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KARACHI ELECTRIC SUPPLY CORPORATION, LTD.

EXECUTIVE SUMMARY FOR

PROGRAM DESIGN FOR EFFICIENCY IMPROVEMENT OF THERMAL POWER PLANTS IN PAKISTAN

OCTOBER 1985

STONE & WEBSTER ENGINEERING CORPORATION

TABLE OF CONTENTS

Section	Title	Page
1	BACKGROUND AND OBJECTIVES	1-1
2	METHODOLOGY AND SUMMARY CONCLUSIONS	2-1
3	DESCRIPTION OF SYSTEM AND CURRENT SITUATION	3-1
4	DETAILED FINDINGS AND RECOMMENDATIONS	4-1
5	COST ESTIMATES	5-1
6	IMPLEMENTATION	6-1
7	ECONOMIC JUSTIFICATIONS	7-1

LIST OF TABLES

Table	Title
3-1	KESC Generating Plants
4-1	Recommended Unit Modifications
4-2	Recommended Modifications - Water Treatment Systems
4-3	Recommended Modifications - Training/Workshops
4-4	Observed Unit Operating Statistics and Anticipated Improvements
4-5	Summary of Anticipated Efficiency Improvements and Capacity Increases
5-1	Summary of Cost Estimates and Cash Flow of KESC Recommended Modifications
7-1	Ranking of Modification Projects

LIST OF FIGURES

Figure No.	Title
3-1	KESC Plant Locations
6-1	Program Team Organization
6-2	Program Design for Efficiency Improvement for Thermal Power Plants in Pakistan - Management Tasks
6-3	Program Design for Efficiency Improvement in Thermal Power Plants in Pakistan - Engineering and Outage Summary
6-4	Program Design for Efficiency Improvement for Thermal Power Plants in Pakistan - Korangi Site
6-5	Program Design for Efficiency Improvement for Thermal Power Plants in Pakistan - SITE Site
6-6	Program Design for Efficiency Improvement for Thermal Power Plants in Pakistan - West Wharf Site
7-1	Pakistan Plant Modification Projects Cumulative NPV of Benefits vs Cumulative Costs

SECTION 1

BACKGROUND AND OBJECTIVES

1.1 BACKGROUND

The project was conceived as a result of on-going dialogue of the United States Agency for International Development (USAID) and the International Bank of Reconstruction and Development (IBRD) with the Government of Pakistan (GOP) Ministry of Water and Power (MWP), WAPDA and KESC concerning ways to meet power demand and reduce periods of capacity shortfalls. One of the measures considered was to improve the performance of existing power generation and delivery systems. IBRD has made known to MWP and power utilities its willingness to provide funding for such activities. IBRD encouraged the performance by a qualified consultant of the evaluation and planning efforts necessary for MWP and WAPDA to request a loan for a comprehensive program for improving the performance of Pakistan's thermal power plants.

MWP, WAPDA, and KESC approached USAID in early 1985 for the assistance of a US consultant to survey the performance of WAPDA and KESC thermal power plants and recommend those actions which could improve thermal plant performance.

USAID agreed to support the conduct of such a survey as set forth in terms of reference jointly prepared by MWP, WAPDA, KESC, and the IBRD. USAID selected Stone & Webster Engineering Corporation (SWEC) to carry out this survey and provide its findings and recommendations to WAPDA and KESC by the fall of 1985. It is expected that negotiations could then proceed promptly between MWP, WAPDA, and KESC with IBRD and USAID for support of plant performance improvement actions which MWP and WAPDA (or MWP and KESC) agreed merited implementation.

1.2 OBJECTIVES

The objectives established for the consulting contractor's survey activities were to:

- Review and assess the operational status and maintenance problems of thermal power stations specified by KESC.
- Recommend actions needed to improve the thermal efficiency and maintenance of the unit's availability, capacity.
- Propose a program for implementing the recommendations, including a time schedule and estimated costs, and
- Evaluate the cost benefit of the proposed plant rehabilitation.

In accord with the statement of work for the survey, the program recommended by the consultant "...should be primarily designed to increase the total generation of the existing WAPDA and KESC thermal units at a lower cost per kWh. This should be achieved by increasing the output of the units in

recuperating a maximum of the efficiency lost from the designed heat rates, in improving their availability and reliability, and in reducing the cost of operation and maintenance."

This Executive Summary addresses the survey and evaluation conducted of the thermal generation units owned and operated by KESC. A separate Executive Summary is provided for those thermal generation units owned and operated by WAPDA. The main report covers in detail the full survey activities, findings, and program recommendations.

SECTION 2

METHODOLOGY AND SUMMARY CONCLUSIONS

2.1 METHODOLOGY

After an orientation meeting and review of available KESC systems and operations data, the key element of the survey was an on-site visit to each thermal generating station by a team of SWEC specialists. During the site visit, the team:

- Conducted an in-depth interview with station management and key operations, engineering, and maintenance staff to learn about unit operations and maintenance approach, problems, and contributing factors.
- Performed a plant inspection.
- Conducted interviews on management and institutional factors.
- Developed preliminary diagnosis of conditions.

Prior to leaving Pakistan in August, the team leader conducted reviews with station managers, MWP, USAID, and IBRD Headquarters staff to provide preliminary insights on the survey team's observations and findings.

Upon return to the Consultant's headquarters, the detailed evaluation process began. Evaluations consisted of comparing present observed operating conditions with unit design data or guaranteed performance current conditions data. Calculations were performed to determine the effects of abnormalities on unit performance. Thermal efficiencies, fuel usage rates, and air heater performance were part of the boiler evaluation. Turbine plant evaluations considered such items as the steam cycle and operating conditions. Balance-of-plant evaluations focussed on systems and equipment which affect design output. Heating, ventilation, and air-conditioning considerations and their effect on operating equipment were also addressed. Control and electrical systems and equipment evaluated included controls for the boiler, turbine, feedwater heaters, water treatment systems, vibration monitoring, circulating water systems, control room annunciators, electrical equipment, switchyard, motor control centers, generators, transformers, and grounding equipment.

A review meeting with KESC, MWP, and USAID was held in early October in Karachi and Islamabad. The purpose of October review was to assure that root causes were properly identified and corrective actions under consideration are appropriate and have a high probability of success.

A benefit/cost analysis was performed to select corrective measures of sufficient economic merit to be included in the program which SWEC would recommend for KESC's consideration. An overall schedule was developed for the recommended unit rehabilitation activities. However, KESC management has already taken necessary steps in some cases to correct these

deficiencies. This overall schedule was used in preparing a comprehensive program implementation plan.

2.2 SUMMARY CONCLUSIONS

While quality and quantity of work by the KESC engineers is impressive, the performance of KESC's thermal g erating units has been significantly degraded by:

- Postponement of preventative maintenance with a resultant shift to increased corrective maintenance brought about by the need for prolonged operations to maximize system generating capacity.
- Use of fuels for which the units were not originally designed.
- Operation of combustion turbines designed for peak load operation as base load units.
- Insufficient stocking and poor inventory control and storage of spare parts.

Other factors adversely affecting the thermal generating units' performance include:

- Less than optimum workshop capability for corrective and preventative maintenance of equipment
- Insufficient management emphasis and incentives for technical training of plant operations and maintenance
- Lack of station manuals, design drawings, unit performance data, and plant operating procedures; and
- Lack of sufficient engineering staff either at plant stations or in KESC Headquarters dedicated to maintaining a high level of thermal plant performance.

The national impact of this degraded thermal plant performance is exacerbated by:

- The low reserve margin of Pakistan's electric generating capacity over peak demand combined with a high rate of increase in electricity demand to support Pakistan's expanding economy, which frequently results in the need for large-scale load shedding;

A comprehensive program conducted over a three-year period could increase the capacity, efficiency, and availability of WAPDA's thermal generation units. The benefits of such a program would include:

- Increasing the KESC thermal generating capacity from 573 MW to 754 MW; this total 181 MW increase consists of:

  63.8 MW of restored steam plant capacity at an incremental cost of $815/kW.

106 MW of capacity by converting two steam and five combustion turbine units to combined cycle units at an incremental cost of $743/kW.

11.2 MW of restored combustion turbine capacity, which could be added to KESC's system for an incremented cost of $253/kW.

- Improved availability of KESC's thermal generation, enabling provision of about 280 GWH/year of additional deliveries of electricity to KESC's system. (This is about a 6.5 percent increase over 1984 thermal unit generation.)

- An improved average heat rate for KESC's thermal units could reduce KESC's fuel consumption per KWh of thermal generation by about 12.1 percent.

The principal elements of the recommended program consist of:

- Overhauls, repairs, modifications, and additions to increase the efficiency, availability, and capacity of units at the six KESC steam stations.

- Converting the five SITE combustion turbine units to combined cycle facilities.

- Converting two West Wharf steam turbine units to a single combined cycle facility.

- Overhaul, repairs, addition of evaporative coolers, and cleaning of compressors to increase the capacity, improve the availability, and reduce the average heat rate of four other combustion-turbine units.

- Increased spare parts and better management storage and application of spare parts.

- Increased equipment maintenance capabilities of KESC's nine workshops.

- A major dedication by KESC of its plant operations and maintenance staff to periodic technical training and an expanded instructional program as explained in Section 6.

Further information about this recommended program is presented in Section 4 of this Executive Summary and Section 4 of the report.

The estimated cost for this comprehensive program is approximately $163 million, applied as follows to the above-noted principal program elements over a three-year period:

- $50 million for rehabilitation of the four steam units.

- $75 million for the conversion of the West Wharf steam plants and SITE combustion turbine plant to combined cycle facilities.

- $2 million applied to other combustion turbine plants.
- $6 million for spare parts and related improvement in KESC's planning, management, and storage of its spare parts inventory.
- $200,000 for training improvements.
- $1 million for shops and warehouse improvements
- $13 million for project planning, management, and engineering.
- $16 million for contingency.

Further details about these estimated program costs and their application to each thermal plant unit are presented in Section 5 of this Executive Summary and Section 8 of the main report.

The proposed plant improvement programs have been evaluated on a net present worth basis and a cost benefit and simple payback analysis performed. The principal evaluation factor was the value of electricity of 1.10 Rs/kWh. We understand this approximates the long-range marginal cost of energy.

Unit improvement programs are recommended that range in attractiveness of a combined benefit ratio of 29.65, with a simple payback period of about 3 months (KTPS-3) to a cost benefit ratio of 1.0 with a simple payback period of 6.13 yr (KTPS-1).

Economic justification is discussed further in Section 7.

Dedicated commitment by the top management of KESC is essential to the timely and successful performance of a program of the scope and breadth of that being recommended. In the course of the survey, it became clear that prior commitment of priority resources to such a program was a result of the simple need to maintain maximum system capacity rather than any lack of appreciation of the need for and benefits of such a program.

Exercise of this near-term window of opportunity requires prompt action on three parallel paths:

(1) Immediate start of engineering, procurement and outage planning for those first units offering the greatest potential for capacity addition (i.e., Korangi and West Wharf);

(2) Arrangement of full program funding to be available by the summer of 1986;

(3) Prior creation of the necessary organizational structures and support capabilities, so that full program activities can quickly get underway as soon as funding is available.

Effective planning and management and implementation of the recommended comprehensive program is a difficult challenge due to the many units involved, the numerous activities required at each unit, and the delicate scheduling required to avoid thermal units being down at times of low

hydro-generation capability in the country of Pakistan. Many of the common and cross-cutting elements of the program should be centrally planned and managed. At the same time, responsibility and authority for those activities specific to individual units needs to be delegated to station managers with assurance of needed support by the central program office.

In this light, it is strongly recommended that KESC utilize the capabilities of a consultant firm highly experienced in the planning, engineering, management, and implementation of major plant rehabilitation projects to assist it in management and implementation of the recommended program. Further details on a suggested concept for program implementation are presented in Section 6 of the Executive Summary.

SECTION 3

DESCRIPTION OF SYSTEM AND CURRENT SITUATION

3.1 ELECTRIC SYSTEM DESCRIPTION

Pakistan has two generation and transmission utilities: WAPDA and KESC. The KESC system represents approximately 18 percent of the total Pakistan generation capacity and consists of:

- 9 steam turbine units with a total installed capacity of 688 MW
- 9 combustion turbine units with a total installed capacity of 225 MW; all units are capable of burning gas and high speed diesel oil
- 10 diesel units with a total installed capacity of 15 MW
- A total nameplate capacity of 928 MW

The locations of the thermal stations are shown on Figure 3-1. Generation capacity and statistics are shown on Table 3-1.

In addition to KESC thermal power stations, there is the KANUPP Nuclear Power Station which is capable of generating 33-38 MW. KESC is also able to purchase up to 60 MW of power from PASMIC (steel mill power station). Both of these power sources, however, are not committed to KESC, and, hence, are not included in KESC's total generating capacity.

The WAPDA and KESC systems are tied together by 132 kV interconnections.

3.2 CURRENT SITUATION

System Capacity

KESC had a peak demand of 948 MW for the 1984-1985 season. With the installed nameplate capacity of 928 MW, this allows no margin. The amount of installed capacity available to KESC at any given time, however, is dependent on KESC units out-of-service for maintenance or repair, operating at derated capacity, or purchased power available from other sources.

Base demand is satisfied primarily by steam turbines. During intermediate demand periods, diesel and gas turbine units are used. The gas turbines, even though intended for peak load operation, are now operating as base load machines due to shortage of generating capacity.

As shown in Table 3-1, the gas turbines represent approximately 24 percent of KESC's generation mix, while the steam turbines constitute 74.4 percent, with a small percentage (1.6 percent) derived from diesel engines.

The currently operable generation capacity has been unable to meet demand. Periods of major load shedding occur, particularly during the low water flow season. Load shedding is defined as the process of deliberately removing

preselected loads from a power system in response to an abnormal condition in order to maintain the integrity (frequency and voltage) of the system. For example, during July 1985, severe blackouts persisted for extended hours due to faults in the system. Although blackouts are possible, KESC is still, at times, transporting 60-130 MW of power to WAPDA to equalize the load shedding situation within Pakistan.

There is a large seasonal variation in hydro power generation capability in Pakistan. The low flow season extends from November to June. During this period, capacity requirements result in extreme dependence on thermal units. Thermal units are kept on line if at all possible. This capacity shortage results in maintenance, schedule inspection, and machine overhauls being deferred until forced outages occur.

The gas turbines, though intended for peak load operation, are operated as base load machines due to current load shedding requirements as needed.

Fuel Considerations

Gas fuel restrictions and gas quotas for major KESC stations have also created major problems by forcing KESC to cope with the incorporation of additional alternate fuel oil storage facilities, converting existing boilers to burn furnace oil, and subsequent derating of the boiler outputs. The corrosive nature of these fuels has caused further deterioration in boiler heat transfer surfaces, resulting in poor boiler performance and increased maintenance.

This gas restriction also applies to simple cycle combustion turbine plants where HSD oil firing instead of natural gas has not only shortened the period of inspection and overhaul intervals but has also caused extensive maintenance problems in addition to decreasing the availability of these machines for power generation during this crucial KESC capacity shortage.

Fuel quality of both furnace oil and HSD fuel is largely uncontrolled. Only annual or sporadic samples are taken for proximate and ultimate analyses.

Delivery from refineries is unassured because of the shortage of transport facilities or lack of oil storage capacity at the stations.

KESC has in place a program for increasing fuel storage capacity and transportation facilities. This program is required and should continue to completion as soon as possible.

Currently for the plants under investigation, only one unit (Korangi No. 3) has a fuel treatment facility; however, Korangi did not have proper proportional feed control due to the unknown quality of delivered fuel. Introduction of a fuel treatment system to other units (steam and gas turbines) is also recommended.

Plant Operation and Maintenance

Plant average availability factors have been approximately 60 percent. Considering the age of these machines, this factor is well within reason.

9

Generally repairs and maintenance work are carried out proficiently by local station labor.

However, shortage of spare parts due to lack of foreign currency for procurement and long leadtimes and current purchasing practices for these tasks contribute drastically to reducing the availability of these units.

The quality and quantity of work of the KESC operations and maintenance engineers is very impressive. In spite of a shortage of trained personnel, spare parts, workshop facilities, and foreign exchange, the units are kept online as long as possible during the country's power shortage.

As the units have aged, the emphasis on maintenance has shifted from a planned preventative maintenance program to one of corrective maintenance as forced by the grid requirements. Forced outages are mounting and creating problems.

All records, including equipment history, are manually written by the engineers in registers when time allows. The operating procedures were, however, available to each engineer who wrote and memorized them during his on-the-job training program. The procedures were then retained in engineers' homes.

Spare Parts and Warehousing

The procurement procedure is too cumbersome to allow efficient management. Approval authority for purchase requests is too low. This results in stockouts and outages while awaiting approval from a higher authority.

Two and three-year leadtimes for foreign manufactured parts are normal turnaround for spare parts procurement. Local procurements were generally well managed, and posed no particular problem for the maintenance engineers.

Workshops

Both corrective and preventative maintenance is hampered by the capability of the station workshops. Lack of test equipment, machines, NDT capability, and trained personnel result in the stations contracting work out to local workshops or to the major repair shops. Advanced planning for work accomplishment is not being conducted due to the capacity shortage resulting in the lack of planned outages.

The leadtime to schedule, plan, transport, accomplish, and return work to the stations during a forced outage is excessive.

Training of Personnel

The KESC system of training for both engineers and technicians assumes the students have some technical background and proceeds to cover the basic elements of power plant operations and maintenance.

The entire system of training revolves around the stations on-the-job training programs, which are not formalized programs. Personnel are trained formally at the training centers, and informally at the students' plant.

Notebooks are kept by the students in preparation for an examination given in operations or maintenance (plant-specific). To provide incentive for completing the training program for entry level engineers and technicians, an allowance is paid in increments at the successful completion of each examination. It is difficult to obtain quotas for follow-on training of station personnel, e.g., advanced operators' school, as well as for vendor maintenance schools and foreign training programs. This difficulty in meeting quotas is due to a lack of space, lack of funds for training, and reluctance on the part of plant upper management to release people during the high power demand periods.

Management

The station management for all KESC plants is aware of manufacturers' recommendations for inspection and overhaul schedules, and they plan well in advance; however, all these efforts are negated when the dispatch cent r calls for power due to a system capacity shortage. Therefore, any program for inspection/overhaul is either revised, postponed, or abandoned entirely until the forced outage is imminent or occurs.

During the survey it was evident that none of the stations have an engineering section devoted to power plant design and operation. KESC Headquarters also did not have a dedicated engineering group for plant improvement and new design concepts.

Most technical and clerical work at these stations is being performed manually by engineers using outdated calculators and other devices. No duplicating, typing, or word processing facilities exist to facilitate effective use of talent and time.

Lack of station manuals, design drawings, unit performance data, heat balance diagrams, and plant operating procedures is evident at some of the stations. The unavailability of these items causes extensive hardship to station operators and management during emergency trips or for routine plant equipment monitoring.

TABLE 3-1

KESC GENERATING PLANTS

Power Station	Installed Capacity (MW)	Derated Capability (MW)
Bin Qasim	210	210[L1]
Korangi 1 and 2	132	
Korangi 3 and 4	250	210
West Wharf B 6 and 7	30	24
West Wharf BX 8 and 9	66	45
Korangi Town Gas 1-4	100[L2]	76
SITE Gas Turbines 1-5	125[L3]	100
SITE (Diesel Plant (10 x 1.5)	15	15
Totals	928	798

[L1] - New unit, no derating

[L2] - ISO rating

[L3] - ISO rating

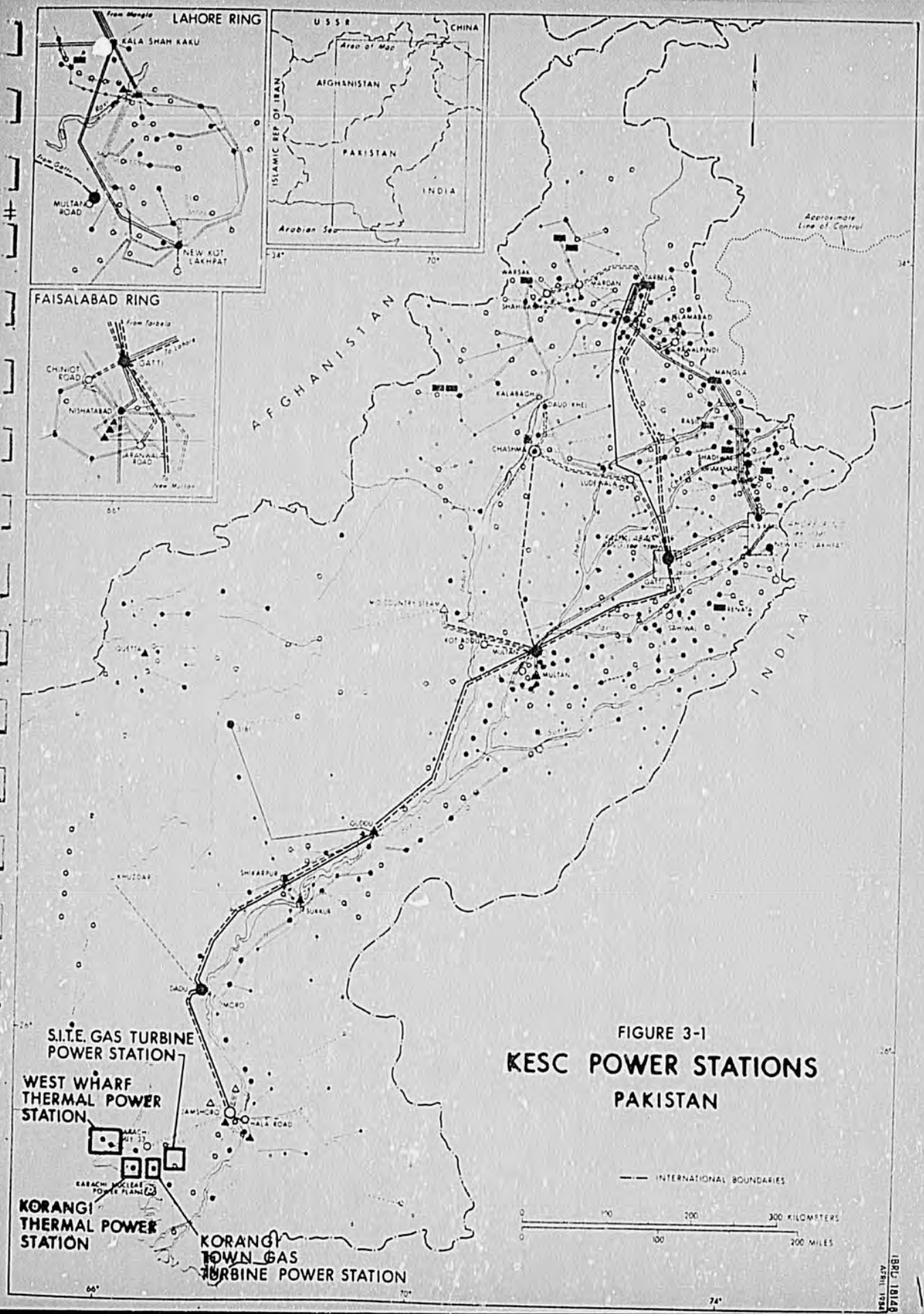

FIGURE 3-1

KESC POWER STATIONS

PAKISTAN

IBRD 18148
APRIL 1984

13

SECTION 4

DETAILED FINDINGS AND RECOMMENDATIONS

4.1 TECHNICAL

4.1.1 General

An analysis has been completed for each of the KESC thermal units in order to evaluate current performance. As previously discussed in Section 2, existing conditions have been compared with unit design, guaranteed performance data, and industry practice. In addition, spare parts inventory programs, maintenance workshops, and preventative maintenance programs were also analyzed. The intent of these investigations was to formulate a comprehensive program to upgrade the efficiency, capacity, and availability of KESC thermal units in a cost-effective manner.

A summary of the unit performance evaluations listing repairs, upgrades, changes, and additional equipment recommended by SWEC is provided in Table 4-1. The evaluations are divided into four major categories, Boiler, Turbine, Balance of Plant (BOP), and Instrumentation, Controls, and Electrial (IC&E). Table 4-2 provides a separate listing of water treatment system recommended modifications. Table 4-3 provides recommendations for training and workshops.

These tables provide a summary of the recommended modifications discussed in depth in Section 4 of the report. Some of the most common modifications listed by area are as follows:

<u>Boiler</u>

- Install steam coil heaters
- Install sootblowers
- Upgrade fuel oil unloading
- Repair fans and air heaters

<u>Turbine</u>

- Add evaporative cooling system
- Repair lube oil and air coolers
- Selective turbine overhaul
- Selective blade replacement

<u>Balance of Plant</u>

- Replace water filtering system
- Repair condensate pumps
- Repair feedwater heaters
- Provide fuel treatment facilities

<u>Instrumentation, Controls and Electrical</u>

- Replace combustion control system

14

- Add fuel metering stations
- Replace turbine supervisory elements and recorders
- Improve substation and circuit breaker operations

Water Treatment

- Provide additional equipment to increase capacity
- Provide additional test equipment

A review of Tables 4-1 and 4-2 indicates while there are a number of items common to many plants, there are also many items that apply to only one or two units. As a result, the implementation program is not presented on a generic basis; rather, it is unit-specific.

4.1.2 Fuel Oil Effects

Both the steam boilers and combustion turbines at KESC stations were originally designed to burn gas. The gas fuel supply was favored at the time because of its availability and inexpensive cost as compared to other fuel supplies. The availability of gas in recent years has been insufficient and infrequent while costs have been escalating. This situation has forced the use of substitute fuel supplies. Furnace oil (No. 5 oil) is now supplied to the steam units and high speed diesel oil (HSDO) to the combustion turbines. The substitute fuel has caused significant problems in the operation and maintenance of the stations for a number of reasons.

Essential to the evaluation of plant performance and plant life is a determination of the effects of fuel types on susceptible equipment, such as the boiler and the combustion turbine blades.

KESC gas-fired furnace designs use smaller furnace volumes, have high combustion gas velocities, and have higher heat transfer rates than boilers designed exclusively for oil or coal. When oil is fired in a gas-designed furnace, flame impingement is a major problem. Other problems found by the inspection were relative heat absorption problems in the furnace and significant oil ash buildup problems.

The quality of oil varies and often contains impurities such as vanadium, sodium, and sulphur which cause significant corrosive damage to boiler tubes and preheaters, as well as combustion turbine blades. Inhibitors can be added to the fuel oil to help reduce corrosive conditions caused by the oil impurities.

Because of the untreated impurities that exist in the fuel oil used, corrosive conditions were found in the boiler and the combustion turbine blades at some units. It is recommended that the fuel oil source be documented by place of origin, refinery source, method of transportation, storage site, and treatment employed. Along with the fuel data, a fuel and ash laboratory analysis should be performed to determine chemical constituents, such as carbon, oxygen, hydrogen, sulfur, vanadium, sodium, and fuel burning characteristics such as heat content, flashpoint, viscosity, and asphaltene content. This information is required to assess the suitability of the materials in existing equipment (boiler tubes, combustion turbine blades).

15

Installation of fuel treatment plants to improve and regulate the quality of HSD fuel oil is critically needed for the fuel supply systems of KESC combustion turbines. The plants require metering stations and monitors, as well as new atomizing equipment, removal of potassium and sodium from the oil, and replacement of pump suction and discharge strainers and piping.

As indicated in Table 4-1, a variety of boiler improvements, modifications, and changes are required due to the effects of the fuel types used in the gas-designed units. For example, additional retractable soot blowers should be provided to the air heaters, superheaters, reheaters, and economizer tubes due to the buildup of corrosive oil ash deposits. SWEC's recommendations for improvements to the use and control of fuel types are essential to improving the performance of the KESC units.

Critical to the improved efficiency of the KESC steam units are improvements to fuel supply and storage capacity. There are no fuel oil metering stations for "as-received" fuel oil, and equipment for the storage and transfer of oil is poorly maintained at some stations.

It is evident from the inspections performed at each KESC station that dedicated fuel supply trains or tank trucks are needed to provide an uninterrupted and adequate oil supply for continuous operation. Dedicated fuel supplies, adequate receiving transport facilities, and storage capacities, and monitoring and measuring equipment are needed to control the quality and quantity of fuel supply to both the steam and combustion units. This is vital to providing an unconstrained conversion from fuel gas to fuel oil.

There is currently an improvement program for oil storage and transport. This program addresses the above problems and should continue to completion. We have not included work or estimates for this program in our plan.

4.1.3 Anticipated Results

Based on the recommended action discussed above, calculations were prepared to determine the effects of such action on unit performance, plant capacity and availability. Unit thermal efficiency and output as well as individual component efficiency and capacity limitations were evaluated. Table 4-4 provides a summary of the anticipated improvements that can be realized in unit performance and capacity based on implementation of the technically feasible modifications. This table is presented on an individual unit basis and provides a summary of results based on implementation of those items listed in Tables 4-1, 4-2, and 4-3.

The following discussions cover the anticipated results for the economically justified projects only. The results are summarized in Table 4-5.

Efficiency

A significant improvement in the thermal efficiency of many of the units is obtainable. Such an improvement, as indicated by a reduction in the heat input and turbine heat rate of the unit, will result in substantial fuel savings. Fuel consumption for all units could be reduced by approximately 10 ton/hr of fuel oil equivalent. The fuel savings per year based on an

average 12.1 percent increase in efficiency would be approximately $16 million U.S. dollars per year at a capacity factor of 80 percent.

Capacity

Additional capacity can be provided by the existing KESC thermal units as a result of the recommended upgrades. Steam units' capacity could be improved by 63.8 MW and combustion units by 11.2 MW. An additional 106 MW would result from the addition of combined cycle unit retrofits to SITE and West Wharf Stations. Combined cycle conversions were selected because they are a cost-effective way to increase the system capacity. They result in large increases in efficiency, reducing wasted energy. SITE and West Wharf were selected because their site layouts will accommodate the required equipment additions.

The total of these capacity increases would increase the capacity of the KESC thermal units by 181 MW or 32 percent of the existing derated capacity. Detailed information on anticipated increases in efficiency and capacity is presented in Section 4 of the report.

Availability

The availability of a unit is a result of many interacting factors. Unit size and age are two important factors in predicting acceptable availability levels. Furthermore, the small size and age of many of the units contribute to the large drop in availability. The age of six of the eight steam units is greater than 20 years, and two units are 20 or more years old.

The quality and quantity of fuel oil must be improved to significantly improve the availability of the KESC units. Recommended steam unit improvements include improving the fuel quality as well as providing spare parts, replacement blades, and air preheaters. Recommended gas turbine unit improvements include installation of fuel treatment plants at each station to improve and regulate fuel quality.

Anticipated improvements in unit availability have been estimated as part of this investigation. These changes have been factored into to economic justification described in Section 7.

4.1.4 Spare Parts

The immediate spare parts requirements determined by the station management and the inspection team are estimated to cost over $5 million. Certain of these spares, considered critical for the operation and maintenance of the plants, should be purchased from the original equipment manufacturers. All spare parts that are not critical to the operation of the plant due to redundancy, alternate operational mode, or availability of suitable substitutes should be tendered for competitive bidding.

To assist the engineers and stores officers in establishing and maintaining inventory control, a desk top computer is recommended for each station warehouse. These computers could transfer information from the stock record cards and books into permanent data storage. High and low load levels must be calculated according to usage rates and leadtimes for procurement. On

reaching the low level inventory point, procurement activities should be commenced. In KESC, an annual budget is submitted and approved for each station. To reduce the communications time lost in procuring spares, it is recommended that resident engineers be allowed to manage their stations within the established budgets. Proper tendering of qualified vendors is required and should continue to be subject to audit by higher authority. A copy of all correspondence involving payment of vendors should be sent to higher authorities for their information and use. In this way, financial authority and responsibility would be delegated to the resident engineers and monitored by the chief engineers.

To implement the procurement of spares, priorities have been set for each plant to support the specific requirements (See Section 4 of the Report). Proprietary first priority spares would be initiated for procurement followed by competitive bid items that are more readily available. Alternate sources of supply will have to be investigated and qualified for the competitive items during the implementation phase of the program.

4.1.5 Maintenance

Workshops

The capabilities of KESC workshops are not sufficient to handle KESC major repair work; however, the WAPDA workshops at Faisalabad, Guddu, and the proposed workshop at Jamshoro are considered sufficient for the Pakistan utility system. Facilities at the shipyard in Karachi and at Taxila are available as needed in the event of a major industrial work requirement. Radiographic testing for high pressure components is available at Taxila and at the Nuclear Research Center. The services of these facilities and the local workshops should be scheduled in accordance with each station's planned overhaul schedule and preventive maintenance (PM) schedule to properly plan for transportation of equipment and trained personnel. Repair and replacement of out-of-service machines and the addition of machines as recommended in the plant summaries will increase the self-sufficiency of the plants at nominal capital expense. A major addition of equipment at the central workshop in Faisalabad is recommended.

Operations and Maintenance Program

Since it was apparent that those stations with a designated Inspection, Test, and Record (IT&R) officer had a better preventative maintenance program and operability record, it is highly recommended that all stations have an IT&R officer assigned to track and record the Plant PM Program and efficiency. To assist the IT&R officer, the Plant PM Program should be programmed into a desk top computer. Daily, weekly, monthly, and semi-annual checks would then be printed out daily for each maintenance section. Completed maintenance checks with actual readings would be entered into the computer and incomplete checks would be rescheduled. This same computer can be programmed to assist the IT&R officer in calculations for daily heat rates and trending of cycle components to provide the maintenance officers with the operational condition of their equipment.

4.2 INSTITUTIONAL

4.2.1 Recommended Organizational Changes

In order to balance responsibilities and provide better control, organizational changes are recommended at both the main office and power station levels. Main office organizational changes are necessary to create a staff of experts to provide direction concerning in-plant equipment efficiency, electrical and mechanical maintenance, and chemical and environmental control. Some central control should be instituted by the Head Office in monitoring the action taken by the stations when units are out-of-service. Instead of relying on the plant personnel to resolve the problems, the Head Office should practice participative decision-making to ensure that all resources are applied to return units to service as soon as possible. More centralized management should be a long-term goal.

Purchasing practices should be modified to expedite procurement without loss of control. This will enable units to deliver more power since downtime is affected by materials and spare parts availability. A number of procedures has been listed in the main report to serve this purpose.

Management practices in supervision, personnel utilization, decision-making, and computer applications should be expanded. Standards should be created in some areas of Thermal Power management to provide consistent decision-making and uniform treatment of personnel. This applies to preparation of reports, station organization and infrastructure practices for education, medical services, and housing. Training in management is included in this recommendation. Improved training at the individual station basis is recommended as outlined in Table 4-3 and in Section 6 of this Executive Summary.

Operating data are abundant but dispersed and time consuming to extract and collate for application in decision-making. Separate reports for production and costs are suggested, with emphasis on efficiency and reliability for the production report. Appropriate formats generated for these purposes are included in Section 4.

System fuel costs vary from 91 percent to 93 percent of bus bar costs, indicating that a reduction in fuel consumption will have a large effect on total bus bar costs. For this reason, we recommend that a performance monitoring program be instituted. Details are provided in Section 5 of the main report.

4.2.2 Preventative Maintenance Priority

Currently, an organized preventative maintenance program is not in effect for the thermal units, although such a program is considered a high priority by KESC management. With no reserve generating capacity, it has been impossible to take a planned approach to preventative maintenance. However, an increased capacity resulting from implementing the recommendations provided in this report, KESC should have some generating capacity to allow initiation of such a program. We recommend that this opportunity be taken to carry out this high-priority task.

TABLE 4-1

UNIT PERFORMANCE RECOMMENDATIONS

LEGEND
- ◆ - UNIT OUT OF SERVICE
- ● - UNIT NOT ON LINE
- X - RECOMMENDED ACTION
- ** - UPGRADE UNITS PER REPORT

	KESC																
	STEAM UNITS								GAS TURBINES								
STATION	KORANGI				WEST WHARF				KORANGI				S.T.T.E.				
UNITS	1	2	3●	4	6**	7**	8	9●	1	2	3	4	1●	2	3	4	5
BOILER EVALUATION / MW	66	66	125	125	15	15	33	33	20	20	20	20	20	20	20	20	20
WASH ECONOMIZER				X				X									
INSTALL ECONOMIZER SOOT BOILERS							X										
REPAIR OR INSTALL AIR HEATERS & PREHEATERS				X				X									
INSTALL OXYGEN ANALYZER		X	X														
INCREASE BACKUP FUEL STORAGE TANK WITH DIKE WALL	X	X	X	X													
SOOT BLOWERS																	
ADD RETRACTABLE BLOWERS								X									
FUEL OIL																	
ADD CHEM TANK, METERING PUMP & CONTROLS								X									
REPLACE FUEL OIL METER		X															
INSTALL STRAINER AT HEATER INLETS	X	X	X	X													
REPAIR METAL LAGGING/INSULATION								X									
REPAIR AIR HEATER EXPANSION JOINTS								X									
DEAERATOR																	
PERFORM INSPECTION								X									
BLOWDOWN																	
REPLACE WATER CONTROL & ISOLATION VALVES	X	X		X													
REPAIR STEAM LINE								X									
CLEAN BOT HEARTH & AIR DUCTS & INLET VANES								X									
TURBINE EVALUATION									X	X	X	X	X	X	X	X	X
ADD EVAPORATIVE COOLING SYSTEM										X						X	
OVERHAUL COMPRESSOR																	
CONDENSER HIGH BACKPRESSURE	X			X													
REPAIR FEEDWATER HEATER	X			X										X			
OVERHAUL TURBINE							X	X									
REPLACE TURBINE BLADE	X	X		X													
REPLACE COOLING TOWERS									X	X	X	X					
REPLACE CONDENSERS							X	X									
REPLACE HEATERS							X	X									
REPLACE CONDENSATE PUMPS			X														
BOP																	
UPGRADE CIRCULATING WATER SYSTEM	X	X	X	X			X	X									

TABLE 4-1

UNIT PERFORMANCE RECOMMENDATIONS

LEGEND
- ● - UNIT OUT OF SERVICE
- ● - UNIT NOT ON LINE
- X - RECOMMENDED ACTION
- ** - UPGRADE UNITS PER REPORT

		KESC																
		STEAM UNITS								GAS TURBINES								
	STATION	KORANGI				WEST WHARF				KORANGI				S.I.T.E				
	UNITS	1	2	3●	4	6**	7**	8	9●	1	2	3	4	1●	2	3	4	5
BOP	MW	66	66	125	125	15	15	33	33	20	20	20	20	20	20	20	20	20
HIGH SPEED DIESEL OIL																		
UPGRADE FUEL UNLOADING										X	X	X	X					
UPGRADE VENTILATION/COOLING SYSTEM																		
UPGRADE BOILERFEED PUMP AREA		X	X		X													
UPGRADE ELECTRIC PUMPS		X	X		X													
CLEAN AIR PREHEATERS		X	X		X													
INSTALL ADDITIONAL FUEL OIL HEATERS		X	X		X													
IMPLEMENT MAINTENANCE PROGRAM								X	X									
REPAIR CONDENSATE STORAGE TANK								X	X									
REPAIR STEAM PUMPS								X	X									
PROVIDE EQUIPMENT WATER SUPPLY														X	X	X	X	X
RELOCATE GAS PIPE LINE														X	X	X	X	X
REPLACE IN LINE STRAINER WITH DUPLEX														X	X	X	X	X

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TABLE 4-1

UNIT PERFORMANCE RECOMMENDATIONS

LEGEND:
- ● UNIT OUT OF SERVICE
- ● UNIT NOT ON LINE
- X RECOMMENDED ACTION
- •• - UPGRADE UNITS PER REPORT

	KESC																
	STEAM UNITS								GAS TURBINES								
STATION	KORANGI				WEST WHARF				KORANGI				SITE				
UNITS	1	2	3●	4	6 ••	7 ••	8	9●	1	2	3	4	1●	2	3	4	5
ICAE / MW	66	66	125	125	15	15	33	33	20	20	20	20	20	20	20	20	20
RETROFIT FOR TURBINE WATER PROTECTION	X	X	X	X													
REPLACE HYDRAULIC CONTROL SYSTEM									X	X	X	X					
REPLACE LUBE OIL SYSTEM ORIFICE PLATES									X	X	X	X					
DC GROUND CIRCUIT																	
REPLACE GROUND MODULE INDICATING CARDS									X	X	X	X					
REPLACE UV FLAME SCANNERS WITH COOLING AIR CAPS							X	X	X	X	X	X	X	X	X	X	X
TURBINE GENERATOR																	
PROVIDE FILTER BASKETS & COOLING CRITERIA									X	X	X	X					
RECORDERS																	
PROVIDE MW/MVAR & TEMP RECORDERS									X	X	X	X					
FUEL OIL HEATERS																	
PROVIDE REPLACEMENT PARTS									X	X	X	X					
REMOTE CONTROL ROOM																	
UPGRADE HVAC									X	X	X	X					
COMPRESSOR & CRANKING MOTOR																	
PROVIDE MEDIUM VOLTAGE CONTACTORS									X	X	X	X					
CALIBRATION/TEST EQUIPMENT																	
REPLACE TRANSMITTER WITH CIRCUIT BOARDS AT GAS FLOW STATION									X	X	X	X					
COMPRESSOR																	
ADD AIR DRYERS TO EACH CONTROL AIR COMPRESSOR													X	X	X	X	X
COMBUSTION CONTROL BURNER M&M SYSTEM																	
ADD CONTROL VALVES	X	X					X	X									
REPLACE ALL PNEUMATIC REGULATORS			X	X													
REBUILD ALL BURNER FRONTS			X	X			X	X									
ADD O_2 & COMBUSTIBLE ANALYZERS			X	X													
REBUILD ALL TRIM & SEATS			X	X													
REPLACE SAFETY RELIEF VALVES	X	X	X	X													
CALIBRATE & BALANCE SYSTEM									X	X	X	X					
REPLACE SYSTEM							X	X									
REPLACE ANNUNCIATOR MODULES							X	X									
REPLACE CONTROL/INDICATING ELEMENTS							X	X									
UPGRADE SYSTEM FUEL SAFETY INTERLOCKS							X	X									
ADD CONTROL ROOM INTERFACE PANEL							X	X									

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22

TABLE 4-1
UNIT PERFORMANCE RECOMMENDATION

LEGEND
- ➔ - UNIT OUT OF SERVICE
- ● - UNIT NOT ON LINE
- X - RECOMMENDED ACTION
- ** - UPGRADE UNITS PER REPORT

		KESC																
		STEAM UNITS								GAS TURBINES								
	STATION	KORANGI				WEST WHARF				KORANGI				SITE				
	UNITS	1	2	3●	4	6 **	7 **	8	9●	1	2	3	4	1●	2	3	4	5
IC&E	MW	66	66	125	125	15	15	33	33	20	20	20	20	20	20	20	20	20
TURBINE CONTROL & SUPERVISORY INSTRUMENTS																		
REPLACE ALL TURBINE SUPERVISORY INSTRUMENTS		X	X	X	X			X	X									
COMBUSTOR UPGRADE																		
RESTORE O_2 TRIM		X	X															
CALIBRATE INSTRUMENTS - TURBINE CONTROL ROOM & RELAYS										X	X	X	X					
SOOT BLOWER CONTROL																		
PROVIDE REMOTE CONTROL				X	X													
REPLACE RUPTURE DISCS		X	X															
UPGRADE CONTROL ROOM																		
UPGRADE HVAC AND LIGHTING		X	X	X	X			X	X									
REPLACE INDICATING LAMPS WITH CONTROL SWITCH MONITORS										X	X	X	X					
UPGRADE BTG BOARD								X	X									
UPGRADE FOR FIRE PROTECTION								X	X									
UPGRADE BATTERY ROOM								X	X									
INSTALL CONTROL ROOM MONITORS, FUSE & ALARMS				X	X													
UPGRADE VENTILATION				X	X													
STATION LIGHTING/WIRING																		
UPGRADE EXTERIOR/INTERIOR LIGHTING & WIRING		X	X	X	X													
VIBRATION MONITORS																		
ADD VIBROMETERS TO FD, BOILER, FEEDWATER PUMPS		X	X	X	X			X	X									
INSTRUMENT/CONTROL AIR SYSTEM																		
ADD AIR DRYERS								X	X									
FEEDWATER SYSTEM																		
INSTALL SIGHT GAUGES, BLOWDOWN & RELIEF VALVES		X	X	X	X													
FEEDWATER HEATER DRAIN EXTRACTION																		
UPGRADE TURBINE WATER INDUCTION								X	X									
CATHODIC PROTECTION SYSTEM																		
ADD FOR SWITCHYARD, STRUCTURAL STEEL, TANKS & LINES								X	X									
SWITCHYARDS																		
INSTALL RODENT CONTROL				X	X													
REPLACE ASKAREL INSULATING MEDIA		X	X															
ADD DELUGE SYSTEM TO RESERVE TRANSFORMER								X	X									
CLEAN PORCELAIN - 66V								X	X									

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LEGEND
● - UNIT OUT OF SERVICE
● - UNIT NOT ON LINE
x - RECOMMENDED ACTION
•• - UPGRADE UNITS PER REPORT

TABLE 4-1
UNIT PERFORMANCE RECOMMENDATIONS

	KESC																
	STEAM UNITS								GAS TURBINES								
STATION	KORANGI				WEST WHARF				KORANGI				SITE				
UNITS	1	2	3●	4	6••	7••	8	9●	1	2	3	4	1●	2	3	4	5
IC&E MW	66	66	125	125	15	15	33	33	20	20	20	20	20	20	20	20	20
HOUSE & RELOCATE CARRIER RACK							x	x									
EVALUATE INTEGRITY OF GROUND GRID							x	x									
CLEAN EQUIPMENT GROUNDS							x	x									
MEDIUM VOLTAGE SWITCHGEAR																	
CALIBRATE & EVALUATE REPLACEMENT							x	x									
REPLACE FEEDERS TO TRANSFORMERS							x	x									
HYDROGEN GENERATION FACILITY																	
UPGRADE FOR LIGHTING, WIRING, FIRE PROTECTION, HVAC							x	x									
FUEL OIL SYSTEM																	
ADD METERING STATION & MONITORS			x	x			x	x					x	x	x	x	x
ADD BLENDING STATION	x	x															
ADD FIRE PROTECTION TO FUEL STORAGE FACILITY							x	x									
FUEL UNLOADING FACILITY																	
ADD FUEL OIL METERS									x	x	x	x					
CENTRAL DISPATCH OFFICE/RELAY ROOM																	
UPGRADE HVAC, FIRE PROTECTION, LIGHTING							x	x									
CIRCULATING WATER SYSTEM																	
REPLACE ALL PRIMARY CONTROLS							x	x									
REPLACE CONDENSATE STORAGE TANK							x	x									
FUEL GAS STATION																	
REPLACE HARDWARE & MONITORS							x	x									
GENERATOR EXCITERS																	
PROVIDE BUSH REPLACEMENT KITS									x	x	x	x					

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TABLE 4-2

WATER TREATMENT SYSTEM RECOMMENDATIONS

	Korangi	West Wharf	SITE
1. Effluent Systems			
o Replace controls from piping valves, caustic acid day tanks, and pumps	X		
o Replace semi-automatic operation	X		
2. Demineralizer System			
o Increase storage capacity	X		
o Increase size of trains	X		
o Replace valves, pressure indicators, piping		X	
3. Blowdown System			
o Modify piping for better control	X		
4. Water Quality			
o Add chlorine to minimize algae	X		
o Operation check of pH and residual chemicals for clean operation	X		X
5. Cooling Towers			
o Operate towers to manufacture's recommendations			X
6. Makeup Water			
o Replace hot line soda ash softners		X	

TABLE 4-3

TRAINING WORKSHOPS RECOMMENDATION

	Korangi	West Wharf	SITE
1. Training Personnel			
o Provide additional training for officers	X		
o Provide formal program for operations and maintenance personnel	X	X	X
o Provide integrated merit and advancement system	X		
o Provide practical training for instructors		X	X
2. Training Program			
o Provide additional training to technician to allow engineers time to work on improved performance and availability	X		
o Upgrade workshops using ASME Standards	X		
o Provide outside professional training for engineers and technicians			X

TABLE 4-4
KESC PLANT STATISTICS

	STEAM								GAS									•COMBINED CYCLE			TOTALS				
	KORANGI				WEST WHARF				KORANGI				S.I.T.E.					WEST WHARF COMBINED CYCLE GAS TURBINE ADDITION		S.I.T.E. COMBINED CYCLE STEAM TURBINE ADDITION	TOTAL STEAM (EXISTING)	TOTAL GAS (EXISTING)	TOTAL COMBINED CYCLE (ADDITION)	SUB-TOTAL STEAM & GAS (EXISTING)	GRAND TOTAL STEAM & GAS (EXISTING) PLUS COMBINED CYCLE (ADDITION)
STATION TOTAL CAPACITY (MW)	382				96				80				100												
UNIT NUMBER	1	2	3●	4	6	7	8	9●	1	2	3	4	1●	2	3	4	5	1	2	1	8	9	1	17	20
DESIGN CAPACITY (MW)	66	66	125	125	15	15	33	33	20	20	20	20	20	20	20	20	20	28	28	50	478	180	106	658	764
UNIT AGE	20	20	15	8	29	29	23	23	7	7	7	7	6	6	6	6	6	NEW	NEW	NEW	21 AVE	6 AVE	NEW	13 AVE	11 AVE
FUEL	F.O	F.O	F.O	F.O	F.O	F.O	F.O	F.O	G	G	G	G	G	G	G	G	G	G	G	-	-	-	-	-	-
OBSERVED TURBINE THERMAL EFFICIENCY (%)	31.5	31.1	34.9	35.0	25.6	25.9	27.8	25.5	24.1	25.6	25.9	26.4	26.2	25.6	26.5	26.3	26.2	-	-	-	-	-	-	-	-
IMPROVED TURBINE THERMAL EFFICIENCY (%)	33.4	37.1	35.7	37.0	25.9	25.9	27.8	25.5	26.0	26.7	26.3	26.5	27.0	27.7	27.0	27.1	26.5	35.9	35.9	-	-	-	-	-	-
DERATED CAPACITY (MW)	60	58	105	105	12	12	18	27	18.4	19.6	22	22	20	18.4	20	19.5	20	-	-	-	367	175	-	573	573
CAPACITY IMPROVEMENT (MW)	5.28	6.5	20	20	0	0	10	0	2.4	1.2	8	8	8	2.4	8	1.2	8	28	28	50	63.6 18.1%	11.2 6.4%	4.8	75 13.1%	187 31.9%
DESIGN/EXPECTED TURBINE GROSS HEAT RATE BTU/KWH	9.565	9.074	8.684	8.656	11.531	11.531	10.235	10.235	12.911	12.781	12.785	12.637	12.252 AVERAGE	12.167	12.282	12.016	12.342	14.000	14.000	8.680	-	-	-	-	-
OBSERVED TURBINE GROSS HEAT RATE BTU/KWH	10.698	10.379	Δ 9.779	9.764	Δ 13.481	Δ 12.631	12.293	Δ 13.391	14.145	13.230	13.203	12.928	13.292 AVERAGE	13.315	12.867	12.986	13.041	-	-	-	10.700	13.193	-	11.3[illegible]	-
IMPROVED TURBINE GROSS HEAT RATE BTU/KWH	10.233	10.629	9.529	9.214	-	-	12.995	12.345	13.145	12.930	13.003	12.728	12.852	12.315	12.867	12.586	12.841	14.000	14.000	8.680	9.343	12.784	-	10.424	11.004
IMPROVEMENT TURBINE GROSS HEAT RATE BTU/KWH	465	250	250	450	0	0	100	0	1.000	400	200	200	400	1.000	200	400	200	-	-	0	1.357 10.9%	409 3.1%	-	958 8.4%	1.378 12.1%
OBSERVED HEAT INPUT ** BTU/HR (10^3)	719.255	724.514	1.292.315	1.275.045	192.219	192.219	425.847	441.639	282.900	294.000	284.000	258.560	281.040	265.300	257.340	259.720	250.820	-	-	-	3.374.831	2.374.745	-	5.749.543	-
IMPROVED HEAT INPUT ** BTU/HR (10^3)	675.378	721.514	1.191.125	1.154.700	0	0	402.567	441.639	252.900	256.000	250.000	234.360	252.040	246.300	253.343	251.720	256.820	392.000	392.000	0	3.363.917	2.294.745	-	5.658.713	5.642.713

LEGEND

- ◆ = UNIT OUT SERVICE
- ● = UNIT NOT ON LINE
- Δ = INSUFFICIENT DATA AVAILABLE TO MEASURE TURBINE HEAT RATE, SO THE DATA FROM PLANT STATISTICS WAS USED TO CALCULATE THE TURBINE HEAT RATE
- • = RECOMMENDED COMBINED CYCLE
- •• = FUEL CONSUMPTION BASED ON 100% CAPACITY FACTOR
- C = COAL
- F.O = FURNACE OIL
- G = GAS FUEL
- H.S.D.O = HIGH SPEED DIESEL OIL

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TABLE 4-5

SUMMARY OF ANTICIPATED EFFICIENCY IMPROVEMENTS AND CAPACITY INCREASES

KESC	No. of Units	Improved Efficiency	Potential Capacity Improvements	Derated Capacity	Total Potential Capacity	Total Installed Capacity
Steam Units	8	10.8%	63.8 MW	397 MW	460.8 MW	478 MW
Gas Units	9	3.1%	11.2 MW	176 MW	187.2 MW	180 MW
Total KESC Units	17	8.4%	75 MW	573 MW	648 MW	658 MW
Recommended Combined Cycle Units at SITE and at West Wharf	3	N/A	106 MW	N/A	106 MW	106 MW
Total KESC Units Plus Recommended Combined Cycle Applications* **	20	12.1%	181 MW	573 MW	754 MW	764 MW

*Add one 50 MW combined cycle steam unit to existing SITE Gas Turbine Power Station.
**Add two 28 MW combined cycle combustion turbine units to West Wharf Thermal Power Station Units 6 and 7.

SECTION 5

COST ESTIMATES

5.1 ESTIMATED COSTS

Items recommended for implementation in the KESC thermal units which will result in an increase in unit efficiency, capacity, and/or availability were described in Section 4. A capital cost estimate was prepared for each unit's recommended equipment modifications. Also included on a unit basis are the costs for spare parts, test and monitoring equipment, personal computers, and workshop additions. These are an order-of-magnitude estimates with an accuracy of ± 25 percent.

We believe that institutional and general management improvements can be obtained with some outside assistance, by better utilization of largely existing resources. KESC costs should be supported by existing budgets. The outside assistance is included in the program. In addition, we have included an estimate of $200,000 for training program improvements.

The estimate includes a 10 percent allowance for program management and engineering activities, which reflects the retrofit nature of the work and the limited information available from which to determine engineering requirements. More engineering work is required per capital expenditure to assess the current plant condition than with a grass-roots project. Additional work is required to accommodate the operating plant environment--such items as isolation of equipment, tagging out electric power, accounting for clearances, and less-than-optimum installation and removal sequences. Program management estimates must take into account the wide range of corrective actions required, and the in-depth coordination that will be involved among the several operational organizations of KESC (e.g., plant operations, dispatch, engineering, procurement, training, etc).

The estimate for contingency is higher than for a grass-roots project. This is due to the nature of the improvement program. A contingency of 12 percent has been added to the estimate. We recommend this larger contingency to allow for unknowns that further inspection engineering or actual repair may uncover.

Interest used during construction is not included in the estimates, nor is import duty charged by the Government of Pakistan.

5.1.1 Steam Turbine Stations

The cost estimate to upgrade KESC steam stations is $52,008,000. Those modifications included in this total are based on Tables 4-1, 4-2, and 4-3.

5.1.2 Combustion Turbine Stations

The estimated cost to upgrade KESC combustion turbine stations is 2,832,000. The modifications included in this total are based on Tables 4-1, 4-2, and 4-3.

29

5.1.3 Combined Cycle Unit(s) Retrofit

The cost required to retrofit a 40 MW combined cycle unit to SITE Station Unit Nos. 1 through 5 is estimated to be $39,375,000. A 56 MW combined cycle unit retrofit to West Wharf Station Unit Nos. 6 and 7 is estimated to cost $39,375,000.

5.1.4 Total Estimated Cost

The total of costs for KESC thermal station recommended improvements is $162,980,000. This includes $13,359,000 for engineering and program management and $16,031,000 for contingency. A breakdown of estimated cost by station is provided in Table 5-1.

5.1.5 Cash Flow Requirements

The cash flow required for project implementation is illustrated in Table 5-1. The cash flow is based on a three-year implementation schedule presented in Section 6.

TABLE 5-1

SUMMARY OF CAPITAL COST ESTIMATES FOR KESC PLANT MODIFICATIONS
(All Costs Expressed In Equivalent 1985 U.S. $ x 10^6)

No. of Stations	Station	STEAM PLANTS Local Currency	STEAM PLANTS Foreign Currency	STEAM PLANTS Total Currency	GAS TURBINE PLANTS Local Currency	GAS TURBINE PLANTS Foreign Currency	GAS TURBINE PLANTS Total Currency	COMBINED CYCLE PLANTS Local Currency	COMBINED CYCLE PLANTS Foreign Currency	COMBINED CYCLE PLANTS Total Currency	TOTAL PLANTS Local Currency	TOTAL PLANTS Foreign Currency	TOTAL PLANTS Total Currency
1	Korangi-KTPS	11.378	36.031	47.409	--	--	--	--	--	--	11.378	36.031	47.409
2.	West Wharf	1.104	3.495	4.599	--	--	--	12.400	26.975	39.375	13.504	30.470	43.974
3.	Korangi-KTGPS	--	--	--	0.294	1.256	1.550	--	--	--	0.294	1.256	1.550
4.	S.I.T.E.	--	--	--	0.244	1.038	1.282	12.400	26.975	39.375	12.644	28.013	40.657
	SUBTOTALS	12.482	39.526	52.008	0.538	2.294	2.832	24.800	53.950	78.750	37.820	95.770	133.590
	Administrative/Engineering										3.782	9.577	13.359
	Contingencies										4.538	11.493	16.031
	GRAND TOTAL										46.140	116.840	162.980

CASH FLOWS

Year	Equivalent 1985 U.S. $ x 10^6
1986	13.418
1987	107.982
1988	41.580
	162.980

(One US $ equals 15.82 Pakistani rupees)

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SECTION 6

IMPLEMENTATION

6.1 PROGRAM IMPLEMENTATION

Design of an implementation plan for the Efficiency Improvement Program for KESC Thermal Power Plants was directed at:

- expediting and maximizing the attainment of the benefits available from the program;
- minimizing the impacts of unit downtime for the purpose of planned unit rehabilitation, modification or upgrading facilities;
- making full use of existing KESC capabilities and effectively applying them to the varied capability requirements of the program; and
- recognizing the processes and related times required to mobilize the funding and establish the organizational arrangements for the conduct of such a large and varied program as that being recommended.

Key features of the implementation plan which is being recommended include:

Establishing a single organization in KESC which is given overall responsibility for program implementation. Assignment of authorities to that organiation consistent with that responsibility and with those of other staff and operational elements of KESC.

A policy announcement by top management of KESC making clear the high priority to be given to improving the performance of its thermal power plants and commitment of well qualified staff to the KESC organization established for program implementation.

Expedited processing of arrangements for the funding required for the program such that all necessary program activities can be underway by the summer of 1986.

Early acquisition of the services of an architect-engineer consultant (A/E) in-depth prior experience in the planning, engineering, procurement, and field activities of thermal plant rehabilitation, and modification and upgrading activities to assist KESC in its planning and implementation activities. This consultant should establish a functional organization in Pakistan that would work closely with KESC both in Karachi and at the stations when field activities are active.

Early preparation of a plan for major equipment procurement which takes into account the procurement guidance and requirements of KESC and/or its funding sources.

In-depth initial implementation planning to confirm the priorities of improvement tasks, fix the schedules of initial improvement tasks, establish

program coordination and communications procedures, and define and assign responsibilities and authorities of the generation station managers with respect to field tasks on units at his station.

6.2 ORGANIZATION REQUIRED TO EXECUTE THE WORK SCHEDULE

It is our recommendation that the Project Team concept be utilized. This type of organization facilitates integration of engineering, design, and procurement and is more effective because management and technical personnel are in continuous contact. The suggested project is organized as shown on Figure 6-1. Overall program responsibility rests ultimately with KESC. To demonstrate commitment to the program KESC must make available the necessary resources, material and human, for this undertaking.

KESC should appoint a Program Director with the authority to discharge those responsibilities that include:

- Overall Program Definition
- Establishing Utility Program Staff
- Program Funding, Schedule and Control
- Procurement of required materials and equipment
- Selection of an A/E and general supervision of the support activities provided by that consultant.

For effective assistance by the selected A/E, there should be similarity in the organizational structure and functional assignments of both organizations. Effective coordination of A/E activities and commensurate channels of communication must be established to ensure KESC retention of responsibilities and authorities.

The selected A/E should provide the appropriate organization to implement the program as follows:

The Program Manager is the Senior A/E representative and is responsible for cost control, schedule performance, and quality of work. The Chief of Party will report to the Program Manager and is accountable for all in-country activities. He will have primary responsibility for day to day liaison with KESC and for the joint definition of their assistance requirements.

The Project Engineer reports to the Project Manager and is responsible for the engineering of the project. He is accountable for the quality of the technical analysis recommendations and the timely completion of all phases of the engineering. The Management Consultant will be responsible to the Program Manager and is accountable for activities related to institutional program activities.

The Program Manager and Chief of Party are the primary Client contacts. Key personnel, identified as Home Office and Field Engineers, from required engineering disciplines are assigned to provide technical and design input to the project. Construction Supervisors are assigned to perform the

supervision of construction/installation activities. Equipment and System Specialists should be assigned to the Project Team on an as-required basis to accomplish specific tasks requiring their expertise.

The Project organization can be finalized and team per nnel identified once the scope of work, schedule and an agreed-upon project approach are approved.

To minimize costs and provide the most effective utilization of personnel we suggest the maximum amount of work be performed in the selected A/E's home office. In country personnel will be assigned as required. Based on the scope of work recommended in this study, six home office personnel will be required on a continuing basis to perform engineering and to support procurement activities. This team will be increased, during the design period peak for the combined cycle conversion, to approximately 30. We estimate that initially, six site office personnel will be needed to coordinate and manage site activities. At peak, however, there could be as many as 15 in country personnel. [It is intended that one station's tasks will be completed before proceeding to another site.]

6.3 SCHEDULE

In developing the schedules for the program, the following assumptions/criteria were used:

- 36-month Project duration.
- 18-month home Office Engineering and Design period.
- Implementation based on priority of improvement.
- No planned outages will be undertaken between November and July (low hydro season).
- 125 MW maximum generating capacity to be removed during each outage window.
- All materials, parts, and services for each activity must be available before the start of each outage.
- Contracts are "furnish and erect" to maximum extent possible.
- General contractor support will be available at each site during planned outages.

To ensure maximum improvement as early in the program as possible, schedules have been set according to a plant ranking that recognizes the greatest potential for increased capacity. That ranking, in descending order of potential increased capacity, is:

- Korangi Thermal
- Korangi Gas

- SITE

- West Wharf

For each site, tasks scheduled first will result in the largest generation increase. Other recommended tasks for the site requiring major engineering design, equipment procurement or anticipated outages of two weeks or longer were also included in the schedule This was done so that major engineering and design for a particular station would be completed in support of scheduled outages. Once the field work for one station is complete, the field staff will be assigned to the next station for a similar assignment.

Detailed schedules for the engineering, procurement, and implementation of the major SWEC recommendations for each site are shown on the networks at the end of this chapter. Figure 6-2 depicts the schedule required to implement the management, maintenance, and operations activities recommended by this study. Figure 6-3 summarizes the engineering, procurement, and implementation schedules by plant. The networks in Figures 6-4 through 6-6 provide details of the major improvement program activities. Procurement, training and management assistance services are provided on a separate schedule to highlight their priorities.

It should be noted minor study recommendations have not been included in the schedules at the end of this section. Minor improvements and those which can be implemented during normal plant operation on short forced outages can be scheduled as a level of effort activity after the improvement program workscope has been finalized. The project engineering team would handle these routine engineering tasks, durations of 3 months or less, by assigning project staff engineers to perform the necessary activities.

Achievement of this recommended schedule will bring into being major increments of benefits (i.e., increased capacity, efficiency and availability of thermal units) for the dry periods beginning in November 1987 and November 1988. However, to achieve this, the schedule requires:

- Mobilization of total program funding to be available by the summer of 1986; and

- Expediting the establishment of the KESC organizational structures and support capabilities for the program so they will be fully functional at that time.

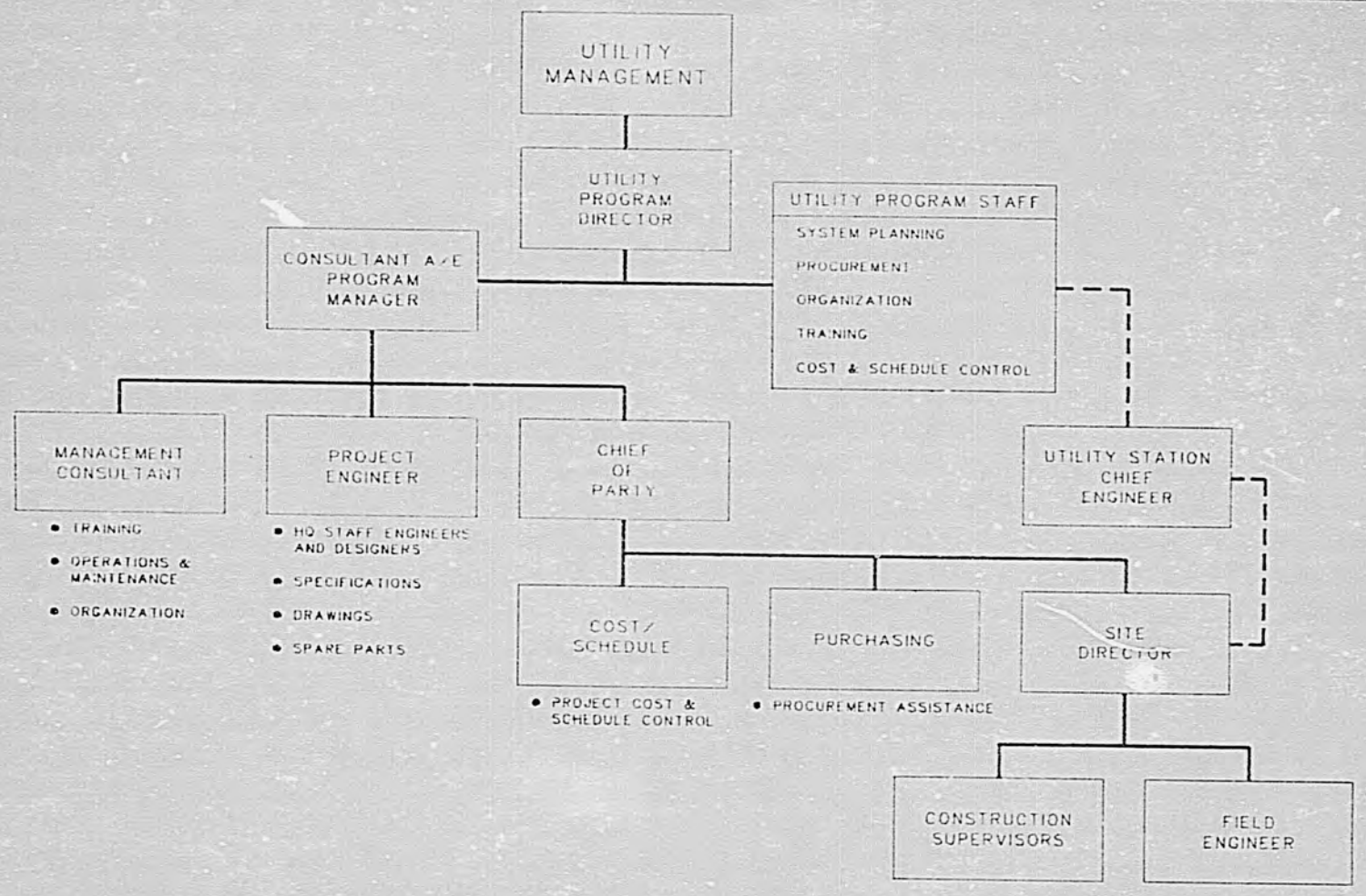


FIGURE 6-1
PROGRAM ORGANIZATION

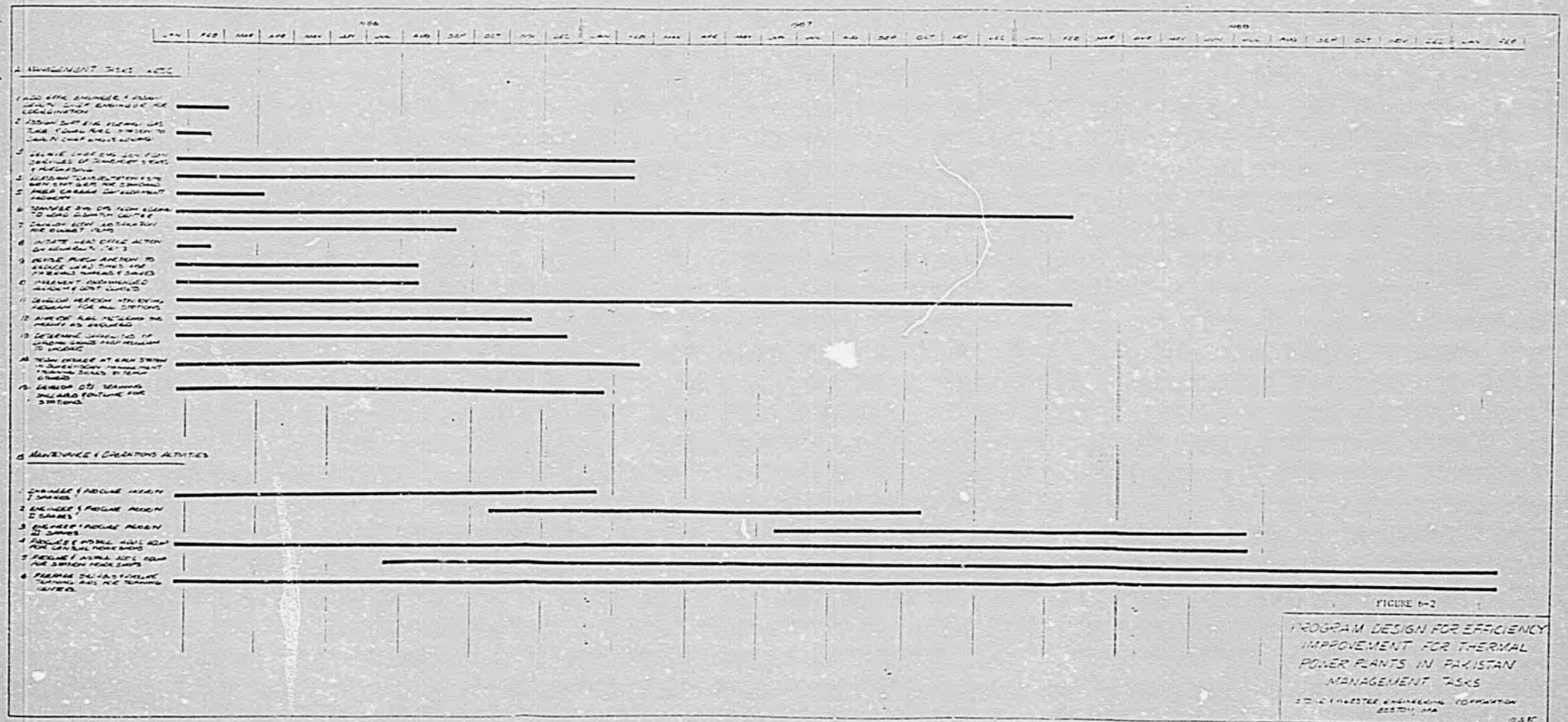


FIGURE 6-2

PROGRAM DESIGN FOR EFFICIENCY IMPROVEMENT FOR THERMAL POWER PLANTS IN PAKISTAN
MANAGEMENT TASKS

THE WESTER ENGINEERING CORPORATION
BOSTON, MA

10.5.87

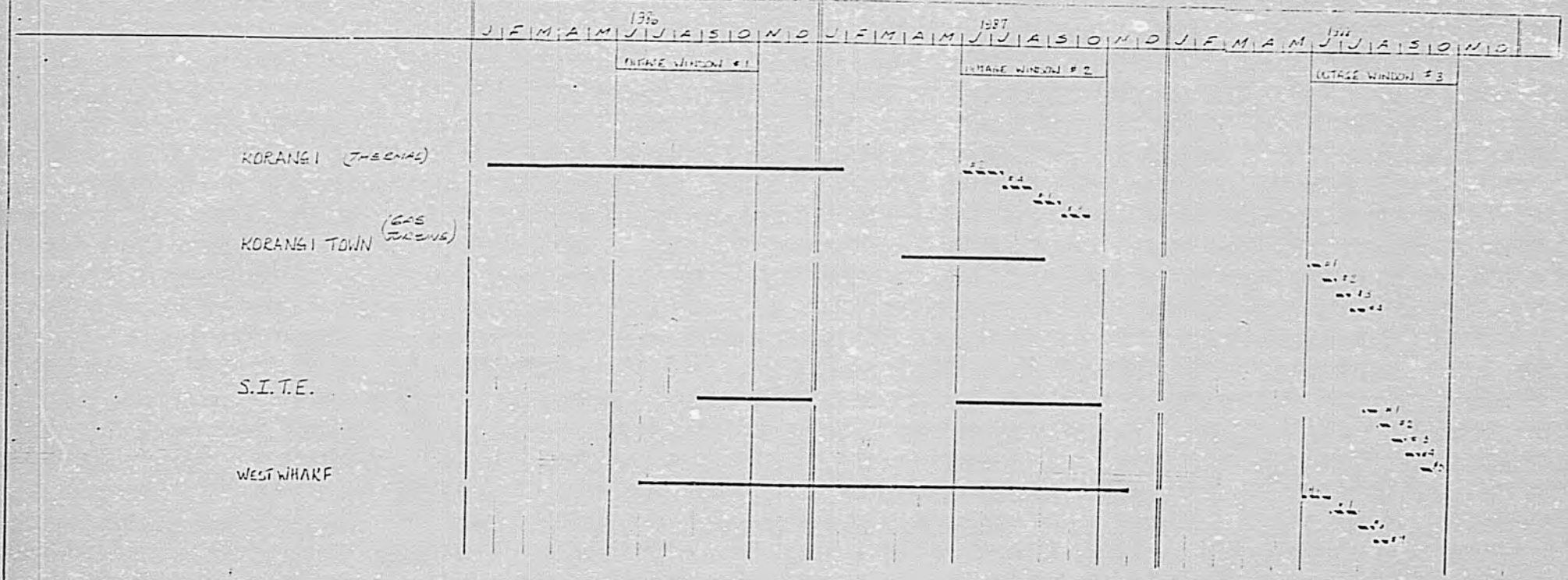


FIGURE 6-3

PROGRAM DESIGN FOR EFFICIENCY IMPROVEMENT IN THERMAL POWER PLANTS IN PAKISTAN ENGINEERING

STONE & WEBSTER ENGINEERING CORPORATION

31 OCTOBER 1995 SK-

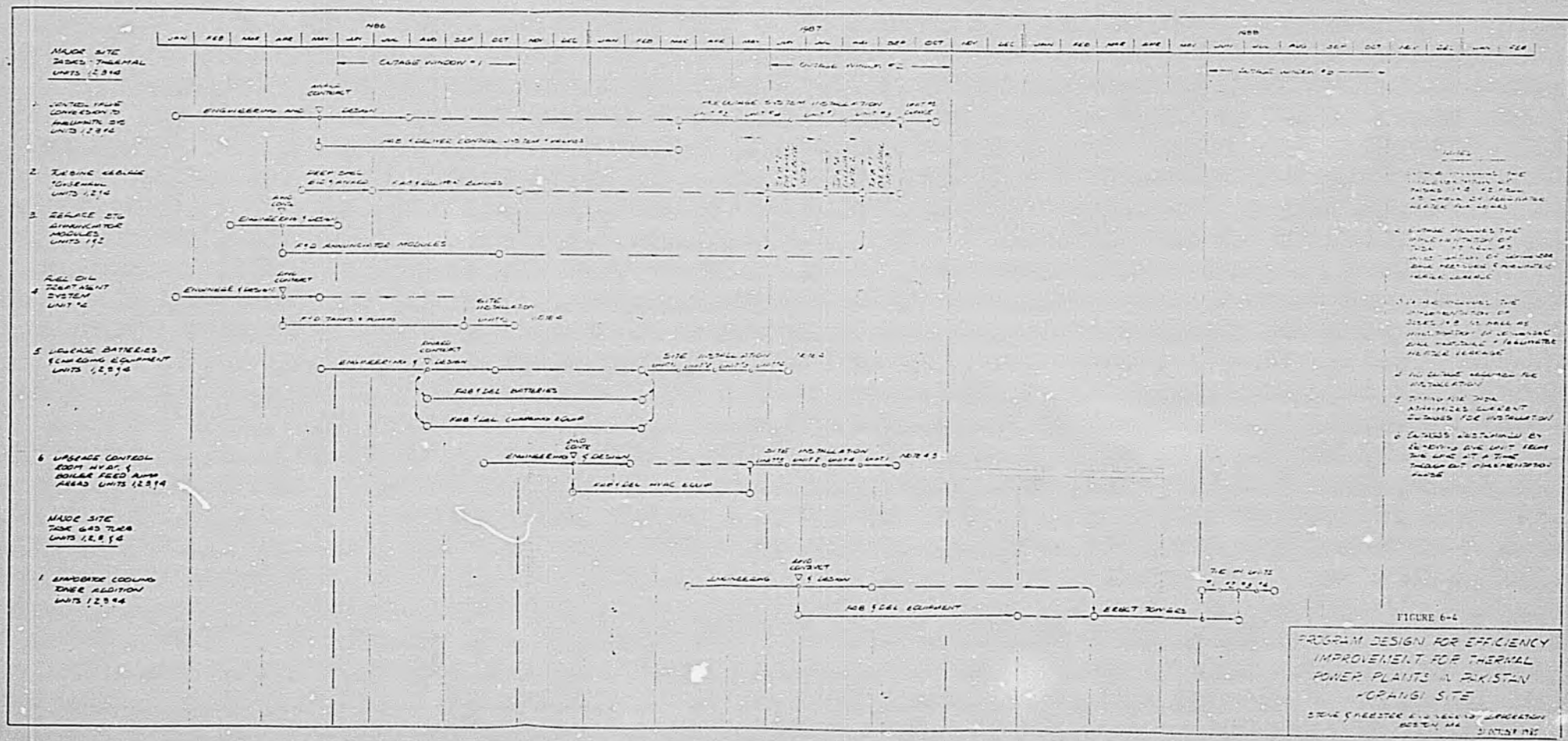


FIGURE 6-4

PROGRAM DESIGN FOR EFFICIENCY IMPROVEMENT FOR THERMAL POWER PLANTS IN PAKISTAN
HUBAI SITE

STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MA

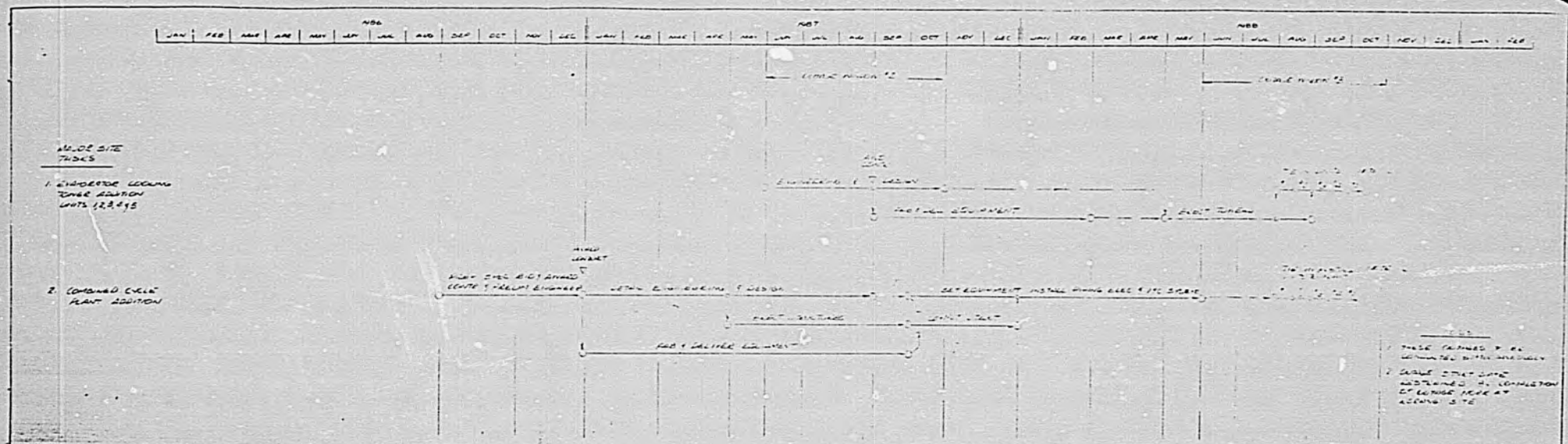


FIGURE 6-5

PROGRAM DESIGN FOR EFFICIENCY IMPROVEMENT FOR THERMAL POWER PLANTS IN PAKISTAN

SITE SITE

STONE & WEBSTER ENGINEERING CORPORATION
BOSTON MA

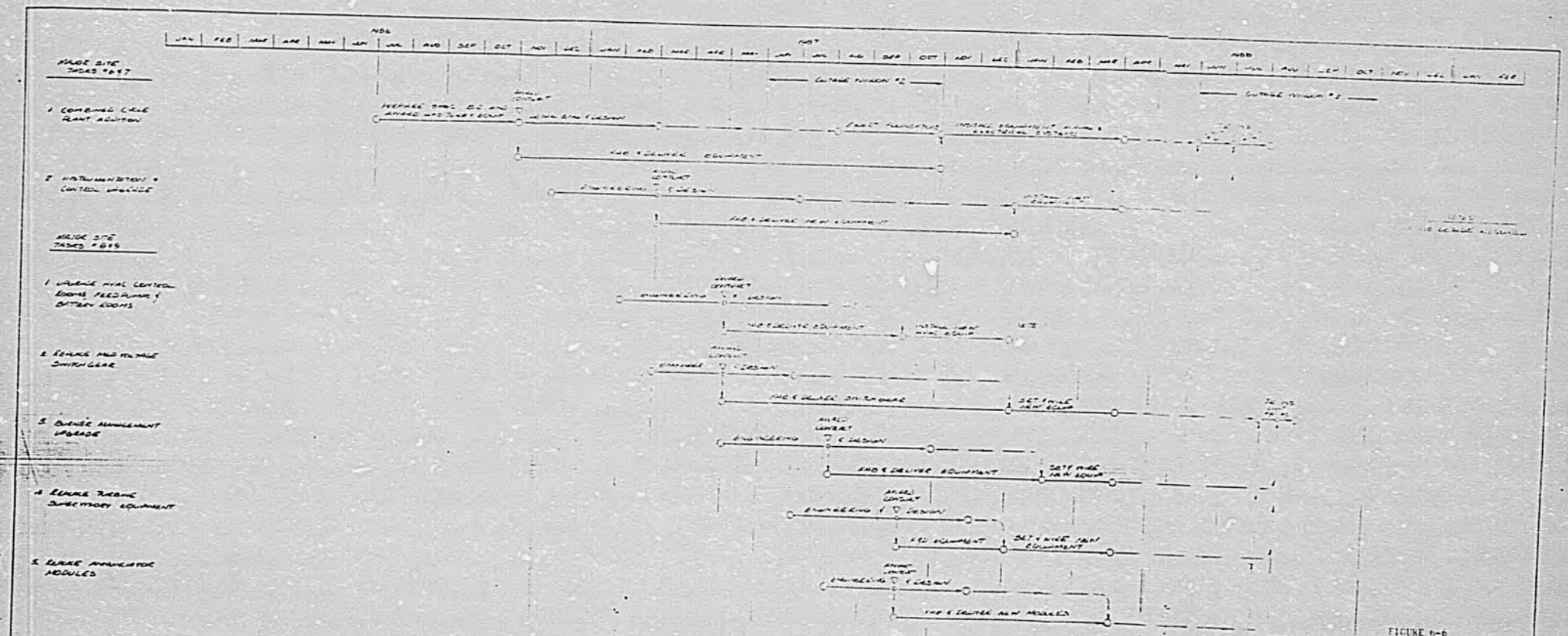


FIGURE 6-6

PROGRAM DESIGN FOR EFFICIENCY IMPROVEMENT FOR THERMAL POWER PLANTS IN PAKISTAN
WEST WHARF SITE

STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MA

KS 88

SECTION 7

ECONOMIC JUSTIFICATIONS

The proposed plant improvement projects for the KESC generating units were evaluated on the basis of net present value and benefit to cost ratio. For each category of improvement tasks at a unit, capital requirements, O&M cost effects, and incremental changes in heat rate, capacity and availability were estimated. These benefits were evaluated over the assumed remaining life of the unit. The expected life used to develop the assumed remaining life was 20 years for gas turbines, and 30 years for steam units. These benefits were aggregated at the unit level and evaluated based on the following major assumptions:

Present Worth Discount Rate	10%	
Inflation/Escalation Rates	0%	
Long Range Marginal Cost of Energy	1.10 Rs/kWh	(1985)
Fuel Prices		
Furnace Oil	65.97 Rs/10^6 Btu	
High Speed Diesel Oil	87.33 Rs/10^6 Btu	
Coal	38.76 Rs/10^6 Btu	
Natural Gas	65.97 Rs/10^6 Btu	
Currency Exchange Rate	15.82 Rs/$1.00	U.S.

The results of these analyses are shown in Table 7-1 and Figure 7-1. In Table 7-1 unit projects have been listed in order of decreasing benefit to cost ratio. In Figure 7-1 cumulative net present values are plotted versus cumulative capital costs. The recommended program includes 17 unit projects with benefit to cost ratios greater than 1.0. These projects involve an investment of about 2.08 billion Rs and have an aggregate net present value of over 5.336 billion Rs.

All projects recommended for modification were found to be economically justified. Further details on the economic evaluation are provided in Section 7 of the main report.

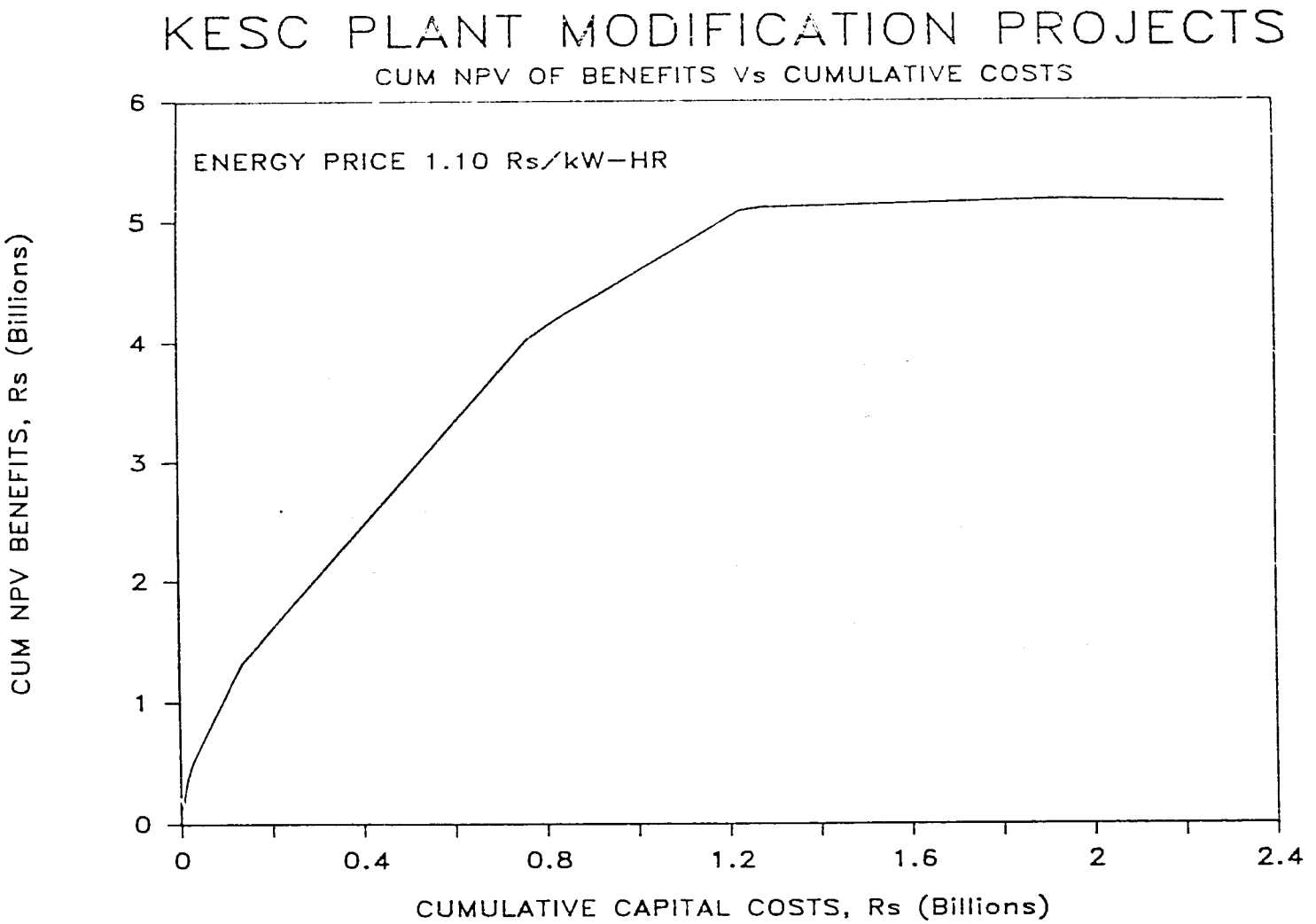
TABLE 7-1

RANKING OF MODIFICATION PROJECTS

KESC PLANT MODIFICATION PROJECTS
PROJECT DATA

UNIT DESIGNATION	PLANT TYPE	INSTALLED CAPCTY,KW	CAPITAL COST 1000 Rs	TOT DELTA BENEFITS 1000 Rs	OVERALL NPV BNFT 1000 Rs	BENEFIT /COST RATIO	SIMPLE PAYBACK ,YEARS	CUM CAP COSTS 1000 Rs	CUM NPV BENFTS 1000 Rs
SITE 2	GAS TURB	20000	3988	141537	137911	39.04	0.21	3988	137911
KTPS 3	STEAM	125000	30955	834276	806135	29.65	0.26	34943	944046
SITE 4	GAS TURB	20000	3197	68087	65181	23.43	0.36	38140	1009227
SITE 1	GAS TURB	20000	3197	65622	62716	22.58	0.37	41337	1071943
KORANGI 1	GAS TURB	20000	5759	117416	112180	22.43	0.37	47096	1184124
SITE 3	GAS TURB	20000	3197	44057	41150	15.16	0.55	50293	1225274
SITE 5	GAS TURB	20000	3197	43226	40319	14.87	0.56	53490	1265593
KORANGI 2	GAS TURB	20000	4968	59546	55029	13.18	0.67	58458	1320623
KORANGI 4	GAS TURB	20000	4968	39385	34868	8.72	0.74	63426	1355491
KORANGI 3	GAS TURB	20000	4968	36290	31774	8.04	1.02	68394	1387265
KTPS 2	STEAM	66000	50277	297499	251793	6.51	0.74	118671	1639058
SITE 00	COMB CYC	0	622913	3261274	2694990	5.76	1.48	741584	4334048
KTPS 4	STEAM	125000	315850	1199995	912858	4.18	2.04	1057434	5246906
WEST WARF 8	STEAM	33000	43451	63501	24000	1.61	1.08	1100885	5270906
WEST WARF 9	STEAM	33000	8053	10398	3077	1.42	1.22	1108938	5273983
WEST WARF 00	COMB CYC	0	625050	632419	61465	1.11	6.87	1736988	5335448
KTPS 1	STEAM	66000	344541	313821	602	1.00	6.13	2081529	5336050

FIGURE 7-1


KESC PLANT MODIFICATION PROJECTS
CUM NPV OF BENEFITS Vs CUMULATIVE COSTS
ENERGY PRICE 1.10 Rs/kW-HR
CUM NPV BENEFITS, Rs (Billions)
0
1
2
3
4
5
6
0
0.4
0.8
1.2
1.6
2
2.4
CUMULATIVE CAPITAL COSTS, Rs (Billions)