside the apparatus is extremely small.
4) Maintenance is easy and the maintenance cost is low.
5) Corrosive gas and dust can be treated.
6) Treating of high-temperature exhaust gas is possible.
7) The quantity of gas treated is big.

(8) Countermeasures for High Electrical Resistivity of Lakhra Lignite Combustion Dust

1) Electrical Resistivity of Dust and Dust Collecting Efficiency

As a result of measuring the electrical resistivity of ash from samples of the coal planned to be used for the Coa-fired Thermal Power Station, it was $3.5 \times 10^{13}\Omega$-cm at a gas temperature of 130°C and $2.5 \times 10^{13}\Omega$-cm at 160°C.

In general, regarding the relation between electrical resistivity of dust and dust collecting efficiency as shown in Fig. 5-40, it is said that 10^4 to $10^{11}\Omega$-cm is the normally applicable range for a low-temperature electrostatic precipitator.

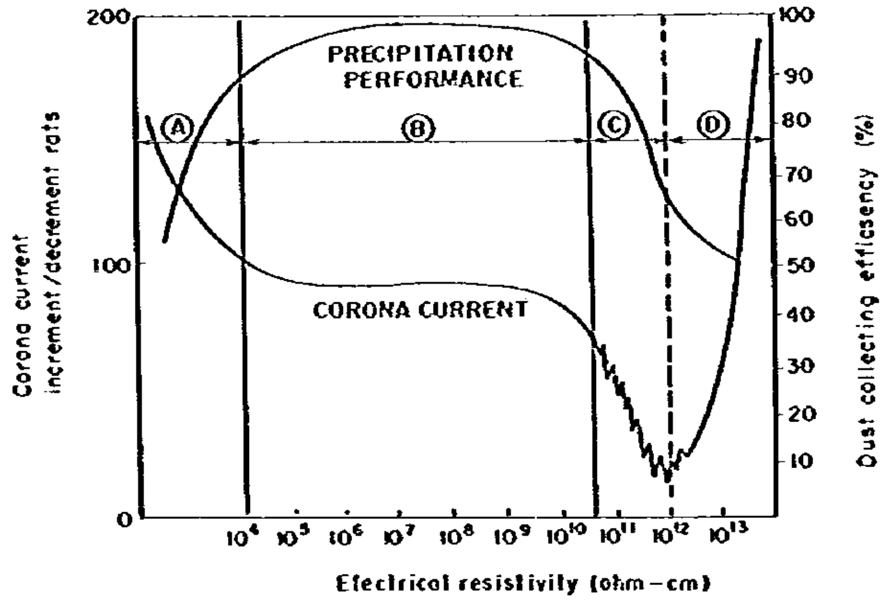


Fig. 5-40 Relationship between Precipitator Performance and Resistivity of Dust

In the area (Area D) where electrical resistivity exceeds $10^{12}\Omega$-cm as shown in Fig. 5-40 "Back corona" will be generated in the entire portion of the dust layer of collecting electrodes. Back corona phenomenon is a back discharge phenomenon which occurs when the voltage generated (V = R x I) by corona current passing through a dust layer exceeds the dielectric breakdown voltage of gas in the dust layer, which results in unstable loading. Efficiency will be lowered as a result. Further, when high-resistivity dust is caught on a collector plate, the charge is not immediately lost so that it will be forcedly pressed onto the collecting plate with a large electrical force.

2) Relation between Sulfur Content in Coal and Electrical Resistivity

The relation between the sulfur content in coal and the value of electrical resistivity is shown in Fig. 5-41.

In general, the electrical resistivity value tends to be lower the higher the sulfur content of coal. However, this tendency cannot be seen in the case of Lakhra lignite.

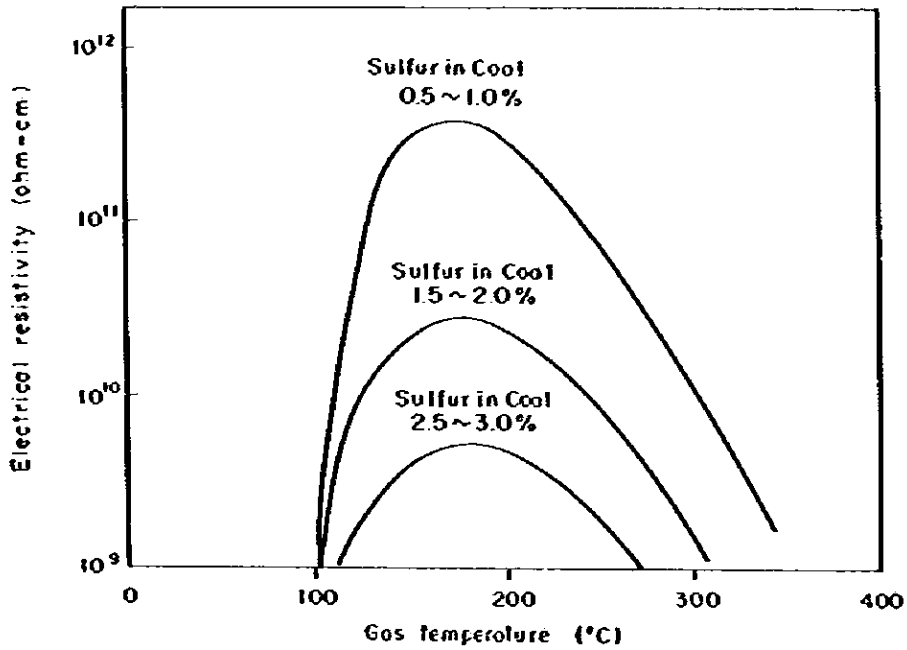


Fig. 5-41 Resistivity of Fly Ash with Variations in Flus Gas Temperature and Coal Sulfur Content

3) Relation between Chemical Composition and Electrical Resistivity of Fly Ash

As seen from the chemical composition of fly ash, since SiO_2 and $A\ell_2O_3$ have relatively high electrical resistivities, the electrical resistivity of the ash becomes high when these components increase in quantity.

CaO, MgO and K_2O are oxides of alkali metals and have the properties of neutralizing the action of SO_3, and when the content of these is high, the electrical resistivity will be high.

Electrical resistivity is lower the higher the SO_3 content.

There is no factor for high electrical resistivity to be seen in the chemical composition of the ash of Lakhra lignite.

4) Considerations and Countermeasures

The electrical resistivity of dust of Lakhra lignite is very high as previously stated and indicates a figure in the range where back corona phenomena would be produced, but the sulfur content in the fuel is high, while the composition of fly ash does not indicate any figure which would cause electrical resistivity to be high.

There are the methods below for handling dust of high electrical resistivity with a dust collector.

a) The drop in performance due to high-resistivity dust is to be coped with by increase in electrostatic precipitator capacity, improvement in discharge electrodes and strengthening of rapping force.

Back corona and dust accumulation attributable to dust take place in case of collection of high electrical-resistivity dust. In order to prevent this from happening, a discharge electrode with which effective corona discharge current is obtained even at a low voltage such that back corona is not generated is selected, a hammering system with which powerful rapping forces on the collector plates can be obtained to counter dust accumulation is adopted, and to secure an efficiency of 90%, capacity is enlarged approximately 20% over that of a conventional electrostatic precipitator.

b) Provision of Dust Stabilizer

There are measures for stabilizing the resistivity of dust by injection of water or chemicals. For example, a method of injecting SO_3 to the outlet flue of the preheater could be cited. However, since the content of SO_3 in dust is about 6% even in the present state, it is questionable whether there will be any effect of such SO_3 injection. A further question is whether the injected SO_3 will be evenly distributed over the ash particles to be useful in lowering electrical resistivity of ash as a whole since the quantity of ash produced in combustion will be large. On the other hand, there is a risk of corrosion of the inner surface of the flue and the lining material at the inner surface of the stack being accelerated when there is trouble with the SO_3 injection apparatus, while there is also the risk of sulfur oxide concentration increasing to cause an environmental problem.

c) Use of High-temperature Precipitator

The electrical resistivity of ash in general is unrelated to the degree of sulfur content. The dust collection efficiency becomes stable at about $10^9\,\Omega$-cm at a gas temperature of around 300°C. This characteristic is taken advantage of and a high-temperature precipitator is installed before the air preheater for dust collection in a high-temperature range. However, the construction cost of the electrostatic precipitator will increase by approximately 30% since the precipitator capacity must be increased (6%) with the increased volume of the gas due to the higher temperature, use of heat-resistant materials, and increased thickness of insulting materials.

5) Conclusions

From technical and economic standpoints, planning is to be done adopting the method of increasing the capacity of the electrostatic precipitator, improving the discharging electrodes, and strengthening the rapping force. However, in carrying out definite design, it will be necessary to reinvestigate the matters below and select a type of precipitator suited to the results.

It will be necessary to obtain 4 or 5 samples of lignite each from the West Open Pit, East Open Pit and underground at the proposed Mine at Lakhra and measure electrical resistivities of ashes in the range of 100°C to 300°C and investigate in detail properties such as the particle-size distributions and chemical compositions of the ashes.

5-4-8 Turbine Facilities

(1) Adoption of T-type Arrangement

The layout of the turbine was made a T-type with respect to the boiler in view of the relations with the arrangements of the condenser water cooling pipes and main transformers.

(2) Adoption of Reheating Cycle

(3) Adoption of Tandem Compound System

(4) Quantity of Condenser Cooling Water

The condenser cooling water is to be drawn from the Indus River in the vicinity of the site. The quantity of cooling water was calculated approximately according to the following:

$$G_W = \frac{Q}{\gamma \times C_p \times \Delta T}$$

where

G_W = condenser cooling water quantity (m^3/hr)
C_p = specific heat at constant pressure (Kcal/kg°C)
γ = specific gravity of cooling water (kg/m^3)
ΔT = difference between cooling water outlet temperature and cooling water inlet temperature
= 37°C – 28°C
= 9°C
Q = condenser exchanged heat (Kcal/hr)

300 MW x 1 unit

$$\frac{3.2 \times 10^8 \text{ Kcal/h}}{1{,}000 \text{ kg} \times 1 \text{ Kcal} \times 9°C} = 35{,}600 \text{ m}^3/\text{h}$$

150 MW x 1 unit

$$\frac{1.7 \times 10^8 \text{ Kcal/h}}{1{,}000 \text{ kg} \times 1 \text{ Kcal} \times 9°C} = 18{,}900 \text{ m}^3/\text{h}$$

(5) Condenser

1) The design conditions are to be as indicated below.

	300 MW unit	150 MW unit
Vacuum Level	700 mmHg	700 mmHg
Cooling Water Inlet Temperature	28°C	28°C
Cooling Water Quantity	35,600 m^3/hr	18,900 m^3/h
Exchanged Heat	3.2×10^8 Kcal/hr	1.7×10^8 Kcal/h
Cooling Tube Material	Aluminum brass (with protection coating)	Aluminum brass (with protection coating)
Flow Velocity inside of Cooling Tube	2 m/sec max.	2 m/sec max.
Cooling Tube Cleaness Factor	85%	85%

(6) Capacity and Number of Units of Circulating Water Pumps

The capacity of the circulating water pump is to be the sum of the items below.

		300 MW x 1 unit	150 MW x 2 units
a)	Condenser Cooling Water	35,600 m^3/h	18,900 m^3/h x 2 units = 37,800 m^3/h
b)	Cooling Water Cooler	1,100 m^3/h	1,500 m^3/h
c)	Demineralization Plant	60 m^3/h	60 m^3/h
d)	Make-up Water for Bearing Cooling Water	10 m^3/h	10 m^3/h
e)	Make-up Water for Ash Handling System	10 m^3/h	10 m^3/h
f)	Water for living use	40 m^3/h	40 m^3/h
g)	Other	50 m^3/h	50 m^3/h
	River Water Quantity Required for Power Station	36,870 m^3/h	39,470 m^3/h

The capacity of the circulating water pump is to be calculated below.

300 MW unit

$$\frac{36{,}870\ m^3/h}{2\ \text{pumps}/1\ \text{unit}} = 5.1\ m^3/\text{sec.}/1\ \text{pump}$$

$5.1\ m^3/\text{sec.} \times 1.1 = 5.6\ m^3/\text{sec.}$

150 MW unit

$$\frac{39{,}470\ m^3/h}{4\ \text{pumps}/2\ \text{units}} = 2.7\ m^3/\text{sec.} \times 1.1$$

$2.7\ m^3/\text{sec.}\ g\ 1.1 = 3\ m^3/\text{sec.}$

Therefore, in case of

300 MW x 1 unit

5.6 m^3/s x 3 sets (incl. 1 reserve)

150 MW x 2 units

3 m^3/s x 5 sets (incl. 1 reserve for common use)

are to be provided.

According to the results of analysis of water quality of the Indus River, the turbidity value is a maximum of 3,500 ppm, and a reserve unit was provided considering wear of pump impellers.

(7) Capacity and Number of Units of Condensate Pumps

Condensate pumps are to be 50% capacity x 3 sets.

300 MW unit

340 m^3/h x 3 sets (incl. 1 reserve)

150 MW unit

190 m^3 x 3 sets (incl. 1 reserve)

(8) Capacity and Number of Units of Boiler Feed Water Pumps

The capacity of a boiler feed water pump is to be 55% of the boiler evaporation.

300 MW x 1 unit	150 MW x 1 unit
980 t/h (boiler evaporation) x 0.55 = 540 t/h	500 t/h x 0.55 = 270 t/h

Consequently, the capacity and number per unit

540 t/h x 3 sets (incl. 1 reserve)	270 t/h x 3 sets (incl. 1 reserve)

are to be provided.

5-4-9 Control Apparatus and Control System

Boilers, turbines and generators are to be centrally controlled and supervised providing boiler, turbine and electric control panel and auxiliary panels at the central control room.

Of the appurtenant facilities, intake facilities, feed water treatment apparatus, coal and ash handling facilities are to be provided with control rooms at the individual sites, and operation and supervising are to be done using the respective control panels.

Regarding supervisory instruments for the main turbines, besides it being possible for supervising to be done from the central control room, panels are to be installed to permit local monitoring of temperatures and pressures.

The principal items in the control system of this project are indicated below.

(1) Automatic Boiler Control
The automatic boiler control is to be mainly electrical, and mainly air types are to be adopted for the control apparatus for pressure, temperature, flow quantity and level at the site.

1) Combustion Control
2) Feed Water Control
3) Steam Temperature Control

(2) Turbine, Generator Control

1) Governor Control
2) Automatic Turbine Speed Control
3) Automatic Synchronous Parallel-In System
4) Automatic Voltage Regulation
5) Automatic Load Control

(3) Other Automatic Control Apparatus

1) Soot Blower Control
2) Automatic Burner Control
Gas burner control with flame detecting systems
3) Digital Computer