3.MANAGEMENT OF OPERATION, MAINTENANCE AND EXECUTION OF PROJECT FOR ELECTRIC POWER FACILITIES AND SYSTEMS

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3-1 OPERATION AND MAINTENANCE OF ELECTRIC POWER FACILITIES AND SYSTEMS

3-1-1 Introduction

(1) In this section, we present an outline of the management of the operation of electric power system and facilities, and our recommendations concerning the fundamental direction and the improvement measure to be immediately taken for the solution of the organizational and managerial problems. Our discussions on the concrete problems of the operation and maintenance of a thermal power plant are presented in the section 3-2. titled "Cost Saving Method of Power Generation".

(2) In the electric power industry which is a facilities industry, the efficient management and operation of power system and facilities are very important and indispensable for the stable and economical power supply. In the management and operation of system and facilities, a systematic approach to integrate all the power facilities should be taken, as required by the nature of power system.

Not only the balance between the load and supply, level of service and economy of operation, but also the pattern of investments in facilities depend on whether an appropriate approach is taken or not. In order to carry out the systematic operation of power system and facilities, the proper operation of respective facilities fit for the actual condition and the sufficient maintenance to make the efficient operation possible are essentially needed.

(3) The characteristics of the existing condition of the operation and maintenance of power system and facilities in Indonesia are as follows.

a. Even in the island of Java except West Java, the development of power system is still on the initial stage. In the other islands of Indonesia there exist only small isolated power systems with limited power supply capabilities.

b. Since there once existed a separate and independent power company in each region and the load and supply conditions of regions are different, the actual condition of the operation and maintenance of system and facilities differ substantially from one region to another.

Accordingly, in writing this report, we took into consideration, the existing condition and the design of the future formation of electric power systems, and placed heavy emphasis on the study of required measures to be adopted immediately for improvement.

(4) In the implementation of the policies formulated according to our recommendations in this report, it is essential to understand fully the fundamentals of the management and operation of system and facilities, and to take gradual steps for systematization and modernization in conformity with the stage of power system development.

3-1-2 Operation and Maintenance

(1) Operation of power systems

a. The major works of the operation of power system are the balancing of load and supply, the operation of transmission system and recording.

The actual works of the operation of power system include the orders of the output control of power plants for the balancing of power supply and the switching operation of power plants and substations for system operation, and recording for the collection of data from power plants and substations and the arrangement of such data.

In order to operate a power system adequately, these works must be done somewhere and it is a common practice to establish a load dispatching office and assign the works to this office.

b. The balancing of load and supply includes the estimation of daily load and supply capability, the formulation of supply plan and the load dispatching by monitoring frequency as a guide. (Balancing of load and supply usually means only the adjustment of power, but should also include the adjustment of load under abnormal circumstances.)

In load dispatching the pursuit of the economy of operation of the total power system must be emphasized. For this purpose, it is essential to make full use of hydro power capabilities and minimize the fuel expenses for thermal power stations.

c. The operation of transmission system is aimed at power flow control, voltage regulation and emergency operation for restoration in case of accident.

Power flow control is done mainly for the stability of power supply and the reduction of loss. The switching and alternation of transmission systems are done according to the changes in the system condition. Voltage regulation consists of the operation of voltage regulators and other equipment and the changing of power flow for the maintenance of the voltages of the major points of the system at a specified standard level.

For the operation of system and facilities, it is strongly desired to establish the rules of system operation showing the procedures of operation for various situations in order to secure the stability of system and the safety of operation. The procedures of operations can be predetermined by assuming all the possible situations of system and facilities.

d. In the operation of power system, quickness and certainty are essential.

For this, it is specially important to grasp and record the existing conditions of system accurately. Recording provides the data not only for the grasping of the existing reality, but also for decision making for operation in the future. Thus, sufficient attention should be paid also to the keeping of records and the arrangement of data.

(2) Operation of electric power facilities

a. The safety and efficiency are the basic objectives for the operations of power plants and substations. For this reason, it is necessary to understand thoroughly the functions, structure and characteristics of various machineries and equipments, and to grasp the operational conditions of machineries and equipments as well as the conditions of related transmission systems and loads.

Generally speaking the operational works consist of the following four elements,

- Monitoring of machineries and equipments
- Operation of machineries and equipments
- Patrolling
- Recording and reporting of operational conditions

b. Monitoring of machineries and equipments

Monitoring at power plants and substations is the work to grasp the operational conditions of boiler, turbine generators, transformers, circuit breakers, etc. and of systems including transmission systems and distribution systems with meters on the control boards, so that operations at the specified values can be maintained.

c. Operation of machineries and equipments

(a) Operational works at power plants and substations are as follows.

- To start and stop the operations of machineries and equipments and to control power
- System switching
- Emergency operation in case of accident
- Other operations

(b) As a rule, normal operations are carried out by the orders from a load dispatching office, except for some operations of machineries and equipments which are predetermined. As for emergency operations, the following measures should be taken.

- To get into communication with the concerned agencies as soon as possible
- To take some extemporaneous measures when circumstances compel it, and inform the concerned agencies promptly
- To confirm the cause and scope of accident and minimize the area of service interruption
- To take emergency measures and make efforts to rehabilitate

(c) In order to secure the certainty and safety in the operation, it is necessary to draw up "operational rules", matching with respective field conditions and to carry out the operational works according to the established rules.

d. Patrolling

(a) Patrolling is done for the purpose of preventing the faults of facilities by finding any abnormality or deterioration in machineries and equipments in advance. In patrolling, it is required to establish a course of patrol by considering the condition and importance of facilities. It is also to look for any changes in the whole conditions of machineries and equipments and to search any abnormality in the environmental condition periodically.

In case of faults or under special circumstances like a natural calamity, it is important to carry out emergency patrols promptly and look for the existance of any abnormality.

e. Recording

(a) Recording at power plants and substations consists of meter reading and taking the records of control and patrol for the purpose of formulating a facility plan, an operational plan and a maintenance plan.

(b) In taking operational records, there are two ways. One is to record either daily, monthly or yearly maximum, and another is to take continuous changes of necessary factors by the use of recording instruments.

For example,

- To install and use recording instruments for the factors whose continuous change must be known like the output of power plants.

- To install and use meters with maximum and minimum indicators for the factors whose only maximum and minimum are sufficient to be known like the monthly maximum and minimum of the current on distribution lines.

- To use an automatic oscillograph and record phase current, phase voltage, zero sequence current, zero sequence voltage, etc. for the analysis of fault.

(c) Since the scope of recording depends on the type and scale of machineries, it is difficult to determine the items and frequency of recording uniformly. Thus, it is necessary to decide on the type of meters used, the items of recording and the frequency of recording for each category of facilities.

(3) Maintenance of power facilities

a. As electric power facilities are used for a long time, they gradually become deteriorated with frictions, dust, etc., and their efficiency cannot be maintained, even if they are operated at specified values. The proper maintenance works on machineries and equipments are necessary in order to minimize the loss of efficiency, maintain the proper functioning of facilities and prevent any possible faults in advance.

b. Maintenance works consist of the inspection to seek the existence of any abnormality, the cleaning of machineries and equipments, the diagnosis of the inner parts using the measuring apparatus, the performance test, the repair works for damages, frictions and other abnormalities.

c. In order to perfect the inspection and maintenance works for machineries and equipments, it is essential to formulate "the standard procedures for the maintenance of machineries and equipments" and to execute the maintenance works according to the established rules.

The standard procedures for maintenance should include the items of inspection for every machinery and equipment, the points of inspection, the standard or allowable value of measurement, the essentials of maintenance, and the measures to be taken in case of finding defects.

d. In case of maintenance works which require the stoppage of operation of machineries and equipments for a long period, the time and schedule of works are to be determined by the careful study from the viewpoint of overall system operation.

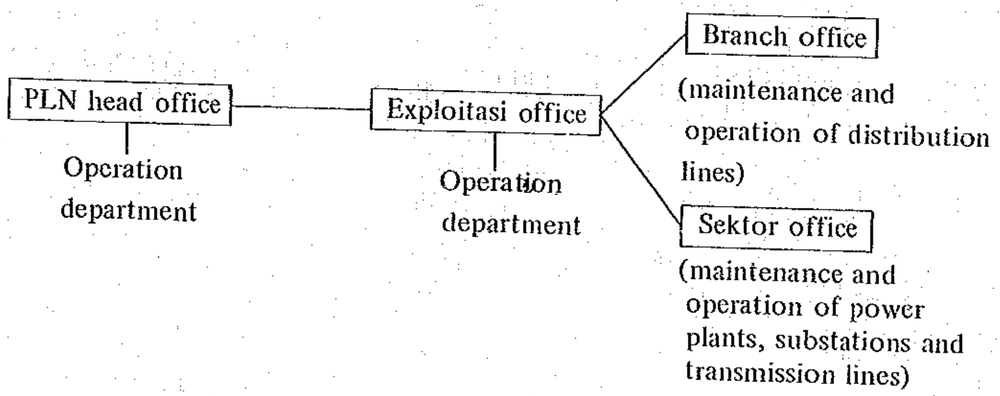
3-1-3 Organization and Management

(1) Basic approach for management

a. In the management of the operational works for system and facilities, the proper administration of daily operational works, the discovery of better methods by grasping the reality, and the strengthening and improving of system and facilities are required. As occasion demands, improvement measures should be reflected in the facility plan.

Looking at the actual condition in Indonesia from this point of view, we can make the following generalizations.

(a) Generally speaking, the organization for the operation and management of system and facilities can be summarized in the following chart.



Operational works and maintenance works at power plants and substations are already separate.

We feel that the existing organizational structure as a whole is adequate for the time being, except the load dispatching systems.

(b) Though efforts are being made for the efficient operation of system and facilities at present, there still exist some regional differences as stated at the beginning of this section. Realizing that there should exist some differences in the operational practices caused by the differences in the conditions of facilities and others, we think that the way of calculating the hydro power supply capabilities, the method of analyzing the existing condition, the method of operation at power plants and substations, and the method of maintenance, should be established, based on the same fundamental concept of the operations of systems and facilities.

The grasping of the existing conditions of facilities and systems and their operational conditions by PLN management agencies, especially PLN head office, is apt to be too general. The informations and data which they collect are insufficient for the managers responsible for decision making in specialized functional areas.

b. It is thought to be urgently necessary for PLN head office to consolidate the method of management for the operation of system and facilities. In the consolidation of the method of management, emphasis should be placed on the following considerations.

(a) Recognizing the characteristics of regions in Indonesia, most of the daily management works should be left to exploitasi offices as they are now. PLN head office should be responsible for the establishment and guidance of the fundamental approach for operation and management, and for the solution of common problems among regions.

(b) The management function of PLN head office should be strengthened, and the clear-cut lines of authority and responsibility between PLN head office and exploitasi offices should be established.

(c) An example of the allocation of authority and responsibility between PLN head office and exploitasi offices, which we feel is appropriate, is presented for reference in Appendix 3-1.

(2) Records, statistics and reports

a. For the consolidation of management system, the proper understanding of the existing condition and the changes is a basic prerequisite. The objective of the existing reporting system is not clearly defined, and the data and informations collected are insufficient for the effective management of facilities.

Thus, it is very important to reform the existing reporting system radically for the collection of the minimum required data and informations and the maximum use of them.

b. The following catagories of data are indispensable for the operation and management of systems and facilities.

(a) Rating of plants, machineries and equipments; present output capability, number and volume (inventory records)

(b) Details of the layout, the structures and performance of plants, machineries and equipments (specification and drawing)

(c) Operational condition (data concerning electricity, water and fuel, and efficiency; the record of the suspension of operation, etc.)

(d) Record of faults (time and date, weather condition, cause phenomena, measures taken, etc.)

(e) Maintenance record (time and date of works done, results, etc.)

(f) Condition of the operation of system (operational records, power flow, frequency, etc.)

(g) System disturbance (relay action, load and supply situation, operation for restoration and rehabilitation, etc.)

c. The following considerations should be made for the systematization of recording, reporting, keeping and using of various data.

(a) Original data taken at power plants and substations should be kept by themselves. Drawings and inventory records should also be kept by power plants and substations.

(b) The frequency of reporting for head office and exploitasi offices respectively should be determined according to the purpose and necessity.

(c) The periods of keeping records and reports should be determined according to the degree of importance.

(d) It is important to compare actual records with previous records and plans.

(3) Training

a. For the consolidation and strengthening of the management system for the operation and maintenance of facilities, the upgrading of the quality of staff is essential.

We feel it is proper and effective for PLN to establish, first of all, a training system for middle-class managers and engineers who are expected to be the field leaders and to implement the training programs. On the second stage, efforts should be made for the training of personnels for operation and maintenance.

b. For this purpose, the following systematic measures should be taken.

(a) The improvement of the ability of managers and leaders

For the manager class, those who have sufficient field experiences should be given higher priority in placement. They should be able to guide their subordinates skillfully with adequate consideration.

For the junior staff and foreman class, the promotion of able engineers should be encouraged and a special training program should be carried out in order to upgrade their ability.

(b) The improvement of the ability of field technicians

In order to upgrade the ability of operators in the field, a training system should be established.

(c) Promotion of self-enlightenment with a technical qualification system

A technical qualification system should be established and a new approach to improve the ability of field personnels with self-enlightenment should be adopted.

(4) Strengthening of load dispatching office

a. Basic approach

(a) The works of system operation consist of the works of load dispatching described before and the works of management and planning. The specialization and systematization of these works must be carried out gradually in accordance with the development of power system. Considering the existing condition of Indonesia, the following steps are thought to be desirable.

(i) In case of one system and one sektor

Sektor office is responsible for management and planning. The load dispatching office belonging to the sektor is in charge of load dispatching operation.

(ii) In case of one system and more than two sektors (one system and one exploitasi)

Exploitasi office is responsible for management and planning. The load dispatching office belonging to the exploitasi is in charge of load dispatching operation.

(iii) In case of one system and more than two exploitasi offices

PLN head office is responsible for general management and planning. The load dispatching office attached to PLN head office is in charge of load dispatching operation.

(b) The following two kinds of the organizational structures are possible for a load dispatching office.

(i) The department or division which is responsible for the management of load dispatching operation, also carries out the daily operation, and establish a load dispatching room. In this room staffs of the department or division serve concurrently and are put on duty alternately. (This is rather a load dispatching room than a load dispatching office.)

(ii) An independent load dispatching office is established apart from the department or division responsible for management, and permanent staffs are assigned to this office.

Which of these two organizational structures should be adopted depends upon the level of quality and the quantity of works required for load dispatching operation.

b. The strengthening of the load dispatching offices of exploitasis

(a) The existing condition of system operation is that exploitasi office or sektor office is directly responsible for management and planning and that the load dispatching offices attached to exploitasi office or sektor office are in charge of load dispatching operation as described in the above (b) (i).

However, as in the case of the Djakarta area, for example, persons are sent as shift to the load dispatching office from the operation divisions of exploitasi office and sektor offices. The line of responsibility for load dispatching operation is not always clear.

(b) In order to establish a clear-cut line of responsibility and improve the quality of load dispatching operation corresponding to the development of power system, the following measures should be taken for the strengthening of load dispatching office in each area in the Island of Java.

(i) Exploitasi XII and XI

The existing load dispatching rooms at Djakarta and Bandung should be reorganized to be independent load dispatching offices belonging to the operation departments of respective exploitasi.

The head and the permanent staff of load dispatching office should be appointed. The load dispatching rooms at Bogor and Parakan are to be abolished after the strengthening of communication facilities. Until that time, these existing load dispatching rooms can continue their operations as branch offices of strengthened Djakarta and Bandung load dispatching offices.

(ii) Exploitasi IX and X

The strengthening of the load dispatching rooms in Exploitasi IX and X should be carried out following Exploitasi XI and XII with the interconnection of Tuntang and Kefenger system in Exploitasi X and the interconnection of Kalikonto and Madium system in Exploitasi IX.

c. Establishment of West Java load dispatching office

(a) The power sources of West Java system which is the largest system in Indonesia are composed of PLN hydropower plants, Djatiluhur hydro power plant, Priok steam power plant and diesel power plants.

The reality that ineffective discharge can be observed at Djatiluhur poses a serious problem for the management of the electric power enterprise. Without the efficient use of the Djatiluhur hydro power plant, the economy of operation and the securing of sufficient supply capability cannot be achieved.

(b) The main reason for the existence of this problem is that the basic approach for holding the reserve capability of system is not well established, and the fundamentals of economical system operation are not observed. Other major reasons are the existance of two exploitasi offices in West Java and the autonomy of P.N. Djatiluhur as a separate enterprise.

(c) Thus, first of all, PLN head office should have deeper understanding of the fundamentals of system operation and make efforts to guide and educate the concerned personnels. At the same time, improvements must be made in the organization in conformity with the abovementioned basic approach.

(d) For the integrated and economical operation of West Java system, a load dispatching office (room) should be established in the operation department of PLN head office as stated in a (b) (i) for the time being.

(i) Work

- Balancing of load and supply and regulation of frequency for West Java system
- System operations for 150 KV system and 60 KV system connecting sub-systems of Exploitasi XI and XII.

(ii) Load dispatching orders

Direct orders

- Orders for power control to Djatiluhur hydro power plant and Priok steam power plant
- Orders concerning the operation of 150 KV system including Tjawang and Tjigereteng substations

Indirect orders

- Orders to the exploitasi load dispatching offices concerning the balancing of load and supply, and specific system operations

(e) The works of other concerned sections

(i) Operation department of PLN head office

- Contracting for power purchase from P.N. Djatiluhur
- Planning for the balancing of load and supply
- Coordination between PLN and P.N. Djatiluhur, and between Exploitasi XI and XII

(ii) Operation department of exploitasi office

- Planning for the balancing of load and supply in the exploitasi
- Planning for overhauls

(iii) Load dispatching office of exploitasi

- The operations of power plants and systems according to the orders from the load dispatching office in PLN head office

(Other works are the same as before.)

(5) Fuel management

a. The proportion of fuel cost to the total power cost is more than 20 percent. The proportion of fuel cost to thermal power cost is more than 50 percent. What is more, as we can expect a rapid increase of energy generated by thermal power plants considering the future increase of load, the problem of fuel management is thought to be very important in the management of the enterprise. Thus, it is necessary to strengthen the management system for fuel used for electric power generation with the objective to secure fuel economically and efficiently.

b. For this purpose, it is thought to be essential for PLN head office to carry out, first of all, the following tasks systematically.

(a) Formulation of the balance of requirement and supply of fuel based on the operational plan for thermal power stations.

(b) Collective negotiation concerning the purchase of fuel with suppliers. (For example, the determination of prices for various categories of fuel, the standardization of quality and the collective negotiation concerning the quantity of purchase.)

(c) The consolidation of standards, rules and regulations concerning the quality of fuel.

(d) The formulation of the rules and the publication of the manual on the works of exploitasi offices and the field works concerning receiving, checking of quantity and quality, making inventory, and transporting.

c. A new and independent division of fuel should be established within the department of logistics of PLN head office. This division is to take charge of the above mentioned works. Under the guidance of PLN head office each exploitasi office is responsible for the specific works of purchasing, receiving and checking of quantity and quality. The clear-cut line of responsibility should be drawn and the establishment of the system for smooth procurement should be promoted.

3-1-4 Other Items for Improvement

(1) The operation of the on-load tap-changers of the transformers

Considering the existing power supply condition in the Island of Java, it is urgently required to improve distribution voltages.

For the drastic improvement of distribution voltages, the rehabilitation of distribution facilities is indispensable. On the other hand, the appropriate regulation of voltage on the output side of substation can contribute significantly to the improvement of distribution voltage.

Therefore, the voltage regulators of the transformers with on-load tap-changers already installed in substations should be immediately utilized and positive efforts must be made for the improvement of distribution voltages by regulating the output voltage of substation.

In Appendix 3--2, we present reference materials concerning the necessity of on-load tap-changers and the method of operation and maintenance.

(2) The over-load operation of transformers at power plants and substations

In case of service interruption caused by a fault of transformer at a power plant or substation, proper relief measures should be taken by making effective use of other sound transformers.

Accordingly, it is required to make studies in advance concerning the extent to which over-load operation is possible for each transformer and to attempt to make the most effective use of existing facilities.

In general, over-load operation is possible under the following conditions without sacrificing the life of transformers.

a. When the difference between the maximum temperature of cooling air in a day and the standard value is very large, over-loading is possible to a certain extent according to the difference between the maximum temperature and the standard value.

Reference: In Japan, when the difference is more than 10°C, the over-loading is possible at the rate of 0.8 percent per 1°C.

b. When the tested value is lower by a certain amount than the stipulated limit of temperature increase, over-loading is possible by a certain percentage per 1°C.

Reference: In Japan, when the tested value is lower by more than 5°C than the stipulated value, over-loading is possible at the rate of 1 per cent for every 1°C decrease.

c. When the loading factor is less than 90 per cent, over-loading is possible by a certain percentage per 1 per cent difference from 90 per cent.

Reference: In Japan, over-loading is possible at the rate of 0.5 per cent for 1 per cent difference from 90 per cent for automatic cooling transformers with the maximum limit of 20 per cent.

d. In the combined situation of the above cases from a to c, over-loading is possible up to the total percentage obtained by adding the allowable percentage of each case.

The methods of overloading explained above are the methods not to sacrifice the life of transformer. There exist other methods which sacrifice the life of transformer.

Nevertheless, we feel that a cautious attitude must be taken for the adoption of the method of over-loading operation which sacrifices the life of transformer.

Taking the above possible methods into account, PLN head office should prepare "The Directions Concerning the Over-loading Operation of Transformers", make them well known by the personnels in the field and establish the rules for emergency operation.

(3) The use of the existing 30 KV transmission towers in case of voltage change to 70 KV

In the Island of Java, there exists a comparatively large number of plans to raise the existing system voltage of 30 KV to 70 KV for the strengthening of transmission system. In this case, it is essential to study the possibility of using the existing towers for 70 KV with some modifications and to make every effort to use existing facilities effectively.

We made a study on the possibility of using the existing 30 KV towers for 70 KV in the Tuntang system of Central Java, and came to the conclusion that they can be used with some remodeling. We present the result of our analysis for reference in Appendix 3–3.

(4) The execution of inspection works for machineries and equipments

a. Repair for oil leakage

It was found that many oil-immersed winding machineries and equipments (for example, transformer, potential transformer, etc.) have oil leakages. If they are left as they are for a long time, water comes into the machineries and equipments, and the insulating materials which are the crucial element of winding machineries become deteriorated. This, in many cases, leads to the occurrence of electric faults.

Therefore, it is essential to carry out inspections and repairs immediately for machineries and equipments with oil leakages and prevent any possible faults from occurring.

b. Inspection and adjustment of relays

The relays installed at power stations and substations are not always given sufficient inspections at present. As relays are the equipments which play very important roles in the operation of systems and facilities, it is essential to carry out inspection works immediately in order to maintain the proper function of relay.

If the present situation continues to exist without the inspections of relays, the relays will not function effectively. They would not function when they should and they might function when they should not. This situation invites an increase in the number of faults or breakdowns of facilities, which greatly decreases the reliability of supply and creates an unfavorable condition for the management of system.

For the proper functioning of relays, the relay setting should be consistent with the short-circuit or rupturing capacity of system and the current and voltage expected in case of fault. The adjustment of relay is a very important task as well as the inspection of relay. Therefore, the establishment of system for the adjustment of relay is urgently required.

c. Inspection works for other machineries and equipments

Also for machineries and equipments other than those mentioned above, the strengthening and consolidation of maintenance system, the execution of inspection and repair works, the maintenance of the proper functioning of facilities and the improvement of the reliability of power facilities are desired.

(5) Strengthening of the facilities related to system operation

In system operation, the quick and accurate communications among power plants, substations, load dispatching offices and related offices, and the detailed and precise understanding of the condition of whole system are the fundamental prerequisites.

The execution of the following measures should be promoted.

a. As we recommended in Section 2-1 of the "Yearly Investment Plan", the strengthening of communication facilities between load dispatching offices and major power plants, substations and related offices is urgently necessary.

b. The load dispatching boards at load dispatching offices should be remodelled so that they are easy to see and handle.

c. The installation and consolidation of meters necessary for the grasping of the system condition should be carried out preponderantly.

Especially, power factor meters or reactive power meters should be installed at representative power plants and substations for the control of voltage. The installation of automatic oscillograph at major power plants and substations is also desired for future planning and operation.

3-2 COST SAVING METHOD FOR POWER GENERATION

3-2-1 Introduction

(1) This section of the report is related to item i, and the most important subjects regarding the cost saving method for existing power generation plans and the choice of fuel for the existing gas turbines are selected. Therefore, the fundamental improvement measures are recommended to solve the problems.

(2) To cope with energetic increase of power demand, and in order to secure the stabilization of electric power supply, the rapid increase of thermal power generating energy as well as the fuel consumption amounting to even greater quantity are both expected.

In the meantime, the fuel cost occupies more than 50% of the power generating cost of steam power stations. For this reason, maintenance and improvement of thermal efficiency basically constitute important points in the method of the operation cost saving.

Accordingly, in order to maintain and improve thermal efficiency, basically effective measures are to strictly observe the operation at specified values during the normal operation.

(3) From such viewpoints, we made reviewals in regard to the operation cost saving of existing power stations.

As the result of our study, we decided to limit our recommendations to the problems which are indispensable in either maintaining the capacities or reinforcing the firm capacities of steam power station and which are, at the same time, the solution of the problems that are deemed greatly effective in saving the cost by means of the improvement of thermal efficiency.

(4) At the beginning, as for Priok units 1 and 2 consisting of a power source of most importance in Djakarta area, we select the technical subjects such as damage of a high

pressure feedwater heater tubes continuous cleaning of condenser tubes, and feedwater treatment, etc., and also review to establish a concrete measures for improving them. As the result of drawing them, we expect the increase of firm capacity of Priok units 1 and 2 and the improvement of their thermal efficiencies.

(5) Subsequently, as for Perak units 1 and 2 consisting of a power source of most importance in Surabaja area, we select technical subject such as inservice washing of a flash evaporater, steam temperature drop at a superheater outlet, corrosion of superheater tubes and preservation method of a boiler, etc., and also review to establish a concrete measures for improving them. As the result of doing them, we expect favorable rise of reliability of Perak units 1 and 2, and improvement of their thermal efficiencies.

(6) On the other hand, in case of a gas turbine plant having a large quantity of fuel consumption and a large occupation ratio at fuel cost in the operation cost as like as general steam power plants, choice of fuel to be used will much more greatly influence their economics considering improvement of their thermal efficiencies.

In conclusion, referring to a Semarang gas turbine plant under now operation, we determined to study and review the possibility to detect the most economic way in making choice of fuel, investigating its way from the standpoint of facilities.

3-2-2 Cost Saving of Existing Units

(1) General description of operation cost saving for existing units

(a) The fuel cost occupies a very large portion of the power generating cost of steam power stations. It actually exceeds 50 per cent in Indonesia. For this reason, maintenance and improvement of thermal efficiency as well as the prevention of deterioration of performances concerning the equipment basically constitute important points in the method of the operating cost saving.

Accordingly, in order to maintain and improve thermal efficiency, basically effective measures are to constantly control the combustion, strictly observe the operation at specified values, endeavour to save the auxiliary power and to calculate the heat balance from operational records and performance test results, to be followed by a reduction of heat losses by means of such reviewals and an attempt to maintain good performances of equipment.

(b) In boilers, for instance, it is essential to check if a proper ratio of excess air is constantly maintained during the operation, if oil burner tips on which the combustion depends are kept in good conditions, and if the exhaust gas temperature is not too high, etc. In the operation of turbines, it is particularly necessary to check if the steam condition at the turbine inlet or condenser vacuum which greatly affects the drops in thermal efficiencies of the plants falls below the rated values. As an inferior control of water quality results in the deposit of scales inside the boilers, occurrence of corrosions, drop in steam purity, drop in thermal efficiency resulting from the deposit of scales on turbine blades, and corrosion of various equipment and piping in the heat cycle, it is important to maintain specified values.

Such combustion control in normal operation, operation at specified values, control of water quality, etc. may be safely said to be the first step in the operating cost saving of steam power stations.

Such a series of points in the control of operation can be easily singled out by reviewing the daily operation records in steam power stations. In addition to the recording of data, numerical grasp of the actualities of operation by means of summing-up of recorded data, analyses by heat calculation, and periodical performance test of plant will be the second step in the operating cost saving of steam power stations.

(c) From such basic viewpoints, we made actualities study of important existing steam power stations for reviewal pertaining to the cost saving in existing plants.

We have previously made recommendations in the section 2 concerning 1969-1970 investment plan with an emphasis placed on the curtailment of spare machines by means of an efficient operation of the power system and measure for the reinforcement of firm capacities of existing plants, with an adequate consideration given to the problems in maintaining the capabilities of existing plants.

(d) In this section, accordingly, we decided to make recommendations on the following seven items to be solved which from the problems presented by power stations where we studied, are indispensable for maintaining the capacities or for reinforcing the firm capacities, and which are, at the same time, considered as very effective in the cost saving by means of improving thermal efficiency of the plants.

(i) Damage of high-pressure feedwater heater tubes for Priok units 1 and 2

(ii) Continuous cleaning device for condenser tubes for Priok units 1 and 2

(iii) Feedwater treatment for Priok units 1 and 2

(iv) Inservice washing of flash evaporator for Perak units 1 and 2

(v) Steam temperature drop at superheater outlet of Perak units 1 and 2

(vi) Corrosion of superheater tube at Perak units 1 and 2

(vii) Preservation method of Prek units 1 and 2

(2) Technical proposals for Priok units 1 and 2

a. Damage of high-pressure feedwater heater tubes

(a) Present condition and problems

(i) Priok Units 1 and 2 experienced leakage troubles with feedwater tubes shortly after their service dates. In spite of a number of repairs, troubles have not been solved to date.

At the present time, the above two units are in service with the two high-pressure feedwater heaters separated from the main heat cycles. For this reason, feedwater temperature at the economizer inlet has dropped to an extreme low of 130°C compared with the specified value of 210°C. Accordingly, not to mention a decrease in thermal efficiency of the plants, firm capacities are as low as 22,000 KW each, falling short of rated capacities of 25,000 KW each.

(ii) If such operating conditions continue, our tentative calculation (Refer to Appendix 3-4) results in an average loss of about 4% in terms of thermal efficiencies of the plants compared with fuel costs when the units are operating with specified values.

For this reason, granting that annual energy production is around 71,500 MWH (actual result for 1968), this is equivalent to a loss of some 20,000 x 10^3 Rp/yr.

If an increase of demand in the future results in an increased energy production, the abovementioned loss figure will take a further upward curve.

(iii) An early solution of such a problem of loss in heat economics is necessary. Besides, if the rated capacities of 25,000 KW each are ensured by repairs of high-pressure heaters, it is also possible to expect an upward swing, at once, of some 6,000 KW (an aggregate of the two units) in the firm capacity of Priok steam power station, providing a stable supplying capability for coping with the increasing demand. For these reasons, an urgent repair will be necessary.

(b) Improvement measures for damage of heater tubes (Refer to Appensix 3-5)

(i) With respect to the damage of the said heater tubes, damage of tubes where they are insert into the tube sheet at the feedwater inlet water box side is conspicuous and this phenomenon is frequently observed with the equipment which adopted carbon steel for heater tubes.

(ii) It is possible to explain this phenomenon by the flow process of feedwater and it has greatly to do with the way feedwater flows into the heater tubes. Namely, it is attributable to the vortexes which are caused by the shapes of water boxes, tubes walls or where the heater tubes are inserted into the tube sheets. For prevention such damage, it is preferable to install a feedwater flow regulating device at the feedwater inlet side.

There are two practice in this. One is a practice which has been adopted by the Atlas Co., a German manufacturer. This is to install an anti-corrosive guide-plate on the tube sheet which is provided with nozzle hole commensurate with a diameter of tubes. The other is to install a flow diffuser, which is also anti-corrosive, on the water box side. Our experiences indicate that both practices are effective.

(iii) In specific installation of these, it is necessary to contact the Man-Siemens Group which is the supplier of the said high-pressure heaters (or Balcke Co. which is a heater manufacturer). Japanese manufacturers can also install the similar equipment. In consideration of guaranties of performances, however, it would be prerequisite to ensure an agreement of the German side.

b. Continuous cleaning device for condenser tubes

(a) Present condition and problems

(i) When Priok units 1 and 2 were initially placed in service, they were not equipped with cleaning devices for condenser tubes. Thereafter, reversible type cleaning devices were installed with an intention of inservice cleaning of condenser tubes. However, they did not function adequately.

Since then, manual cleaning has been effected as required by the contamination of tubes. The effect of cleaning, however, has been inadequate.

The increased frequency of cleaning as the sea water became more contaminated and the incremental fuel cost resulting from drops of vacuum resulted in the present condition which cannot be ignored. As the specific measures for improvement of such condition, there is a pressing need for studying the installation of a high-grade continuous cleaning device or other measures.

On the other hand, results of our field study and analyses of actual operational data make us fully understand the abovestated necessity of study. Immediate adoption of anyone of the above measures, however, is still open to some questions.

(ii) In other words, as the result of our tentative calculation (Appendix 3.6) with respect to the performances of condensers for Priok units 1 and 2, it is possible, at the rated capacities of 25,000 KW each, to maintain the vacuum of 2.3" with the sea water temperature of 30°C at the condenser inlet.

Data showing such figures during actual operation, however, were not found.

This fact indicates that it is difficult to maintain the designed value of vacuum merely by cleaning the condenser tubes. It is possible to suspect, for instance, that drops of condenser vacuum on account of air leakage may also be a cause.

(iii) It is generally possible to prevent the drops of condenser vacuum by means of adequate tests of inferior performances of air ejectors, air leakages from, gland seals, flange bolts, atmospheric relief diaphragm, and manhole packings of turbines as well as air leakages from expansions between condensers and turbine exhausts, piping and valves around condensate pumps, and various vent-piping system which are connected to condenser.

Accordingly, we think the abovestated tests of condenser vacuums should precede the establishment of the most efficient preventive measure for the drops of condenser vacuums.

(b) Continuous cleaning device for condenser tubes

(i) There are many approaches in the methods of cleaning the condenser tubes. For many years, a method of eliminating slimes and dirty muds inside the tubes by applications of pressurized water or compressed air to brushes or rubber balls, a slime and dirty mud elimination plan by means of chemicals, etc. have been performed. In addition to involving such restrictions as shut-downs of turbines or limitations of loads necessitated by partial operations of condensers, all of these measures, however, require much labour and time. Continuous cleaning device for condenser tubes (Refer to Appendix 3-7) was developed as a device by which cleaning can be done at any time during the operation of turbines without involving the abovementioned restrictions.

It is reported for its effectiveness of cleaning and is widely used in the latest steam power stations.

(ii) Its principle is to provide a new and special circulating system, with a medium of a pump and including the condenser, in the condenser cooling water circuit, throw sponge balls into this system, and let them clean the condenser tubes by their forced circulation in the tubes by means of the pressure difference of the cooling water between the inlet and outlet of condenser tubes.

c. Feedwater treatment

As our specific measures for stabilizing and ensuring the rated output as well as improving the thermal efficiency at Priok units 1 and 2 which were pressingly needed, we had previously presented in this section pertaining to early repair of high pressure feedwater heaters and preservation of vacuum degree of a condenser. Both of these factors in our recommendation consist of a pivot on our recommendation in view of not only forming an important theme in reducing cost of power generation but also emphasizing significance on a daily operation of steam power stations based on specified values.

Namely, reviewal of various values for the water quality control, has tended to be made as one of the causes at the stage of repairs after the occurrence of failures. However, a positive attitude toward the betterment of a unit has been recently taken at all times judging from a broad viewpoint of the plant as a whole including the performance of the equipment and composition of cycles, etc., not to mention the enforcement of a rigid water quality control in the daily operation of a unit.

In other words, by taking such a positive way in a feedwater treatment will result in greatly reducing a running cost of a steam power station by means of an advancement in operating techniques coupled with the saving in maintenance and betterment costs (extension of a life of equipment).

From these viewpoints, our recommendation has been decided to investigate the water quality control which is now being performed in Priok units 1 and 2, for the purposes of singling out important problems to be solved immediately and making fundamental studies in regard to the specific measures for improvements thereof.

(a) Present situation and their problems

In Priok units 1 and 2, the city water of Djakarta has been used as a raw water and is also supplied as the make-up water for a heating cycle through a water treatment plant manufactured by the Permutit Company in West Germany. On the other hand, Trisodium Phosphate Na_3PO_4 has been injected into a boiler to prevent deposits of scales in it. Based upon our reviewal of design values and actual values on a feedwater treatment, main problems are itemized as follows.

(i) Actual PH values of the make-up water, feedwater, and condensate are remarkably low as compared with the design values. (Actual value is 5.5 against the designed feedwater PH value of 8.5.)

(ii) Actual values of dissolved oxygen involved in a condensate and feedwater are large. (About 50 ppb in a dissolved oxygen)

Of the above, when the PH value under item (i) is low, fear for enhancement of corrosion is adequately foreseeable when it occurs in the tube side of a feedwater heater using steel pipes. Likewise, a large value of dissolved oxygen under item (ii), can give rise to the corrosion of the equipment. Although the designed allowable value by manufacturers (at a boiler inlet) is about 50 ppb, it is necessary to take some separate countermeasures as the above value is comparatively large for this class of units.

(b) Measures for improvement

With regard to the above problems, we have decided to recommend the following as the result of our studies taking our experiences and recent practices into consideration.

- As the dissolved oxygen elimination measures, improvement in the mechanical elimination methods to and chemical treatment by means of deoxygen chemicals shall be resorted to side by side.

- In order to raise PH values in the feedwater and condensate, injection of PH control chemicals are deemed effective. Our specific recommendations, accordingly are as follows.

(i) Elimination of dissolved oxygen

Dissolved oxygen existing in a heat cycle is mainly attributable, in general, to the dissolution of air into the feedwater and condensate, through an equipment which constitutes a heat cycle, during the start-up, shutdown or operation of a unit. In this connection, adequate attention for deaeration in a heat cycle has been paid from designing and manufacturing viewpoints by the plant manufacturers.

In an actual operation of a unit, measures for eliminating dissolved oxygen vary to some extent, depending upon the frequency of startups and shutdowns, lengths of shutdown periods, conditions of load fluctuations, etc. Therefore, we herein decided to limit our recommendations to the cases of startups after a relatively short period (about one week) of shutdowns as well as of normal operations.

(i)-a Elimination countermeasures for dissolved oxygen at the startup of a plant

a) Fundamentally speaking, it is adequate with thorough deaeration of the feedwater and condensate by full operations of a deaerator and a condenser. For this purpose, it is prerequisite to maintain a satisfactory function of the condenser vacuum as we previously recommended on its improvement.

Subsequently, it is necessary to check whether vent lines of the plant components which are connected to a condenser are properly functioning as vents (whether the location of an outlet of equipment and its connection to a condenser are proper, not to mention the sealing conditions of piping systems).

b) According to our experience, when all the above conditions are satisfactory, it is effective for the elimination of dissolved oxygen to deaerate the condensate in a condenser by starting a condensate pump after the establishment of a vacuum of a condenser at the time of startup and making use of a recirculating line from a condensate pump outlet to a condenser. (Refer to Figure 3-2-1)

This method is adequately feasible by an effective use of existing equipment. Location of a spray nozzle in a condenser on a recirculating line will have to be checked because unless spraying is done above the water level of a hot well, it is ineffective.

(i)-b Countermeasures for elimination of dissolved oxygen in a plant under normal operation

a) During the operation of a plant, maintaining a deaerator inner pressure as well as holding a condenser vacuum at a proper degree are important.

Especially, it is necessary to check the change-over to the heat extraction lines for a deaerator at low loads, and to constantly and absolutely maintain a deaerator inner pressure, to say nothing of maintaining a deaerator inner pressure at the specified value.

In addition, it is also necessary to prevent a pressure drop at a load variation by a clear knowledge of interrelationships between the load and deaerator inner pressure as well as between the load and deaerator inner temperature.

b) At present, Priok units 1 and 2 are equipped with two systems each of the make-up water lines, and the make-up water is supplied to a condenser at startups and to a deaerator during operation. Without solely relying on the deaeration by a deaerator, it is effective also to resort to a vacuum deaeration by a condenser. (Refer to figure 3-2-1)

Therefore, addition of make-up water lines for supply to a condenser during the operation should be studied hereafter.

In this case, attention should be paid to the location of a spray nozzle, alike that on the recirculation lines to a condenser mentioned earlier, so that the spraying may be carried out in the condenser.

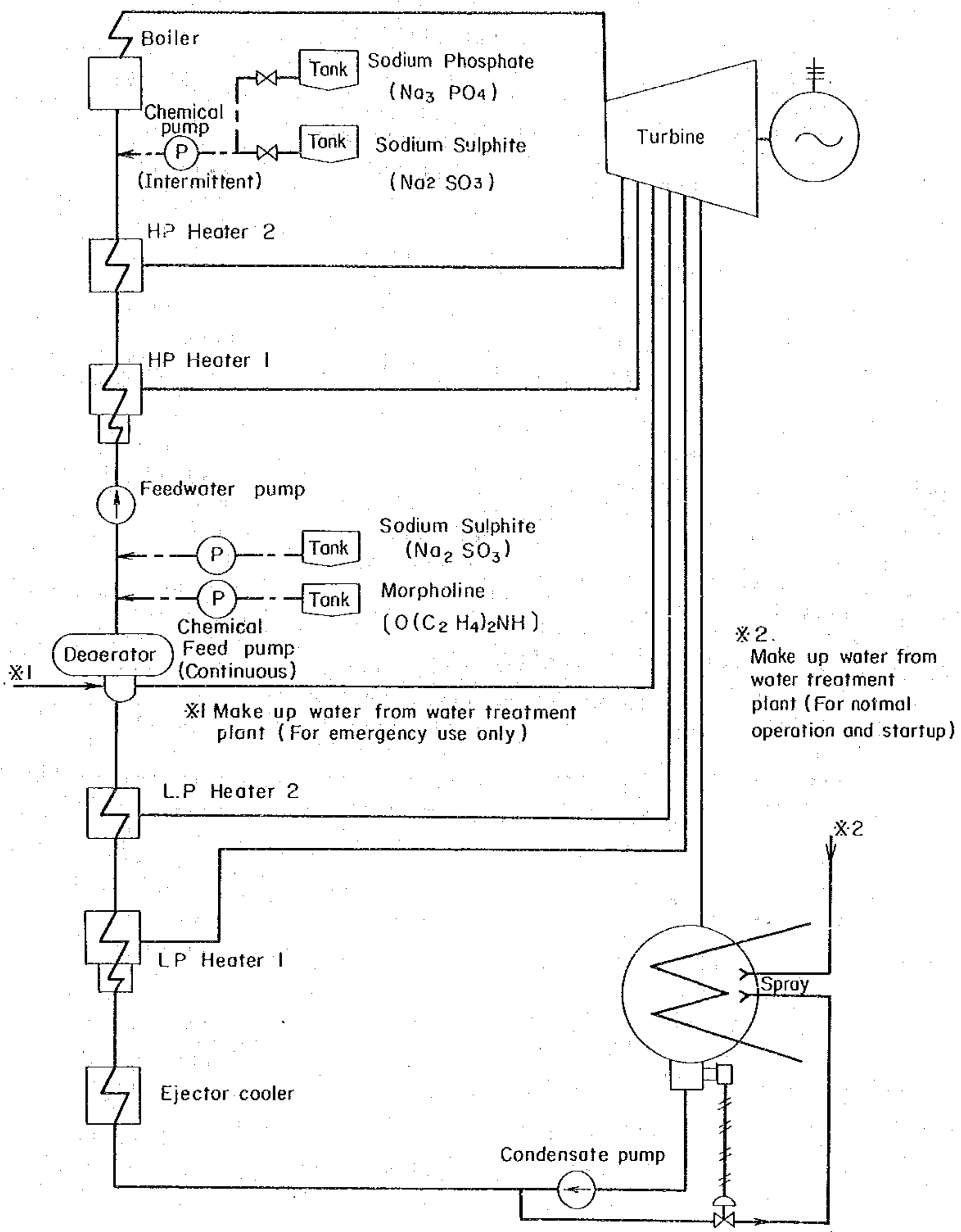
c) As a mere matter of course, it is indispensable that valves of stand-by pumps will be maintained at full-close positions without fail.

Particularly, air leakage to a condenser from a gland-packing of pumps near the condenser like a condensate pump should be strictly prevented.

(i)-c Chemical treatment of dissolved oxygen

a) As stated previously, greater part of dissolved oxygen in a feed-water when a unit is under normal operation is eliminated in the

Fig. 3.2.1 Conceptional Diagram of Chemical Feed System



condenser and deaerator. However, should this elimination be inadequate it extremely effective to continuously inject further deoxygen chemicals (disodium sulfite Na_2SO_3 or hydrazine N_2H_4) at the deaerator outlet. (Refer to Figure 3-2-1)

Quantity of injected deoxygen chemicals shall have around twice as much as that of the dissolved oxygen. However, in case disodium sulfite, it is of vital importance to control the quantity of injection so that dissolved SO_3^{2-} in a boiler water may be kept within 5–10 ppm.

In addition to that, when a large quantity of deoxygen chemicals is injected at startups of a unit (while the boiler is filled with water up to a level) it is effective to inject it into a boiler intermittently (if possible, to inject it directly into a boiler drum).

b) If, for the purpose of the above elimination of oxygen, a capacity of a chemical pump for continuous injection is estimated based on the specification of Priok Units 1 and 2, the capacity of the pump for 5% of disodium sulfite solution, Na_2SO_3, will be around 1.6 l/h for the feedwater quantity of 100 T/h, provided that a value of dissolved oxygen is about 0.05 ppm of a total allowable value.

c) Likewise, a tentative calculation of a capacity of a chemical pump to intermittently inject a large quantity of deoxygen chemicals at the startups of a unit, the capacity of the pump for 5% of disodium sulfite solution, Na_2SO_3, will be about 32 l/h provided that a quantity of about 10 ppm of SO_3^{2-} is injected when the boiler is filled with the water up to a level.

In addition, if this chemical pump can inject chemicals directly into a boiler drum, it is convenient in that, even in the case of preservation in the filling up condition of a boiler water, it is serviceable. When an additional installation of spray nozzles for chemicals is easy, it is more effective to inject chemicals directly into a boiler drum.

(ii) Injection of PH control chemicals

a) In view of preventing corrosion, it is necessary to maintain a PH value to a weak alkalinity ranging from 8.0 to 9.0. Especially, in a cycle for which a steel tube feedwater heater is used, it is desirable to maintain a PH value which is as nearest to the upper limit as possible.

For this purpose, it is popular to continuously inject a PH control chemicals at a deaerator outlet, and morpholine, hydrazine, ammonia, etc. are generally used.

b) Hydrazine is essentially one of the deoxygen chemicals as mentioned above. However, the excess portion is dissolved in the boiler and produces ammonia thus capable of playing a role of a PH control chemical.

In the meantime, when disodium sulfite is continuously injected as one of the deoxygen chemicals for a condensate and feedwater as mentioned above, it is effective to continuously inject morpholine or ammonia at a deaerator outlet as a PH control chemical. (Refer to Figure 3-2-1)

c) Specification of a chemical pump for this purpose may be of the same level as a continuous feed pump of disodium sulfite solution as mentioned above, and its feeding quantity may be adjusted properly so that PH value of the feedwater at a deaerator outlet may be maintained at the specified the value.

Moreover, adoption of pumps with the same capacity gives an interchangeability by which maintenance and handing work will become convenient.

d) In adjusting a PH value of a boiler water, there are two ways of using trisodium phosphate Na_3PO_4 only and using caustic soda NaOH as well. In the former, it is desirable to keep a PH value from 10.0 to 10.5, and in the latter from 10.5 to 11.0.

In both cases, it is effective to inject chemicals intermittently into a boiler with chemical feed pump of a large capacity.

In addition, a capacity of this chemical feed pump is about 30 l/h at 5% of trisodium phosphate solution, Na_3PO_4, provided PO_4^{3-} in a boiler water is boosted to 15 ppm for in about 30 minutes.

As this capacity is almost equal to that of the abovementioned chemical feed pump which is used at start-ups as deoxygen feed pump, the two tanks can be used in common if only a tank equipment is separately provided.

e) Moreover, in the case of using the hydrazine, morpholine, ammonia, etc. as PH control chemicals for a feedwater, specific quantity of injection should be particularly observed as the excessive ammonia may give into corrosions.

f) As actual operating values, PH values of make-up water, feedwater, and condensate water show remarkably low values of 5.5 each. As one of the causes for this malfunction of a degassifier is conceivable (when a degassifier is inferior, removal of CO_2 in a make-up water becomes imperfect, and a PH value lowers). However, it is expects to some question to limit the causes to this.

In consequence, it is necessary to establish an early organization of a specific standards for a water treatment equipment, by contacting the Permutit Company, a manufacturer of this equipment, after checking the PH meters and recent analytical results of raw water quality, actual operating condition of a degassifier, and actual operating condition of a water treatment equipment (mainly, degree of deterioration of ion exchange resin).

g) In addition, although a steam separator is not equipped in a drum, occurrence of carry-over can be avoided by a perforated plate if a feedwater treatment system was strictly implemented and a regular water level of a boiler drum was ensured as mentioned above.

The above statements are our concrete measures for the improvement pertaining to a feedwater treatment. Our recommendations describes only our basic thought on them and therefore for an actual application to a feedwater treatment it will be prerequisite to have to adequate discussions with the Siemens-Mangroup of West Germany, a supplier of the unit, for improvements.

For your information, lists of specific values (the JIS table) for feedwater treatment of Priok units 1 and 2 class units in Japan are shown in the following table.

Table 3-2-1 JIS B 8223 1969's Draft

Specifications of the qualities of boiler feedwater and boiler water are as follows.

	PH 25°C	Hardness $CaPO_3$ ppm	Oils and Fats 3) ppm	Dissolved Oxygen O_2 ppm	M Alkalinity $CaCO_3$ ppm	Total Solids Materials ppm
Feed-water	8.0–9.0	0	Maintained close to 0	0.007 (max.)	-	-
Boiler Water	10.5–11.0 1) 10.0–10.5 2)	-	-	-	-	400 (max.)

	Total Iron Fe ppm	Total Copper Cu ppm	Ion Phosphate PO_4^{3-} ppm	Silica SiO_2 ppm	Ion 4) Sulfite SO_3^{2-} ppm	Hydrazine 5) N_2H_4 ppm
Feed-water	0.05 (max.)	Main-tained low	-	-	-	0.01–0.03
Boiler Water	-	-	5–15	10 (max.)	5-10	

Remarks :
1) Caustic treatment
2) Phosphate treatment
3) n-hexane soluble matter
4) Value when sodium sulfite is added to the boiler water as a deoxygen chemical
5) Value when hydrazine is added to the feedwater as a deoxygen chemical

(3) Technical proposals for Perak units 1 and 2

a. Inservice washing of flash evaporator

(a) Present condition and problems

(i) At the present time, to be used for make-up water, these units are provided respectively with 4.5 T/H capacity flash evaporator feedwater heater unit in their main heat cycles. In recent years, however, plugging of brine heater tubes have become conspicuous because of the reasons including the contamination of sea water. The said flash evaporator feedwater heater units have been subjected for washing, therefore, at an interval of about once in every 3 months.

In order to wash these flash evaporators, they have to be separated from the said heat cycles. As such separation stops the production of make-up water, inservice washing may be done if you wash them at reduced load of turbines.

(ii) Actually, however, there is a noticeable air leakage from accessory piping and valves of these flash evaporator units and trends of condenser vacuum drops are conspicuous. Washing while turbines are in service is, therefore, impossible. For this reason, washing of flash evaporators has been done after shutdowns of units.

Such being the case, if an inservice washing of these flash evaporators becomes possible, it not only results in the saving of startup losses of units but also contributes in ensuring firm capacities of units. We, therefore, decided to study this possibility.

(b) Our proposal in connection with inservice washing

(i) From the data we obtained in connection with these flash evaporators and the results of our field study, what we consider as the causes of air leakage may be itemized as follows.

a) Leakage from extraction steam piping for evaporator heaters

b) Leakage from drain piping for evaporator heaters to evaporator condensers

c) Leakage from brine piping for evaporator heaters to flash chambers

d) Leakage from blow piping for flash chambers and evaporator condensers

Of the above four items, leakage of valves and fittings for extraction steam system on the heating side mentioned under item a) may result in the condenser vacuum drop, irrespective of operation or shutdown of the evaporator.

Special attention is paid to the valves and fittings installed on lines stated under items b) and c) as some of them are positioned on the pressure side during operation of the evaporator and on the vacuum side while the evaporator is shut down.

Leakage from blow valve under item d) is also a point which is liable to be overlooked. It is necessary to check it same as the evaporator heater vent line.

(ii) In checking the abovementioned valves and fittings which are suspectable of air leakage, a method of immersing them in a temporary water box shown on Appendix 3–9 for instance, is effective.

In other words, if you check separately at the rated load and at the reduced load (load at which an inservice washing is possible) of turbines, although there are respective differences in levels, fall of water level will be recognized, should there be any air leakage. After these conditions are confirmed, it is possible to stop the leakage by means of the replacement of packing and tightening of gland for such valves.

Also, as shown on Appendix 3–9, it is deemed effective to newly add isolated valves or adopt water seal valves for large-diameter stop valves on the extraction steam piping system.

(iii) While it is important to prevent air leakage as mentioned above, the basic instruction in the operation of a flash evaporator is to prevent the formation of scales in the brine heat cycle. For this reason, it is necessary to strictly observe the operation at specified values set forth in the operating instruction which is prepared by a manufacturer.

Incidentally, maintaining the brine temperature at the brine heater outlet below 200^{o}F is extremely important for prevention of scale deposit alike the injection of a proper chemical into the make-up stream.

b. Steam temperature drop at superheater outlet

(a) Present condition and problems

The steam temperature at the superheater outlet of boilers was designed at 892^{o}F. On account of conspicuous temperature rise in the period of initial operation, both units curtailed the superheater loops to some extent and installed the spray water systems for steam temperature control.

Such remodellings were successful and troubles did not occur thereafter.

Lately, however, steam temperature at the superheater outlet dropped gradually maybe within the latest one year, to the extent of making it difficult to raise it above 800°F in Boiler No. 1 and above 850°F in Boiler No. 2 in the rated capacities. As such steam temperature drop has greatly to do with the drop of thermal efficiency of the plant, an early improvement is necessary.

(b) Considerations on steam temperature drop at superheater outlet

Based on the latest operational records we obtained and the results of our field study, the following are deemed as causes for the steam temperature drop.

(i) As the steam temperature is measured at the turbine inlet, it indicates the temperature after the spray water valve. Should the spray control valve be shut off incompletely, temperature drop resulting from leakage is expected. Generally, construction of spray control valves makes it difficult to shut them off completely. Granting that there are differences depending upon the kinds of valves, leakage of about 0.001% is unavoidable by nature.

Especially, when a boiler was operated at a light load over a period of time, delivery pressure of boiler feed pump rises.

This creates a great pressure difference between before and after the spray control valve. It is also expected that the position of the valve is near the shut-off point and it is foreseeable that, if the valve gears into foreign materials, etc., erosion may progress.

We cannot ignore such suspicion since the steam temperature has stopped to rise after a certain period.

(ii) Dirtiness of heat transfer surface resulting from incomplete combustion on account of inferior conditions of residual fuel oil burner

When, on account of erosion or plugging of burner tips, inadequate adjustment of air registers, etc., good combustion is not done and much soot was produced, steam temperature at the superheater will be greatly affected, and it is deemed conspicuous for heat transfer surface in this shape of superheaters.

In other words, as superheater tubes are arranged at the furnace outlet in rectangular direction to the gas stream so that they may function as a slag screen, their location is said to be most susceptible to dirts.

Judging from the fact that the steam temperature rises by about 20°F right after the soot blower was placed in service, it is conceivable that the dirtiness of heat transfer surface by soots has been progressing gradually.

Also, this dirtiness is of a nature which cannot be completely eliminated by a soot blower, it is conceivable that the specified value cannot be reached even after the blowing.

This explanation will be inadequate, however, for the phenomenon of the latest occurrences of steam temperature drop.

(iii) Occurrence of carry-over resulting from inferior installation of steam separator inside the boiler drum

For such reasons as the inferior installation of steam separator inside the boiler drum after a scheduled shutdown and the fall of steam separator during operation, if part of the steam bypasses without passing through the steam separator, it is conceivable that the steam temperature at the superheater drops by mixing of water-drops into the superheater.

The said latest superheater temperature drops make us also suspect that the installation of the steam separator after a scheduled shutdown was inadequate. Other than the above and generally speaking, drop in excess air ratio, change in the heat absorption ratio of the boiler heat transfer surface resulting from a rise in the feedwater temperature, scale deposit inside the superheater tubes, etc. are conceivable as the reasons for occurrence of steam temperature drops. Reviewal of operation records, etc., however, makes us determine that these will not be the reasons.

Accordingly, what our reviewal makes us determine is that three items of (i), (ii) and (iii) are possible causes, and that we think more-or-less overlappings of these resulted in the steam temperature drops.

With regard to steam separators mentioned under item (iii), specifically, we recommend that a detail check will be made with boilers which are now shut down for confirmation of their proper or inferior installations.

c. Corrosion of superheater tube

(a) Corrosion of superheater tube

With regard to the analytical result on the superheater tube samples presented from Perak power station and how to interpret the reason for their corrosion, a detailed report has been submitted by Ishikawajima-Harima Heavy Industry Co. (a licensee of Foster Wheeler Corp. of USA) in charge of detailed analysis on the samples. (Refer to Appendix 3–10)

According to this report,

(i) It is estimated that pitting corrosions were not caused by erosions or segregations but by corrosions. In other words, this boiler has been repeatedly shutdown every three months and, during which periods, none of the special measures to protect the boiler such as the nitrogen gas sealing, has been carried out. Such being the case, in horizontal superheater tubes drain might remain and air might enter when laying up the boiler. Due to the above reasons, that rusts start to occur in the tubes and forms a pitting. Furthermore, local circuits are formed between the rusts and the tube body and which has been thought to have grown the pitting.

(ii) As the countermeasures for preventing such corrosions, continuous operation of the boiler is most desirable. However, if it is impossible to do so, the report recommends to take the following measures.

- Drying-up of the boiler ----- (by N_2 gas sealing)
- Filling-up of the boiler with water ---- (addition of hydrazine)
- Addition of hydrazine to the filled-up portion and sealing of other portions by nitrogen gas

Either measure of the above is said to be suitable for anti-corrosion. Judgement of Ishikawajima-Harima Heavy Industry Co. on the above item (i) may be deemed accurate as the result of an estimation based upon the very few pieces of samples presented and the limited explanations which led up to the occurrence of the corrosion.

In the meantime, if this judgement is correct, the undermentioned questions may naturally follow.

If corrosion of a sample is caused by the remaining of drain and encroachment of air, when the boiler is shut down, such phenomenon may not be limitted to the tubes sampled but similar phenomenon may be observed in other tubes as well.

In consequence, it is necessary to continue further scrupulous reviewed of the following points in order to establish the countermeasures for preventing such corrosions.

(b) Items for future investigation

(i) Concerning the confirmation of the locations of superheater tubes and addition of the sample tubes

If the locations of samples presented for analytical tests by Ishikawajima-Harima Heavy Industry Co. at that time were confirmed, and when the locations of this sample exist at the center of the upper portion of the primary superheater loop, progress of corrosion in this zone may be briefly grasped by cutting the tubes at least two pieces on both sides of the sample tube.

(ii) With regard to the lowest superheater tube loop, similarly, where the occurrence of corrosion caused by the remaining of drain during shutdowns of the boiler is foreseeable, it will be generally possible to grasp the condition in this zone by cutting at least three pieces in the same manner which is mentioned above.

(iii) Not only the superheater tubes, the furnace tube where a corrosion is foreseecable, may be almost checked, for example, by sampling tubes near the centers of side and rear walls at about the same level as a burner.

(iv) Generally, in the sampling of these kinds of pieces, the tubes are not partially cut (in circumferential direction), but it is necessary to keep the distinction clear between the upper side and the lower side of tubes as they actually are. As for the length of each piece, it is desirable to cut it for about 500 mm in consideration of the cases of tensile strength tests.

(v) For the moment, corrosion of the superheater tubes, was picked up, by chance, for investigation, collection of information as specific as possible will be necessary regarding the past experiences of leakage caused by tube failures including those of furnace tubes, without limiting the investigation to superheater tube failures only.

In conclusion, it will be necessary to proceed with the reviewal of countermeasures against such failures, keeping in touch with Foster Wheeler Corp. of USA, manufacturer of this boiler, by collecting the samplings mentioned above and the information for the past accidents.

We should like to recommend the establishment of measures for interpretation of the basic reasons for failures which are mentioned above.

d. Preservation method of boilers for using their shutdown for a long period of time

(a) Corrosion of superheater tube and preservation method of a boiler

If the cause of corrosion of the superheater tubes at Perak power station is from remaining of drain and encroachment of air into a boiler under shutdowns as mentioned above, the anticorrosion countermeasures for a boiler under shutdowns should be established.

In the meantime, from the standpoints of daily operation and maintenance as well as of saving the operation cost, the anticorrosion countermeasures for a boiler under shutdowns must be one of the subjects which we cannot overlook.

This means that, no matter how suitable feedwater treatment may be done for a boiler during normal plant operation, occurrence of rust inside a boiler is unavoidable whenever the feedwater treatment is improper during the shutdown periods and also that the preservation method of a boiler during shutdown for a long period of time in the cases of the periodical inspections, repair works, scheduled shutdowns, etc. may become an important factor from the viewpoints of plant operation and maintenance.

In consequence, we decided to recommend herein the preservation method of a boiler for a long shutdown period of time applicable to Perak units 1 and 2. On the other hand, because this method is also applicable to other plants (for example, Priok units 1 and 2), we wish to recommend to proceed with the respective reviewals, taking into consideration the operating condition of the plant, difficulties of purchasing chemicals, etc.

(b) Classification of preservation methods of a boiler for a long shutdown period of time

In shutting down a boiler for a long period of time in excess of ten days to about three months due to the periodical inspections, repair works, scheduled shutdowns, etc. of the plant, there is no other way but to rely on the full-up condition or the dry-up condition.

(i) Preservation method in the filling up condition of a boiler water

As a typical method for this, we have some chemical injection methods. This means that generally the hydrazine, sodium sulfite and trisodium phosphate, vapor phase antirust chemicals and fluid mixing sodium nitrite, etc. with another proper chemicals. In case of simultaneous preservation of the entirety of a boiler including a boiler itself and superheater, etc., the methods using hydrazine and vapor phase anti-rust chemicals are suitable, and in cases of preserving only a boiler itself, the sodium sulfite trisodium phosphate, and fluid mixing sodium nitrite is optimum are suited to.

a) Hydrazine method N_2H_4

After fully blowing out a boiler, the entirety of a boiler including a boiler itself and a superheater shall be preserved, under the filling up condition of a boiler water, with a demineralized water 50 - 100 ppm injection of hydrazine into it.

b) Method using sodium sulfite Na_2SO_3 and trisodium phosphate Na_3PO_4 jointly

After the fully blowing out a boiler, only a boiler itself shall be preserved, by the filling up condition of a boiler water, with a demineralized water injecting 10 - 20 ppm sodium sulfite and trisodium phosphate each into it. In this case, that influx of boiler water into a superheater should be prevented. In addition, when nitrogen gas is sealed in a vapor phase portion of a superheater, it is more effective.

c) Vapor phase anti-rust chemical method

After fully blowing out a boiler, the entirety of a boiler including a boiler itself and a superheater shall be preserved with a demineralized water including 0.05 - 0.1% vapor phase anti-rust chemicals.

d) Fluid mixing sodium nitrite method

After fully blowing out a boiler, only a boiler itself shall be preserved with a demineralized water including 0.25% of sodium nitrite $NaNO_2$, 0.12% of disodium phosphate Na_2HPO_4 and 0.12% of monosodium phosphate NaH_2PO_4.

Of the above methods, preservation methods under items a and b are popular, and actual results on items c and d are very rare.

(ii) Preservation method of a boiler in the dry-up condition

As to preservation method of a boiler in the dry-up condition, we have a method sealed by a nitrogen gas, anticorrosion membrane method, etc. In the case of a drumless boiler such as a once-through boiler, the method sealed by a nitrogen gas is suited to be adopted as a recent tendency is becoming popular. However, the anticorrosion membrane method is rarely used.

a) Nitrogen gas sealing method

After fully blowing out a boiler, it shall be closely preserved at more than 0.3 Kg/cm^2g of nitrogen gas pressure pressurizing nitrogen gas into a boiler.

When a large quantity of leakage occurs, a boiler has not only a large quantity of nitrogen gas consumption but also is accompanied with the installation of nitrogen gas sealing equipment, piping, and injection nozzles as well as with the complexity in handling them.

b) Anticorrosion membrane method

In conformity with the foregoing item i-c, vapor phase anti-rust chemical method, and the item i-d, fluid mixing sodium nitrite method, for a boiler in the filling up condition, water was fully filled up in a boiler for more than three hours and then after making an anticorrosion membrane, a boiler shall be preserved by fully blowing out.

(c) Application of this method to Perak units 1 and 2

(i) In consideration of the steam condition, construction, and other various conditions of a boiler at Perak units 1 and 2, preservation methods for a long period after shutting down a boiler as well as our experience in the past as mentioned above, we judged that the preservation method of the entirety of a boiler by using hydrazine stated in the previous item is optimum.

However, in actually applying these methods instantly to Perak units 1 and 2, there are lots of problems necessary to be solved. Accordingly, we wish to recommend to proceed with a reviewed of the above application solving such problems in the meantime.

This is because not only the cause of superheater tube corrosion solved yet, and a large quantity of demineralized water has to be ensured for replacement by the demineralized water after fully blowing out a boiler in the case of adoption of hydrazine method, but also problems including the prospect for purchasing chemicals remain to be further investigated.

In consequence, as a countermeasures for settlement of the problems at this moment, it will be also necessary to checked from the standpoint of feedwater treatment whether the cause of superheater tube corrosion is due to the air leakage from pipings and valves around a boiler drum.

(ii) As one of these methods, accurately measure the valves of PH, PO_4^{3-} and SO_3^{2-}, conductivity, etc. install a small-capacity head tank at the top of the drum (quantity of water which fully fills-up the space at the top of boiler drum), fills up the boiler drum by injection of demineralized water through an air vent valve. In this case, a boiler water should be prevented from running into a superheater.

Thereafter, it will be possible to judge whether the encroaching of air into a boiler drum from a vapour phase portion at the top of the drum (for instance, from drum vents, fitting of level gauge, and other valves) by means of measurement of boiler water quality every week and compare them with values prior to the filling-up condition of a boiler water.

(iii) In general, a boiler water of Perak units 1 and 2 class units under shutdowns should be preserved in an enriched condition as compared with standard values as shown in the list below.

Table 3-2-2 Specified value of boiler water during filling-up condition of a boiler

PH	10.5 - 11.0
PO_4 ppm	10 - 20
SO_3 ppm	10 - 20

According to our experiences, whenever the sealing for respective parts of a boiler itself is perfect, the above values should hardly vary. Even if there is some leakage, a PH value scarcely varies and a slight amount of SO_3^{2-} lowers only. Accordingly, it is possible to ensure the above standard values by supplying around 5 - 10 ppm SO_3^{2-} for ten days at the most.

(iv) In fully filling the water of a boiler dependent upon the above-mentioned preserved water quality, checking of air encroaching into a superheater will become possible. This also means that, prior to a shutdown of a boiler now under operation, inject disodium sulfite and trisodium phosphate into a boiler drum so that they may reach the above-mentioned value of preserved water quality, and fully fill up the boiler itself with water. (Utilizing the residual pressure, aim at a uniform mixture of chemicals.)

For doing this, confirm the filling-up condition of a boiler water can be confirmed by the above-mentioned overflow from the air vent after watching the water level up to the top of the level gauge of a boiler drum.

Thereafter, checking of the water quality once a week and its comparison with those of other units under cold conditions will enable the checking of the encroachment of the air into the superheater.

Also when a boiler was preserved under such a highly-enriched condition, it is necessary, prior to the restart-up of a boiler, to light off the boiler by lowering the water quality value to a normal value by blowing out of a large quantity of boiler water.

(v) In our recommendation mentioned above, our basic thinking for a preservation method of a boiler is described.

In this connection, we supposed it will be necessary, to specifically implement the recommendation, after an advanced confirmation of the intentions of Foster Wheeler Corporation.

3-2-3 Choice of Fuel for a Gas Turbine

(1) Concerning the gas turbine firing the residual oil

In general, gas turbines have excellent features as follows.

- Only a small construction space is adequate because of their original light weights and small sizes.
- They are relatively low in cost and construction period is also short.
- It is possible to quickly start them up and shut them down.
- Only a small amount of cooling water is necessary.
- Operational practice is simple and automation is easy to accomplish.

Based upon these features, the gas turbine as a prime mover for plant has been adopted recently for the forced transmittance of the gas, pressurization of the oil pressure transmittance of the crude oil, chemical industries, and blast furnace draft fans, etc. After the running performance was proved, an enormous quantity of gas turbines was manufactured, and they are also widely used in an electric enterprise for handling a peak load and as an emergency power source. As of the end of 1968, approximately 4,600 gas turbines of more than 1000 HP (with the exception of all nations belonging to the communist circle) were already manufactured all over the world.

If such enormous number of gas turbine units are classified by the fuels used for them, good quality fuels such as the natural gas, naphtha and light distillate oil occupy an overwhelming majority, and on the other hand, the residual oil firing units are not enough and account for only 5%.

This fact means that the above-mentioned various features can be completely satisfied so far as good quality fuels such as the above-mentioned are used for gas turbines. It can be seen that lots of problems exist in using the crude oil or the residual oil, and this fact means that not so much time has passed since we entered the age of establishing a technical innovation and operational technique.

In an electric enterprise, the development to make steam power station units large in capacities and high in efficiencies is low advancing rapidly based upon the technical development of power generating equipment in residual oil firing steam power stations even if the improvement of plant thermal efficiency is not attempted by heat recovery of the flue gas and the process steam of equipment like the use of gas turbine in general plants for industrial enterprises. Such being the case, gas turbines are turned to advantage for peak loads or emergencies, making the best use of typical features such as the quick start-up and simplified operation rather than the thermic economical veiwpoint, and also the adoption of quality fuels is becoming the general trend.

In an area where natural gas and light distillate oil are easily obtainable at low cost, there is no problem. As for an area where it is desirable to specially use the residual oil including the crude oil for economical reasons, it will be attractive to install the residual oil firing gas turbines.

In general, in the cases of gas turbine plants, main components such as turbine blades and so on are structurally directly exposed to the high temperature firing gas in the process of thermodynamic cycle in comparison with ordinary steam power generating plants. Accordingly, in using the residual oil including poisonous components which brings about high temperature corrosions in these main elements while the gas is fired, it is necessary to establish the countermeasures especially to prevent the gas is fired, it is necessary to establish the countermeasures especially to prevent corrosions in comparison with the cases in which good quality fuels are used.

And then, various inorganic and metallic organic matters included in the residual oil generate varied oxides (V_2O_5, PbO, Na_2O) and sulfides (NiS, SnS) after firing the residual oil. The melting points of ashes of these inorganic and metallic organic matters are relatively low in temperature at each component. The above-mentioned low melting points of the eutectic components with which these matters are mixed at a definite rate which is further lower and lower than the turbine inlet temperature of gas turbines. Accordingly, these eutectic components are run into the turbines at completely or half-solved conditions resulting in the deposition to the driving and stationary blades of the turbines.

If the deposition of ashes in the residual oil to the turbine nozzles and blades goes on, it is anticipated that corrosions of the turbine nozzles and blades will appear before long owing to the deteriorated performances of turbines such as the turbine output and thermal efficiency and also because of the local heatings at the turbine nozzles and blades.

In consequence, in the residual oil firing gas turbines, if the deposition of ashes to the turbine nozzles and blades occurs, it will be unavoidable to clean the turbine nozzles and blades by means of shutting the turbines down after a lapse of certain period.

(2) Problems on gas turbines firing the residual oil and its countermeasures

Various problems pertaining to the deposition of residual oil ashes to the turbine nozzles and blades and corrosions occurring exclusively to the residual oil firing gas turbines cover a wide range from the fuel components to design and manufacture of equipment as well as the operation and maintenance as the categories of reviewal points. Under the circumstances, unless the theoretical analyses are integrated with lots of operational experiences, it may be difficult to make the whole aspect clear and also gas turbines may still have to remain on the stage of examination and study.

Integration of the problems interpreted by gas turbine manufacturers as real ones and development of countermeasures for settling them from technical viewpoints boil down to the following.

a. To restrict the production of dissolved ash contents by lowering the turbine inlet gas temperature

In the use of the residual oil gas turbines, gas temperature at the turbine inlet is low in comparison with the actual cases of using good quality fuels such as natural gas and light distillate oil. It is possible to reduce the absolute quantity of the deposition of ash to the turbine nozzles and blades by either reducing the generation of dissolved ash contents in advance or by converting into an ash with low adhesion in the state of a solid.

In particular, in the case of the design belonging to European line manufacturers (BBC and Toshiba), the policy to lower the turbine inlet temperature to provide a more restriction in accordance with the property of the fuel used is applied upon actual operating experiences on the residual oil firing gas turbines (about 40 units) already developed and manufactured so far.

b. To make poisonous components reduce in advance by procuring the oil with low contents of ash, V (vanadium), and Na (sodium) through careful specification of fuel

Ash and metallic contents in the crude oil or the residual oil vary in accordance with the place of production of the crude oil, the refining process of the petroleum, and the transportation method, etc. However, so long as it is permissible in prices, it is desirable to purchase the oil with less ash contents.

Especially, the contents of V and Na must be taken care of because they are metallic matters with closer relationship with the ash deposition and corrosion than any other matters, and in the case of V_2O_5 and Na_2O or Na_2SO_4, a trend that melting points vary is becoming popular due to their proportional rates in ash contents. Accordingly, it will be inevitable to take also the proportional rates of V and Na into consideration.

As the result, gas turbine manufacturers set up considerably rigid criteria on the choice of fuel with their own recommendations to purchase the qualified fuel to the specification or to make it suitable with the specification through the prearrangement.

One example for these standardized specification is shown in Table 1.

c. To eliminate the sodium base in advance through washing of fuel

When V and Na playing a main role in the ash deposition and corrosions are eliminated from the residual oil in advance, it will be most effective in lessening the troubles caused by the ash deposition.

Paying a special attention to the water solubility of the Na base, measures for Na elimination are recommended by manufacturers. With the existing techniques, it is possible to reduce the Na of 50 - 60 ppm included in the residual oil to about 2 - 5 ppm by means of the equipment recommended by manufac-

Table 3-2-3 Fuel Oil Criteria for Hitachi and GE Gas Turbine (GEZ-3249A)

			Unit	Testing Method JIS (ASTM)	Light Distillate Oil	Naphtha	Diesel Oil	Heavy Distillate Oil	Crude Oil & Bottom Oil	Remarks
Physical Property	Viscosity (100°F)		Centistorks	JIS K 2283 (D 445)	1.8-5.8	0.5 - 5.8	1.8 - 5.8	> 1.8	→	* 1
Physical Property	Pour Point		°F	K 2269 (D 97)	< 0°F	→	→	-		Actual temp. of 20°F + pour point
Physical Property	Carbon Residue		%	K 2270 (D 524)	< 0.25 10% RESIDUUM	→	→			Distilled amount of 98% (D86)
Physical Property	Peat		% (Volume)	K 2275 (D 1796)	* 2 < 0.1	→	→	< 1.0 *3	→	
Physical Property	Thermic Stability			(D 1661)	No.1 TUBE	→	→	No.1 TUBE(>Z10F) No.2 TUBE	→	
Physical Property	Flashing Point				-	-	-	-	-	
Physical Property	Specific Gravity			-	-	-	-	-	-	
Physical Property	Mixing Stability			(D 1661)	-	-	-	No.2 TUBE OR BETTER		
Physical Property	Cetane Number			K 2271 (D 613)	-	-	> 40	-	-	JIS 2204-57 (D 975)
Chemical Property	Ash		PPM	K 2272 (D 482)	< 100 PPM	→	→	< 300 PPM	-	
Chemical Property	Metallic Components	Vanadium	PPM	(D 1548)	< 2 PPM	→	→	→	< 500 PPM	
Chemical Property	Metallic Components	Calcium	PPM		< 10 PPM	→	→	→	→	
Chemical Property	Metallic Components	Lead	PPM		< 5 PPM	→	→	→	→	
Chemical Property	Metallic Components	Sodium + Potassium			< 5 PPM	→	→	→	< 10 PPM (V > 30 PPM) < 5 PPM (V < 30 PPM)	
Chemical Property	Metallic Components	Mg/V			-	-	-	-	3.0<Mg/V<3.5	
Chemical Property	Sulfur			JIS K 2263 (D 129)	-	-	-	-	-	When equipped with exhaust gas collection equipment of 0.5%

Note 1. Viscosity at fuel nozzle 10 Centistorks (Non air injection nozzle)
20 Centistorks (High pressure air injection nozzle)

Note 2. Solid matter 4 mg/100 ml
Note 3. Solid matter 40 mg/100 ml
Note 4. Testing measures in parentheses indicate the criteria equivalent to ASTM

turers, and it will also be effective to control the production of eutectic ash at low melting points for which the proportions of Na and V vary broadly.

On the other hand, it is impossible to eliminate metallic organic matters and V included in the residual oil by washing. However, it is considered that V contents can be lessened by using another method. In this case, economics by using the residual oil will be probably lost because of an extremely high cost to be involved.

d. To lessen the ash deposition by raising the melting point of generated ash by way of putting the additives in it

It has been already testified by lots of operational results to lessen the quantities of ash deposition to gas turbines by putting the additives to fuels and raising the melting points of the productions after firing the fuels and converting the ash into inactivated grain.

In the fuel additives, there are main components of salt and oxides such as Ca, Mg, Si, and Al. They are respectively considered to be effective in producing ashes of high melting points.

In these cases, there may be some defects of making the ash deposition increased rather than decreased, unless a suitable amount of additives is maintained because the additives are fundamentally a sort of ash contents.

In consequence, it is desirable to allocate the amount of additives through the careful investigations with additive and turbine manufacturers after clarifying the fundamental constitution of ash contents on the fuels used.

As the ash contents and the constitution of ash included in the fuels are, needless to say, generally indefinite, the fuel administration for turbines under operation will be one of the indispensable factors for maintaining a good operation of gas turbines.

e. To scale off the ash deposition from turbines by water washing

So long as the residual oil is used, even if the above-mentioned various countermeasures are applied, it may be still impossible to eliminate the ash deposition. Such being the case, when the deterioration of turbine performance due to the ash deposition (deterioration of turbine output and thermal efficiency) exceeded a permissible limit after a certain period of operation, it will be usually necessary to scale off the ash sticked to the turbines by water washing at the time of the turbine shut-down.

Manufacturers attach importance to this point, resulting in some actual examples of providing a water washing equipment inside the turbine to make the water washing feasible as well as to make a combustor independent from the turbine so as to facilitate the overhauling of the turbine. The outdoor equipment of package type are not proper to the residual oil firing gas turbines and, accordingly, it seems to be a desirable design that gas turbines are installed in the turbine room equipped with an overhead crane which makes the water washing and overhauling of the turbines feasible.

f. To promote resisting of oxidation and reinforcing of anti-corrosion materials

A series of countermeasures for reducing the ash deposition as above-mentioned are respectively related to anti-corrosion countermeasures for important parts of the turbines. However, each manufacturer is developing its unique design or material in manufacturing the important parts of the turbines. In other words, in the residual oil firing gas turbines, there are a lots of factors and confused elements relating to the ash deposition and corrosion, other than the chemical constitution of ash contents of the residual oil, including the turbine nozzle and blade materials, construction of fuel injection valves and combustors, turbine inlet temperature and pressure, flow speed of fuel, and how to take the cooling air. In consequence, each manufacturer is still grappling with the development of the optimum design and materials.

For example, concerning the turbine nozzle and blade materials, some manufacturer is developing the treatment to chromize the surface of the turbine nozzle and blade materials (mainly, 1st and 2nd stages) so as to improve the anti-corrosion characteristics for the heat resisting steel caused by the residual oil firing as well as to increase the combustion characteristics in accordance with the increase of atomizing energy by converting the type of combustor to a pressurized air injection system.

The above, however, are the outline of the problems on residual oil firing gas turbines developed so far and testified under operational results by gas turbine manufacturers. These are respective countermeasures in gas turbines aiming at the residual oil firing from the beginning.

Accordingly, when the existing gas turbines, now being manufactured and operated with their duties of using a good quality fuel such as the natural gas or the light distillate oil, are modified to the residual oil gas turbines, it will be necessary to further investigate the above-mentioned problems and other relative items from a separate viewpoint.

(3) Application of the residual oil firing to the Semarang gas turbine

The Semarang gas turbine is made by and delivered from AEG Company of West Germany (affiliated with GE Company of USA same as the Hitachi, Ltd. of Japan) with the capacity of 12 MW, and also one of the important power sources in the central Java area at present as a peak load power station.

Extension of the annual running hours of the power station is fully anticipated in accordance with the future power demand increase in the central Java area. However, as the fuels now being used are the quality light distillate oil and so on, and as the fuel cost is also higher than that of the residual oil firing steam power stations, these factors result in the further increase in the fuel cost, compared with that of the residual oil firing steam power stations, in proportion to the increase of energy production.

In this connection, the standard fuel unit price for power generation in Indonesia in 1968 is 12.5 RP/l in the high speed diesel oil (now being used at Semarang and abbreviated as H.S.D.), 6.5 RP/l in the island diesel oil (now being used for the low speed diesel engine), and 5 RP/l in the residual oil. In the Semarang gas turbine, the fuel as much as twice and half in the unit price of the residual oil is now being used.

In consequence, provided that, instead of the HSD, it is possible to use the IDO or the residual oil, it will be needless to say that the merit in thermal economy must be remarkably revised toward the desirable direction.

From such a viewpoint, we hereon tried to discuss briefly various problems in anticipation of the betterment and addition of the equipment in order to make it possible to use the residual oil for the Semarang gas turbine based upon the latest actual practice on the gas turbines of Japan and USA although this discussion may be considerably audacious.

a. Concerning the choice of fuel to be used

The standard specification on the thermal power generating fuel now being used is as follows.

Table 3-2-4 Fuel Analysis

HSD	Cetane Number		60
	Kinematic Viscosity - 100°F	cS	45
	Pour Point	°F (°C)	55 (12.8°C)
	Sulphur	%Wt.	0.04
	Conradson Carbon-residual	%Wt.	0.01

	Water Content	%vol.	Max. 0.05
	Sediment	%Wt.	0.01
	Ash	%Wt.	Nil
	Flash Point P.M. cc	^{o}F (^{o}C)	Min. 200 (93^{o}C)
	Calorific Value (gross)	KCal/Kg	10,870
IDO	Specific Gravity	Kg/L	0.85 – 0.88
	Flash Point	^{o}F	200 - 240 (93 - 116^{o}C)
	Sulphur	%Wt.	0.10
	Conradson Carbon residual	%Wt.	0.01 - 0.30
	Viscosity RI - 100^{o}F	Sec.	43
	Pour Point	^{o}F	65 (18.3^{o}C)
	Water	%vol.	0.10
	Sediment	%Wt.	0.02
	Ash	%Wt.	trace
	V. Ca. Pb. Na + K	ppm	----------
Residual Oil	Specific Gravity	Kg/L	0.92 - 0.93
	Viscosity RI - 100^{o}F	Sec.	400 - 700
	Flash Point P.M. cc	^{o}F	160 - 200 (71 - 93^{o}C)
	Sulphur	%Wt.	0.15
	Pour Point	^{o}F	Max. 80 (26.7^{o}C)
	Water	%vol.	0.15
	Sediment	%Wt.	0.03
	Hot Filteration Test	%Wt.	0.10
	Ash	%Wt.	0.02
	V	ppm	less than 2
	Ca	ppm	---------
	Pb	ppm	---------
	Na	ppm	$\pm$ 50

Comparing the fuel specification recommended by Hitachi and GE in Table 1 illustrated earlier with that in Table 2, the HSD is approximately equal to the light distillate oil or the diesel oil except for the pour points and metallic contents, and the IDO shows the characteristic close to the heavy distillate oil except for the pour points and metallic contents same as the HSD. In the case of the residual oil, it is impossible to make comparison because of the uncertainty of metallic contents.

However, in consideration of lots of actual results that, in general, the crude oil produced in Indonesia has extremely less vanadium contents compared with the vanadium contents of the crude oil produced in the Far and Middle East Areas, we presumed that, concerning the V and Na contents included in the IDO and the residual oil, V is 2 ppm or less and Na is 5 ppm or less in the former, and also V is 10 ppm or less and Na is 40 ppm or less in the latter.

In the case of the above-mentioned residual oil, as recommended by Hitachi and GE, it will be necessary to eliminate sodium (Na) and to inject the additives such as Mg (OH_2) and so on through the pretreatment equipment.

Moreover, the IDO is, as mentioned above, presumed as a sort of oil belonging to the heavy distillate oil. As a matter of fact, the IDO belongs to just an intermediate between a good quality fuel such as the light distillate oil and the residual oil. Accordingly, the metallic contents can be presumed a little, however it should be not optimistic of quality. In Japan, moreover, oil equivalent to the IDO is so-called "A Residual Oil" and also is qualified as a sort of the residual oil.

b. Revision of fuel supply system

For the fuel supply system of the existing Semarang gas turbine, it is expected that the non-air atomizing system suitable for the HSD now being used is to be adopted. Accordingly, in the cases of using the IDO and the residual oil, it is necessary to revise it to a fuel supply system suitable for respective characteristics.

Generally speaking, in the case of using the heavy distillate and residual oil, GE Company adopts the practice to increase the atomizing energy by blowing a higher pressurized air to the combustor nozzle than the light distillate oil so as to improve the combustion characteristics, and in the case of the IDO, it is a general trend to adopt the low pressure air atomizing system for the IDO and the high pressure air atomizing system for the residual oil.

Due to this, in the case of using the IDO, it will be necessary to revise or add the fuel supply system as follows. (Reference is made to the Appendices I, II-A and II-B concerning the fuel supply system drawing to be revised hereafter.)

(a) For the use of the IDO

(i) Equipment requiring additional installation

- Air compressor for atomizing

  This unit, which compresses part of the discharge air from the main compressor to the pressure necessary for atomizing the fuel, is driven by an accessory gear and this makes it necessary to remodel the accessories. Meanwhile, the power required here is approximately 100 KW, by which quantity the output of the main turbine is to be reduced.

- Atomizing air compressor (motor driven) for starting

- Precooler

  This unit is for cooling the discharge air of the main compressor which requires an additional supply of approximately 50 T/H of cooling water.

- Others

  Snubber, air cleaner, and piping systems

(ii) Equipment requiring remodelling or replacement

- Accessory gear

- Fuel nozzle

  Replace by one for low pressure atomizing

- Turbine shell

  Refabricate the casing to provide an air outlet for spraying

- Package

  Partial remodelling of those of the additional equipment which will be housed into the package

(b) For the use of the residual oil

(i) Equipment requiring additional installation

As in the case of the IDO, addition of an atomizing air system becomes necessary and, moreover, the following units have to be added for the main turbine system:

- Hydromotor

  A hydraulic motor to drive the flow divider

- Hydrocontrol pump

  Designed to supply the hydromotor with the working oil

- By-pass valve and others

  A valve to by-pass any excess in the fuel flow from the fuel pump This operates in gear with the control pump

- Fuel pretreatment system

  A complete system of the residual oil water washing and additive injectors

(ii) Equipment requiring remodelling or replacement

In addition to the same remodelling as for the use of the IDO, the following items require remodelling or replacement:

- Fuel pump

  The fuel pump, which is driven by an accessory gear, has to be replaced by a constant-volume pump due to the change in the fuel control system.

- Flow divider

- Combustor liner

Besides, it is preferable either to replace the first-stage nozzle of the turbine by a nozzle of the highly corrosion-resistant materials or to provide chromizing, but we have decided to avoid remodelling here because it is only a short time since this turbine has been placed into service.

While the foregoing are the main considerations in remodelling into the residual oil firing system, the remodelling plan practically involves a steam source (auxiliary boiler) for the heating of oil and clean water in the residual oil pretreatment system, a source of cooling water for the after-coolers on the compressor discharge side, a turbine washing water source, a filtration sedimentation tank (waste water must be precipitated and filtered in this tank before being released into the neighbouring rivers. Otherwise, pollution of the rivers occurs) for the waste oil discharged from the residual oil pretreatment system, etc. Our investigation results suggest that this residual oil pretreatment system will necessitate a site of about 600 sqaure meters as an independent building space.

In this case of the IDO, it is essential to secure the required water supply sources since we have assumed that the pretreatment system is not necessary.

c. Performance of the gas turbine after addition or improvement of equipment

It is difficult to forecast how the turbine will perform after the additional installation and remodelling of equipment as mentioned before, but if the specifications of fuel were as estimated (particularly for the total metal contents of V and Na, and for the ash content), if our proposals were accepted by the manufacturers, and if a satisfactory operation control was practised, the turbine performance will be generally as stated below.

Namely, the gas temperature at the turbine inlet, which constitutes a basis for determination of the output and thermal efficiency, ought to be selected by the opinion of the manufacturers in charge of the remodelling, but in the case of the IDO operation, it will probably be possible at about the same inlet temperature as its current level because the content of metals in the ash is extremely small.

Consequently, compared with the existing fuel of the gas turbine, the result will be an output decrease of about 100 KW in power because of the changeover to the air atomizing system and a tendency of output reduction due to the increased deposition of ash.

Since the residual oil logically requires the reduction of the turbine inlet temperature, the inevitable result will be a decline of 15 to 20 percent in the output and also of 5 to 10 percent in the thermal efficiency as compared with the existing turbine.

d. Problems on the operation and maintenance of the turbine

Even if the working fuel is changed, there is no change in the fundamental procedure of the maintenance and inspection in ordinary turbine operation and inspection on a priority basis is indispensable as to the load, exhaust temperature, vibration, fuel flow, pressure, etc. In the case of the IDO and residual oil firing, furthermore, particular attention must be paid to elaborate the operation control of heavy oil treatment apparatus and to inspect the combustor body with the turbine held at rest. From these inspection results, it is necessary to determine a proper checking interval, parts replacement period, etc.

Especially because the starting frequency, load variation, and operation and maintenance greatly affect the life of equipment, it will be necessary to operate the turbine after fully studying the running results against the standard interval of inspection and standard life of parts proposed by the manufacturers.

Table 3-2-5 shows a standard inspection interval in the case of the residual oil firing proposed by the GE.

Table 3-2-5 Standard Inspection Interval for a Residual Oil Firing Turbine

Starting Frequency for Every 1000 Hrs	Combustor	Turbine	Overall Inspection
1	2,000	4,000	11,000

The IDO, compared with the residual oil, gives full promise of a longer inspection interval.

It should be noted, however, that the above table is nothing but a general guide, and practically elements are also involved which are hard to identify. For example, the possibility could not be totally ignored that the blades of the air compressor will be contaminated by pollution on the suction air side – an element other than the working fuel – to produce a marked decline in output.

Therefore, the above-listed conditions should be fully studied before determination of the most suitable period of time for which uninterrupted operation is feasible. As a guide in this case, it will be useful to keep the output decline at 3 to 5 percent.

For the service life of principal turbine parts, meanwhile, GE shows standards as tabulated below, which are similar to the above. It will be necessary to have all of these secured as the materials to be covered by the annual costs of operation, maintenance and repair, and in addition to hold a general line of principal parts ready right from the outset to provide against an emergency.

Table 3-2-6 Table of Standard Service Life in the Residual Oil Firing

Starting Frequency Every 1,000 hrs.	Combustor Liner	Combustor Transition Zone	1st Stage Nozzle	1st Stage Blade	2nd Stage Nozzle	2nd Stage Blade
1	10,000	10,000	22,000	44,000	24,000	55,000
100	2,500	2,500	17,000	34,000	16,000	42,500

e. Noteworthy items

The foregoing are our accounts of what would result from convertion of the Semarang gas turbine to the residual oil firing, but all of these have been derived from consultations with the latest practices of the GE, or of Japanese gas turbine manufacturers, so that actual remodelling may encounter cases to which they do not apply. This is because we have little information on hand concerning the detailed design of the Semarang gas turbine, and also because we hold the basic policy that anything which fundamentally affects the performance of the unit, as this remodelling plan will, should first of all fully introduce the opinions of the AEG, manufacturer of the turbine in question. Accordingly, you should, if necessary, have a remodelling plan furnished by the AEG.

Especially, a number of remodelling problems may occur in connection with the equipment which involves fast advancing factors of technical renovation, including the design of combustors, the design of principal parts in the turbine body, and the design of heavy oil pretreatment equipment.

f. Economic evaluation

The power generation cost obtainable from remodelling and expanding the Semarang gas turbine on the basis of general specifications so as to permit the firing of the IDO or the residual oil as stated in the preceding section has been evaluated for economics by comparison with the generation cost of the existing turbine, the result being given in a separate table.

The main items considered in making the economic comparison are as follows:

(a) Gas turbine output

Based on the rated output (12,250 KW) of the existing gas turbine, we estimated that the IDO would permit generation of an almost equal output or 12,000 KW and the residual oil 10,000 KW. Using the utilization rate of these outputs as a parameter, we decided to calculate on a trial basis the annual quantities of generation for comparison of the generation costs per

KWH at the end of the generators.

(b) Construction cost and capital cost

In addition to the construction cost of the existing gas turbine estimated at 650,000 x 10^3 rupees, we allowed for 40,000 x 10^3 rupees as the extra cost of equipment remodelling and expansion for the IDO and likewise 130,000 x 10^3 rupees as the extra cost for the residual oil, to calculate the annual capital cost. In this case, the total of interest payment, personnel expenses, and other costs were estimated uniformly at an annual 14 percent of the construction cost, treating it as a fixed expenditure.

(c) Repair cost

The reapir cost was estimated at an annual 1 percent of the construction cost for the existing gas turbine firing HSD; 1.5 percent of the same in the case of the IDO firing; and 2.5 percent in the case of residual oil firing. On this basis, reduce the repair cost with a decline in the utilization rate. (Refer to Appendix 3-13)

(d) Fuel cost

On the basis of the fuel specifications shown in Table 3-2-4, the fuel cost was calculated, adding some presumptions.

(i) For the HSD

The cost was reckoned at 5.38 Rp/kwh from the unit cost of 12.5 Rp/l , calorific value (LHV) of 10,250 Kcal/kg, turbine heat consumption of 3,660 Kcal/kwh (23.5%).

(ii) For the IDO

In like manner, the cost was reckoned at 2.68 Rp/kwh from the unit price of 6.5 Rp/l , calorific value (LHV) of 10,250 Kcal/kg, turbine heat consumption of 3,660 Kcal/kwh, and fuel treatment cost (after-cooler cooling water, turbine washing water, auxiliary power, etc.) of 0.03 Rp per kg of the IDO.

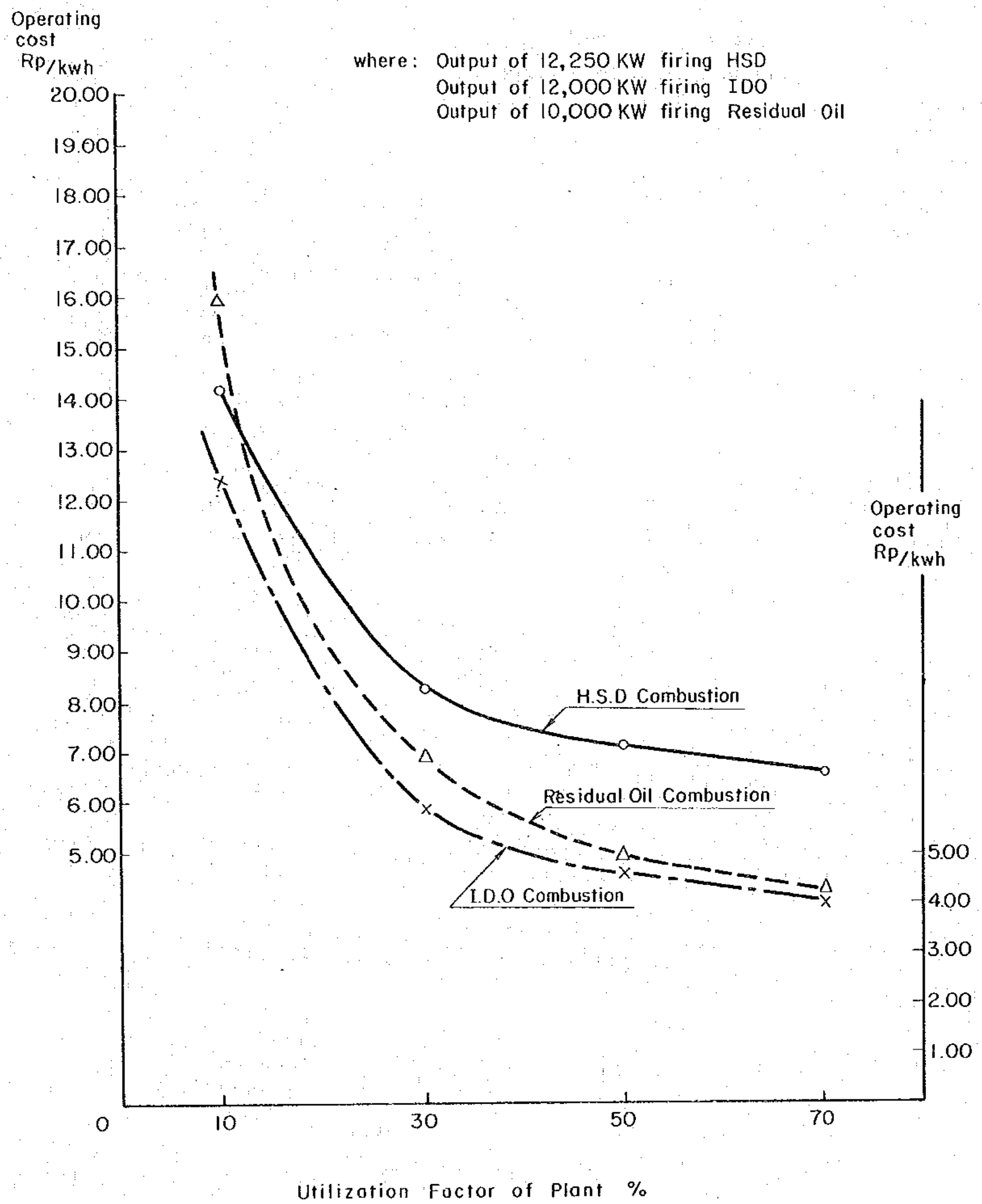
(iii) For the residual oil

Equally, the cost was reckoned at 2.21 Rp from the unit price of 5 Rp/l , calorific value (LHV) of 10,050 Kcal/kg, turbine heat consumption of 3,960 Kcal/kwh (21.7%), and fuel treatment cost (the same cost as for the IDO, plus pretreatment cost) of 0.20 Rp per kg of the residual oil.

Table 3-2-7 Economic Comparison Table of The Semarang Gas Turbine

Item of Comparison				Existing Gas Turbine (HSI fired)				IDO Fired Gas Turbine (Remodeled)				Residual Oil Fired Gas Turbine (Remodeled)			
1. Gas Turbine Output				12,250 kw (base)				12,000 kw				10,000 kw			
2. Construction Cost + Extra Construction Cost 10^3Rp				650,000 (53,000 Rp/kw)				650,000 + 40,000 = 690,000 (57,500 Rp/kw)				650,000 + 130,000 = 780,000 (78,000 Rp/kw)			
3. Annual Fixed Cost (interest Payment, Personnel, Expenses, etc.) 10^3Rp				91,000 91,000				96,600 96,000				109,200 109,200			
4. Fuel Cost + Fuel Treatment cost Rp/kwh				5.38 Rp/kwh				2.68 Rp/kwh				2.21 Rp/kwh			
5. Generation cost according to utilization rate Rp/kwh															
(1) Production energy 10^3 kwh															
70%	50%	30%	10%	75,120	53,660	32,190	10,730	73,580	52,560	31,590	10,510	61,320	43,800	26,280	8,760
(2) Fixed cost Rp/kwh															
70%	50%	30%	10%	1.21	1.69	2.83	8.46	1.31	1.83	3.67	8.20	1.78	2.49	4.15	12.40
(3) Repair cost Rp/kwh															
70%	50%	30%	10%	0.07	0.09	0.13	0.33	0.12	0.15	0.21	0.54	0.27	0.33	0.48	1.22
(4) Fuel cost Rp/kwh															
70%	50%	30%	10%	5.38	"	"	"	2.65	"	"	"	2.21	"	"	"
(5) Generation cost Rp/kwh															
70%	50%	30%	10%	6.65	7.16	8.34	14.17	4.11	4.66	5.96	12.42	4.26	5.03	6.84	15.83

Fig.3.2.2 Comparison Curve on Operating Cost for Power Generation at Semarang Gas Turbine



The trial calculation results obtained with considerations given to these factors are as shown in Table 3-2-7. As is clear from this table, the IDO is the most economical, irrespective of the utilization rate, while the residual oil evidently has the merit of remodelling when the utilization rate is high but tends to become more expensive than the existing gas turbine when the utilization rate is low.

g. Conclusion

Discussed above are the results of our investigation on the selection of fuels at gas turbine power plants, among the existing thermal power stations in Indonesia, as one of the important subjects on the saving of generation costs.

In general, it may be stated that, from the service life of gas turbine equipment, the use of a good quality fuel such as the natural gas or the light oil is desirable and permits the maintenance of a high reliability, and it should be kept in mind that when the residual oil is used for economic reasons, some loss in the service life of equipment and some decline in performance must be accepted.

Careful consideration should be given by the electric power industry which must attach the highest importance particularly to the supply reliability.

We have so far investigated and studied the important problem of ash adhesion and corrosion in the residual oil firing gas turbines and solutions therefore while introducing the latest technical information. On the basis of the investigation results, we have evaluated specific remodelling plans for the existing gas turbine of Semarang by way of examples.

This series of studies has shown that the use of the IDO would prove a realistic and economical proposal as summed up in the form of economic evaluation.

Of course, as stated before, our remodelling proposals stay within the limits of basic planning, and for the carrying forward of a closer study, not only detailed analysis of the IDO properties (particularly for metals contained in the ash) but also various surveys to tool up for the supply of the IDO as a power generating fuel and the close exchange of information with the AEG are indispensable.

Especially, as has been repeated, we have taken a fairly optimistic view on the analysis of the oil properties, but if actual analytical values show a great difference from our estimated values, we cannot totally deny the possibility that, even in the case of the IDO, various remodelling and additional steps, such as the installation of pretreatment equipment and the reduction of gas temperatures at the turbine inlet, may become necessary which will impair the economics of the IDO.

Based on this recognition, we recommend that the Semarang gas turbine be adopted as the model in proceeding with future studies on the utilization of the IDO.

3.3 MANAGEMENT OF EXECUTION OF PROJECT FOR ELECTRIC POWER FACILITIES

3.3.1 Introduction

(1) In this chapter, we are going to present our recommendations concerning the construction management in the execution of an electric power facility project and the material and financial management accompanied by the execution of the construction.

(2) An electric power facility project seeks to maintain stability in the supply of electric power which is indispensable for the economic and social development of the country and the welfare of the people. But, since the execution of an electric power facility project needs an enormous sum of capital and labor as well as a long construction period, deliberation must be made concerning the scope of the project and the timing of construction in deciding on the plan. And the most efficient investment plan should be formulated.

(3) Therefore, once a project is formulated, the importance and significance of the project should be fully understood, and the effective use of the fund and the efficient construction works must be maintained through the whole period of the construction. For this purpose, a general system of construction management for the whole enterprise should be established.

(4) For the electric power industry of Indonesia which imports almost all the plants, machineries and equipments from abroad, the acceptance schedule control of imported goods is a very important problem.

(5) Especially, in case of steam power project, a complete management system of accepting and keeping of large machineries and of a great quantity of steel materials is required.

(6) In order to carry out the efficient utilization and appropriate allocation of the large amount of materials and fund for an electric power facility project, an effective and consistent management system for logistics and accounting works including the purchase of machineries and equipments, the installation, the contracted construction works, the purchase of construction materials the utilization of stored materials and so on, is needed.

(7) It is recommended that PLN should institute as soon as possible a definite, unified system of accounting based on sound and modern public utility practices.

(8) From the above-mentioned viewpoints, we have examined the management of

the execution of electric power facility project of Indonesia.

3.3.2 Management of Construction Works

(1) General management of construction process

a. As indicated by the following example of steam power project, the management of construction for an electric power facility project is a matter of concern for the whole electric power enterprise including not only the construction department, but also almost all the departments of the enterprise.

A steam power project is determined after the careful consideration of the balance of load and supply, the system development plan, financial plan, the harmony with regional development, the condition of fuel transportation, the securing of cooling water for condenser in quantity and quality and so on.

b. In executing an electric power facility project, a general construction management system of the whole enterprise should be established. The management system should clearly define the substance of the works of each department and division within the PLN head office as well as of construction offices, and should make it possible to execute a project efficiently with effective co-ordination.

c. From this organizational viewpoint, we recommend to the electric power enterprise of Indonesia, the following points concerning the construction management in the execution of electric power facility project.

(a) To make a definite distinction of works between the PLN head office and the construction office and draw a clear-cut line of responsibility for the execution of project.

The works of PLN head office:

- Over-all planning for the establishment of plant
- designing of plant
- preparation of specifications for purchase and construction works
- making of purchase contract
- committing contracts for construction works
- guidance and supervision of construction office

The works of construction office:

- construction schedule control and quality control for the execution of construction works in the field

(b) The construction department of PLN head office should prepare "General construction management table" for each project which specifies the main points of construction management, and promote the effective co-ordination and co-operation among the departments of PLN head office and between PLN head office and construction office. The major works from the determination of project to the completion of construction which must be indicated in include designing of plant, preparation of purchase specifications, examination of bids, conclusion of purchase contract, securing of site, boring, temporary construction, field installation, test operation and so on.

Note: An example of "General construction Management Table" is shown in Appendix 3–14.

(c) Within PLN head office, the committee of general construction management comprising the concerned departments of PLN head office and construction office should be established and held as the occasion may demand. The committee should take flexible measures to meet the various situations and strengthen further the system of co-operation among the concerned departments.

Note: If the system of vice-presidency is established as we recommended, the chairman of the general construction management committee is the vice-president in charge of power facilities.

(2) Use of consultants

a. In case of large project, the works of consultants are usually determined by the negotiation between the contracting parties, and it is very difficult to apply the same rule to every case. But, the following generalizations can still be made.

Generally speaking, the works of consultants can be classified into designing services and technical advisory services. These are some consultants who only make advices and recommendations for the execution of the whole project from the viewpoint of designing and construction management.

(a) Here designing services include basic surveys at the beginning of planning for the project and the preparations of the plan of projects, designs and specifications based upon the technical analyses.

(b) Technical advisory services include engineering supervision in the execution of project, safety management, and guidance for the construction works in the field.

b. Any consultants are the persons who are requested by a client to carry out a specific work in the implementation of project. Thus, the responsibility of the execution of the project is on the client who is the execution of the project.

c. From the above viewpoints, we recommend the following points as a consultant policy to the Indonesian electric power industry which will require an increasing number of large projects as the economy develops in the future.

(a) In case of entrusting a consultant with a work in a project, it is essential, first of all, to understand fully the role of consultant, determine the function of consultant in advance according to the substance and scope of project and define the line of responsibility considering the predetermined function of consultant. The contract between a consultant and a client should be concluded after the clarification of the work assigned to a consultant as much as possible...

(b) In the selection of consultant, the decision concerning what work should be assigned to the consultant has a very important influence on the execution of project. The decision must be made after the careful consideration, not only of the execution of project, but also of problems after the completion of the project and future projects. For example, if the consideration of systematic technical improvement for the whole project is emphasized, an package order can be placed in including designing services and technical advisory services.

(c) In concluding a contract with a consultant, it should not be forgotten that the man responsible for the project execution is the project executor.

(3) System of receiving and keeping of imported machineries and equipments

a. There is a great number of machineries and equipments having various performances for large project (including imported machineries and equipments.)

b. Especially, as imported machineries and equipments have to go through a long period of sea transport and land transport from the shipment from factory to the arrival on site, the damages of machineries and equipments cannot always be prevented.

c. In keeping machineries and equipments on the site, special attention should be paid to the prevention against the damage of machineries by the wrong keeping method (for example, insufficient rust prevention) and to the prevention of other accidents such as robbery and fire.

d. Looking at the existing condition in Indonesia from the above point of view the management system for keeping is not always thought to be sufficient.

Therefore, we recommend to strengthen the management system by paying special attention to the following points.

The overall responsibility of the management of the acceptance schedule for imported machineries and equipments should be born by the logistics department of PLN head office. The logistics department should be well informed of the movement of ship, and should keep informations concerning the invoices for each arriving goods. In case of finding some damages to the machineries, immediate and appropriate measures should be taken for the investigation of the cause and for repair and replacement.

For this, after discussion with consultants, the logistics department of PLN head office should establish the rules concerning the measures to be taken in case of finding damages done to imported machineries and equipments by the supplier of imported goods, PLN head office, construction office and so on.

It is also desirable to consolidate the management system for materials including the modernization of customs works the strengthening of communication system with the supplier of machineries and equipments, and others.

(4) Management of construction at site

a. Construction at site, as shown in the following example of a steam power project, involves a considerably long period of complex works which are carried out in a very small area, and a variety of works including unloading of large machineries, keeping transporting, lifting and so on.

b. Thus, special attention should be paid not only to the prevention of accidents and the ensuring of the safety of human body, but also to the coordination of the work procedures, and the rationalization of construction process. With the safety of construction and the assured period of construction, the economy of construction should be secured and the repetition of the same work caused by the lack of coordination must be avoided.

c. For this purpose, it is essential for the construction office to make a more detailed construction schedule based on the general construction management table made by PLN head office, under the guidance of consultant on PLN head office. From the detailed construction schedule, the major management targets can be derived and a proper control system of construction works can be established.

(Some examples of the field construction works for a steam power project)

(i) Securing of land, ordering of major machineries and equipments, temporary construction works for construction roads, construction office and for the securing of electric power and water.

(ii) Civil works and architectural works including the construction works for the channel of condenser cooling water and the foundation works for major machineries.

(iii) Construction works for main building

(iv) Construction of the structural steel for boiler, lifting of boiler drum, welding works for pressure parts of boiler

(v) Foundation works for turbine generators, installation of condenser

(vi) Installation of turbines and generators after the completion of shop test

(vii) Installation of auxiliary electric equipments in the plant

(viii) Initial firing of boiler, and boiling out, washing for the inside of the boiler, flushing of major's pipes

(ix) Test operation of turbines and generators after the completion of installation

(x) Testing of various protecting devices, comprehensive test operation of the plant, completion inspection

(5) Inspection

a. It is a general rule that in a project of electric power facilities, the construction works proceed with necessary inspections according to the progress of works.

b. The following is an example of inspection works for a steam power project.

(a) Inspection during the production in the factory:

Chemical and physical test of materials of equipments and welding parts with standard testing code, shop test of turbine generator, etc. There are some cases that inspection works are left to the makers when the plant have to be imported.

(b) Inspection during the installation:

Inspection works are done for the discovery of defect and the prevention of accident during the process of construction and installation of machineries and equipments.

- In case of boiler

  Hydrostatic test after the completion of the welding works of boiler pressure parts, and, in case of pressurized furnace, air leakage test of furnace are the major tests.

- In case of turbine

  Inspection of the centering of turbine foundation and turbine rotor, and the checking of the alignment and clearance of turbine rotor are the major works.

(c) Test of trial operation:

- In case of boiler

  Initial firing test, combustion test, safety valve test, etc.

- In case of turbine

  Test of protection devices, governor test after steam admission to turbine, etc.

(d) Acceptance test:

This test is to confirm the actual operating performance for the makers guarantee based upon the contracted proposal in the operating condition of rated capacity.

(e) Inspection of facilities by the supervising authorities:

The commercial operation can be commenced with the passing of examination of facilities by the supervising authorities after the test of trial operation and acceptance test.

c. Our major recommendations for the electric power industry of Indonesia are as follows.

(a) Abovementioned items (a) and (b) of test and inspection are usually done by the supervising authorities and the makers of machineries and equipments. Even though the above mentioned tests are done by them, it is very important to pay special attention to the keeping and filing of the test records.

Because the test records become the basis of inspection in case of periodical inspections, repair works after commercial operation and of operating guide for daily operation.

(b) As the acceptance test is for the confirmation of the overall performance of the plant, it is desirable that tests are carried out by the person responsible for the execution of project himself.

For this reason, it is to be desired that in accordance with international code (for example IEC acceptance test code of steam turbine) the rules and standards of test are established and that the system of acceptance and checking is strengthened as soon as possible.

3.3.3 Material and Financial Control

(1) The works of purchasing materials and contracting for constructions should be unified in one organization as well as the technical works concerning construction and maintenance, in order to make clear the responsibility for and increase the efficiency of respective works.

a. Present situation

(a) Department for Operation and Logistic manages technical development, purchasing, supply, and import works of materials concerning the maintenance of facilities only.

(b) Department for Construction also manages the provision of materials and the contracts of local works for projects as well as the making of designs or specifications for projects.

b. Problem

(a) The works of purchasing materials and contracting construction works are separated into two departments.
The overall management and control of such works cannot be expected.

(b) The responsibility for technical works and materials or contracting works cannot be separated clearly. This sometimes leads to indistinct relations with a maker or a contractor.

(c) The technical or material works of the same kind are handled by two departments. It is apt to bring about the irrational and inefficient elements in the process of works.

c. Recommendation

(a) Construction department should execute the works of making designs and specifications for projects, the maintenance works of facilities, and the collection of necessary data related to these works. Purchasing materials and contracting construction works should be assigned to the materials department.

(b) Upon the request of construction department, materials department should select a maker or a contractor, collect the cost estimates and check the

payment conditions, etc.
Technical reviews should be assigned to the construction department.

(c) Materials department should conclude contracts and give orders for materials and works in consideration of all the abovementioned aspects. Construction department should manage the inspection of construction.

d. Expected effects by this recommendation

(a) The responsibility for technical works and materials or contracting works will become distinct, works will be checked, and relations with makers or contractors will become clear.

(b) Technical works and materials or contracting works concerning facilities can be controlled respectively and intensively, which improves works, makes them efficient, and decreases the number of staff members concerned.

(2) Management of quantities and amounts of money concerning the materials should be unified in order to make works efficient and make control of materials intensive.

a. Present situation

(a) Quantities concerning the materials such as the receiving, delivering, and storaging are controlled by Department for Operation and Logistic. Booking of amounts of money concerning materials is executed by Department for Commerce.

(b) PLN sometimes lends or sells its materials to a project which is constructed by government financing.

b. Problem

(a) Movement of documents is complicated and works are sometimes delayed.

(b) Complete and responsible control of materials cannot be expected by the documents which have no indications of the amounts of money, but quantities only.

(c) To separate the quantities control from the amounts of money does not contribute to checking each other.

(d) In the case of a. (b), collection of bills is sometimes impossible because Department for Operation and Logistic cannot decide immediately the selling price at the present system. Accordingly, request for payment is delayed.

c. Recommendation

Materials department should control not only the quantities but also the booking of the amounts of money concerning materials.

d. Expected effect by this recommendation

(a) Quantities, unit price and amount of money can be handled altogether in one section when materials are transferred.

(b) It will make works efficient.

(3) Calculating method of materials delivering unit price should be simplified to make such works efficient.

a. Present situation

When materials, which have different purchase prices, are delivered out of the warehouses, delivering unit price is calculated at each time by means of averaging the quantity and amount of price of the materials.

b. Problem

This method is very complicated and troublesome especially in the cases of materials which are received and delivered very often and have many kinds.

c. Recommendation

(a) Estimated delivering unit price should be settled beforehand every fiscal year based on certain standards, concerning the materials which are received and delivered often and of the same kind, quality and standard.
(In this calculation, received or delivered price should be estimated as accurately as possible.)

(b) Every delivering of such materials should be booked with this estimated price during the fiscal year.

(c) At the end of the fiscal year, the final delivering unit price should be settled by the average method during the year.

The differences between the final price and the estimated price should be allocated to delivered price and materials price proportionately at the end of the year.

d. Expected effect by this recommendation

Works of calculating the delivering unit price will be simplified and managed quickly.

(4) Accounting management should be unified in one organization in order to grasp the real financial condition of PLN and to control it extensively.

a. Present situation

(a) Financial statements of PLN such as the balance sheet are completed by Department for Commerce. It consolidates such statements from Exploitasi, Department for Construction and other departments.

(b) Accounting for project is managed substantially by Department for Construction.

(c) Abovementioned situation means accounting management of PLN is separated into two systems; concerning the projects and the other.

b. Problem

(a) Management of total fixed assets which occupy most part of the whole assets amount is not executed sufficiently and properly.

(b) This situation sometimes causes the weakening of the function to manage very important financial problems such as the depreciation, revaluation of assets, profit or loss estimation, funds program, revision of electric tariffs and so on.

c. Recommendation

Accounting management including the projects should be executed as a whole in a staff department which controls management in general. This will contribute toward establishing a unified systematic control for general management.

(5) Accounting management should be executed normally by accurate transaction of project assets account.

a. Present situation

(a) Accounts concerning the projects which started commercial operations have not been transferred immediately to the fixed assets account.

(b) When accompanied small works are left for a long time, main project account is not transferred immediately to the fixed assets account after its operation.

(c) Accounting procedure is not completed on an equipment financed by a foreign currency, except for the local costs only such as import duties or transportation costs.

b. Problem

(a) Expenditure based on actual fixed assets such as the depreciation, maintenance, personnel cost and so on, cannot be appropriated accurately.

(b) Abovementioned situation greatly misleads people about the financial situation.

(c) To revaluate or depreciate fixed assets in the future will be difficult.

c. Recommendation

(a) It is necessary to let the staff members concerned recognize the significance that they do not transfer project account which should be transferred to the fixed assets account, thereby accumulating the project account more and more.

It is also necessary that their superiors know the situation exactly and instruct them properly concerning such transfers.

(b) More communications and negotiations should be made among the sections concerned.

(c) When accompanied small works for projects are left for a long time after their operations, a completed main part of project should be transferred temporarily to the fixed assets account with roughly calculated amounts, and such account should be finally corrected at the time whole works for projects complete thoroughly. (Refer to a. (b))

(d) When a project was transferred from PLN to another organization, transfer of accounts must be done at the same time.

(e) In the case of an equipment financed by a foreign currency (Refer to a. (c)), accounting procedure should be completed at each time of acquisition based on the invoice amounts.

To determine the exchange rate between the foreign and domestic currencies, government should cooperate with PLN.

(6) Distinction between expenditure on capital account and revenue account should be established clearly, in order to make financial management possible through exact capital and revenue accounting.

a. Present situation

(a) There is no general standard which distinguishes between the expenditur on capital account (that is, construction expense) and the revenue accoun (maintenance expense, for instance).

(b) At the moment, distinctions are made in different regions according tc their old standards.

Financial control cannot be done satisfactorily on the basis of sucl distinctions.

b. Problem

(a) This situation causes inconsistency in PLN as a whole.

Accordingly, accurate capital and revenue accounting cannot be expectec

(b) Proper budgetary or management control is very difficult.

c. Recommendation

(a) Basic standard which distinguishes between the expenditure on capital and the revenue account should be established in consideration of characteristics of electric enterprise and through adjustments with tax authorities.

(b) Based on this standard, specific and unified instruction should be executed by PLN head office.