(9) Administrative department chief

Administrative department chief is the person responsible for giving the daily administration and direction the personnel such as clerk, warehouse staff, guard, driver, sweeper and other personnel than the above-mentioned personnel necessary for the plant operation.

### 15.1.3 Personnel qualification and experience

(1) Common department

| | Education | Actual Job Experience | No. of person |
|---|---|---|---|
| a) Plant manager | University graduate | Over 20 years | 1 |
| b) Deputy plant manager | University graduate | Over 15 years | 2 |
| c) Secretary | | | 3 |
| | | Sub total | 6 |

(2) Administrative department

| | | | |
|---|---|---|---|
| a) Administrative department chief | University graduate | Over 5 years | 1 |
| b) Clerk | High school graduate | - | 9 |
| c) Warehouse staff | - | | 6 |
| d) Guard, driver, etc. | - | | 20 |
| | | Sub total | 36 |

(3) Operation department

| | | | | |
|---|---|---|---|---|
| a) | Operation department chief | University graduate | Over 15 years | 1 |
| b) | Operation engineer | University graduate | Over 10 years | 2 |
| c) | Shift chief operator | High school graduate | Over 5 - 10 years | 10 |
| d) | Operator | High school graduate | Over 2 - 3 years | 160 |
| e) | Chemical analyzer | High school graduate | Over 3 years | 2 |
| | | | Sub total | 175 |

(4) Maintenance department

| | | | | |
|---|---|---|---|---|
| a) | Maintenance department chief | University graduate | Over 15 years | 1 |
| b) | Senior engineer | University graduate | Over 10 years | 6 |
| c) | Engineer | University graduate | Over 5 - 10 years | 9 |
| d) | Staff | High school graduate | Over 3 - 5 years | 22 |
| e) | Technician | High school graduate | Over 1 - 3 years | 76 |
| f) | Others | - | - | 17 |
| | | | Sub total | 131 |
| | | | Total | 348 |

### 15.1.4 Personnel employment plan

The employment plan is determined taking into considerations of the completion time of this plant and training plan schedule. It is desirable that the responsible persons and the key personnel for this plant, namely, plant manager, deputy plant managers, operation department chief, operation engineers, maintenance department chief, and maintenance senior engineers participate in this project at least before 12 months prior to the start of the test operation of No. 1 unit in order that they have the sufficient understanding of the complex plant through ivents in accordance with a series of construction schedule such as design, manufacture, factory test, construction, training and test operation.

Other personnel such as shift chief operators, operators, maintenance engineers and maintenance staff are introduced at least before about six months prior to the start of the test operation of each unit, as they become necessary for the operation and maintenance of the individual unit and they are provided with education on a step-by-step basis in accordance with the training plan to be referred to later.

Also, it is necessary that the administrative department chief and all other necessary personnel are introduced before one month prior to the start of the test operation of No.1 unit. It is necessary that the employment of the personnel planned for this complex plant is completed in this manner before the completion of the final unit.

## 15.2 TRAINING PLAN

This training plan is to give training to the personnel employed by MEW such as operation engineers, shift chief operators, operators, maintenance senior engineers, maintenance engineers and maintenance staff. The training plan starts before about six months prior to the start of the test operation of No.1 plant in parallel with the progress of the plant construction and after the start of the commercial operation of No.1 plant, the follow-up of the operation and maintenance is performed under the guidance of the guarantee engineer until the guarantee period of the final unit.

Although the training curriculum differs depending on the type of the assigned plant, job classification, personnel qualification and grade, it basically consists of the following major subjects.

(1) Basic technical lecture on the individual equipment

(2) Lecture on the specification, function, construction and system of the individual equipment

(3) Lecture on the operation and handling procedure for the individual equipment

(4) Lecture on the maintenance and inspection procedure for the individual equipment

(5) Factory practice at the manufacturer as required

(6) Practice at the existing plant

(7) Practice at the new plant

(8) Lecture and practice on safety

(9) Follow-up of the operation and maintenance by the guarantee enigneer

It is desirable that the plant model, photograph, color slide and video are included in the training plan, in addition to the instruction book, complete literature and complete drawing to be delivered at the time of the completion of the plant, in order that the training is easily understandable even by the inexperienced personnel.

# CHAPTER 16

# PLANT CONSTRUCTION SCHEDULE

# CHAPTER 16 PLANT CONSTRUCTION SCHEDULE

## 16.1 CONSTRUCTION SCHEDULE

The construction schedule of this power and desalination complex plant is shown in Fig. 16.1 and Fig. 16.2. To solve urgent shortage of power and water supply, some of each power and desalination units is to be completed as soon as possible, and remaining power and desalination units is to be constructed in accordance with the increase of each demand. But last 3 units of desalination plant are to be completed in advance of water demand within the final completion date of whole power plant, so that construction cost will be saved and availability of desalination units will be much increased, as already explained in Chapter 5.

According to the construction schedule in Fig. 16.1 and Fig. 16.2 the design work must be started from the beginning of May 1986 and No.1 gas turbine generator must be put into service at the beginning of July 1988 and No.1 desalination plant must be in commercial operation at the beginning of November 1988.

To keep the above construction schedule, the definite specifications and the selection of the project contractor must be made at the beginning of 1986 and actual project must be started from May 1986 at the latest.

The outline of procedure from this feasibility study to the completion of whole plant is as follows:

(1) The finalization of definite specifications, and the preparation of tender document

(2) Tender and their evaluation

(3) The selection of contractors and the contract of this project

(4) Design

(5) Manufacturing of the equipments and procurement of materials

(6) Site construction

(7) Trial operation

(8) Commercial operation

In addition to the above, MEW or other concerned parties are requested to make the following arrangements.

Acquisition of new plant site

Natural gas supply facility to new plant site

Blending well water supply facility to new plant site

Recruiting of plant operation and maintenance personnel

Housing facilities for plant operation and maintenance personnel

Other associated facilities if any

## 16.2 SELECTION OF CONTRACTORS AND PROJECT CONTRACT

Considering both water and power demand, as well as construction period of power and desalination complex plant, the selection of contractor and the project contract must be carried out in a short time and be finalized at the beginning of 1986.

For this purpose, the employment of consultants or advisers, who can give suitable advices and useful informations to MEW, is recommended.

Also, in selecting and evaluating contractors for this large scale power and desalination complex, it is needless to say that the reliable contractors must be selected, who have rich engineering capability, actual construction evidence of large scale plant, systematic project execution capability, and also have well familiarity with Oman's local conditions.

## 16.3 PLANT CONSTRUCTION

At plant construction stage, the contractor is fully responsible for plant delivery schedule. To make ease the contractor's work, MEW is kindly requested to take quick actions for approvals for necessary project matters and to back up strongly the contractor in obtaining necessary approvals and/or permissions for government authorities concerning project matters.

Main events of plant construction are as follows:

(1) Design

1) Power plant

As the gas turbine plant is basically standard type, it will not take much time in completing both the basic design and detail design. While, the steam turbine power plant is combined with the desalination plant, it is necessary to complete the basic design, that includes heat des heat mass balance, piping and instrumentation drawing and plot plan, and the detail design, that includes auxiliary equipments, piping, electrical and instrumentation, foundation and architectural. Therefore, the design of power plant would take approximately 10 months from the basic design to the completion of detail design that includes manufacturing and erection drawings.

2) Desalination plant

Same as the steam power plant, the desalination plant is not standard type and is combined with the steam power plant, so it will take approximately 10 months for the preparation of the basic and detail design.

(2) Manufacturing of equipments and material procurement

1) Power plant

Most of auxiliary equipments for gas turbine power plant are packaged units, so these packaged units are split in a suitable blocks to meet transportation schedule as required. The manufacturing period per one gas turbine power unit is approximately 13 months including transportation to site.

In case of steam turbine power plant, steam turbines and electric generators are manufactured at respective manufacture's shop in one unit, as steam generator is large in size, pre-fabricated pannel is constructed at shop and final assembly is carried out at site. The manufacturing period per one steam generator is approximately 20 months including transportation to site.

2) Desalination plant

The evaporator itself takes the longest period to manufacture compared with other components. The evaporator is pre-fabricated in a suitable block size in the shop and each block is welded and assembled at site. The delivery of one evaporator unit is approximately 10 months including transportation to site.

(3) Construction field works

1) Civil and architectural works

a) Investigation Works and Preparatory Works

In order to establish the design conditions for definite design of the principal civil and architectural facilities such as plant equipment foundations, sea water intake and discharge facilities, etc., investigation works consisting of geological surveys and sea depth sounding are to be carried out at the plant site as soon as possible after execution of the contract. Approximately 4 months will be required for these investigation works.

Transportation of construction equipment to the site and arrangements for laborers are to be carried out at an early stage, and preparatory works such as construction of an access road from the trunk highway to the site and preparation of the plant construction lot are to be started. Approximately 3 months will be required for these preparatory works.

b) Sea Water Intake and Discharge Facilities

Since test operation of the No.1 unit desalination plant is planned in August 1988, civil works related to sea water intake and discharge facilities should be completed by March 1988 considering 5 months work schedule for installation of sea water supply pumps, screens, etc. and connection of pipelines. The construction of open channel type intake waterway will be almost completely underwater work. Approximately 23 months will be required for dredging and embankment of dykes of the intake waterway, and this work will essentially be critical and govern the entire construction schedule. The intake and pump pit work and the discharge line work will require 16 and 12 months respectively, and these will be performed in parallel with the construction work of the open channel type intake waterway.

c) Plant Equipment Foundations

The foundation works of principal items of plant equipment such as gas turbine generating plant, steam turbine generating plant and desalination plant are to be completed in sequence by the time when installation works of the respective plants are started.

d) Architectural Facilities and Chimney Work

The administration building and power generation control building must be completed by the start of tests on the No.1 unit and No.2 unit gas turbine generating plants scheduled in March 1988. Approximately 20 months will be required for these building works. As for the powerhouse for the steam turbine generating plants, it is to be prepared to such extent that installation work will be possible at the start of individual steam turbine unit erection and this is to be completed in sequence by the times when tests are to be started.

No. 1 chimney work work must be completed by the end of 1989 when firing of the No.1 steam turbine generating plant is scheduled.

The desalination control building is to be completed by the time when the trial operation of No. 1 unit is started.

2) Product water pumping equipment and product water pipeline

These can be completed within approximately 24 months after contract and these construction work are not critical pass to total project schedule. However, in determinating final pipeline route and in actual construction works, the negotiations with Oman Government authorized parties for necessary permissions if any and with inhabitants for obtaining their consent if required must be carried out as quickly as possible, so that there is no delay in work schedule.

3) Power plant

The equipments and parts for gas turbine power plant are package units, so the erection work at site is comparatively simple and it will take approximately 10 months from the start of erection to trial operation at site.

The associated equipments and pipings of steam turbine power plant are constructed at site, and boiler plant is applied with pre-fabricated construction method, and there are many welding work and piping work, so it will take approximately 19 months to complete one unit of boiler plant.

4) Desalination plant

Desalination plant consists of 6 units and construction period at site is approximately 10 months per 1 unit.

First 3 units are to be constructed in series at 2 months intervals to meet the water demand. Together with these desalination plants, 2 units of gas turbine power plant, 2 auxiliary steam generators, sea water intake facilities and outfall, product water pumping equipment and pipelines are to be completed, so necessary electric power, steam and associated facilities become available for start up of the actual water supply to meet water demand.

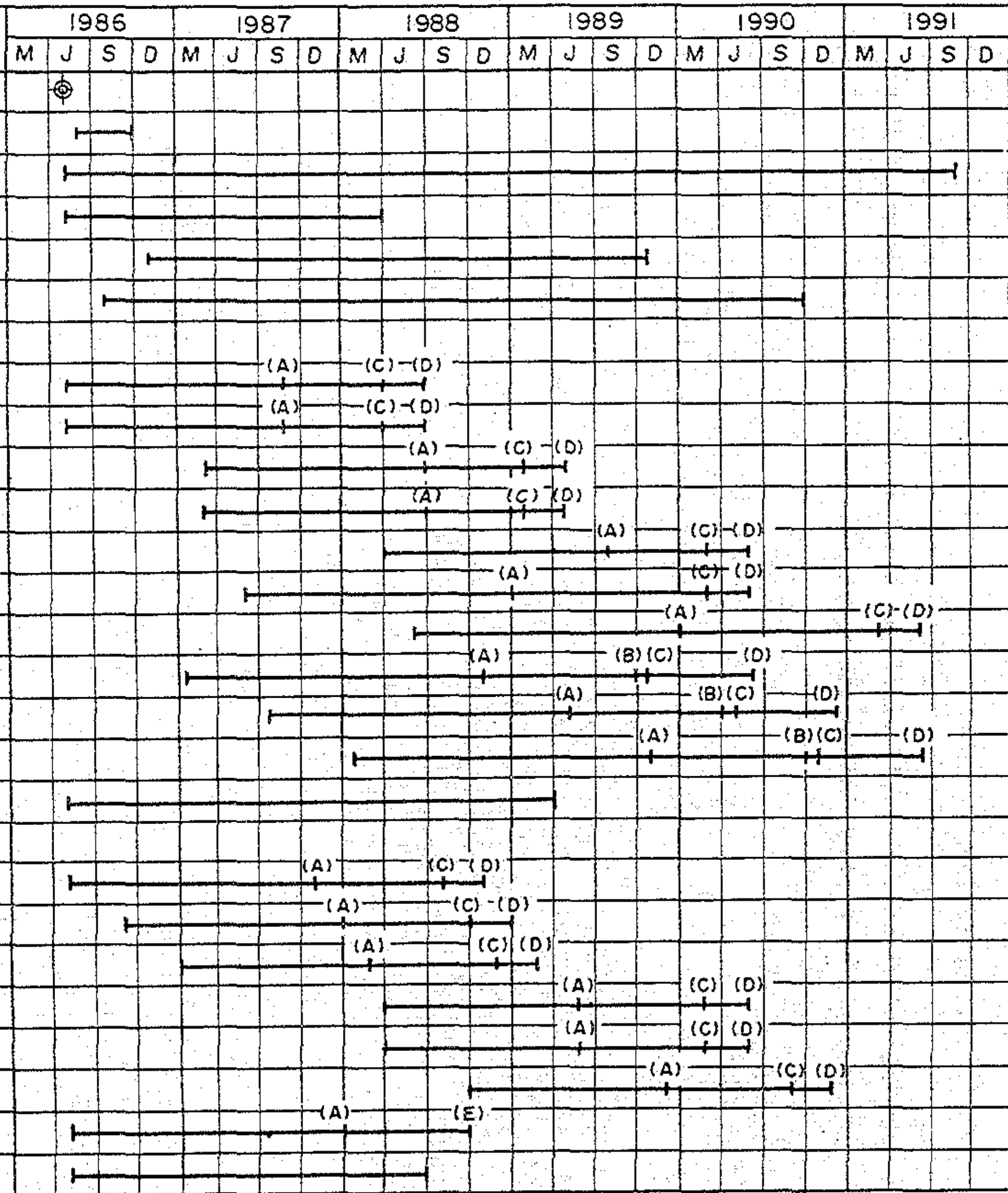
Though the construction of remaining 3 desalination units are not so tight in water supply schedule, these units are to be constructed together with steam turbine power plant construction. Because this project is basically complex plant of steam turbine power plant and desalination plant, so the completion of complex plant at the same time is reasonable and cost saving, as explained in Chapter 5.

(4) Trial operation

One month's continuous reliability test is scheduled for both power plant and desalination plant before taking over.

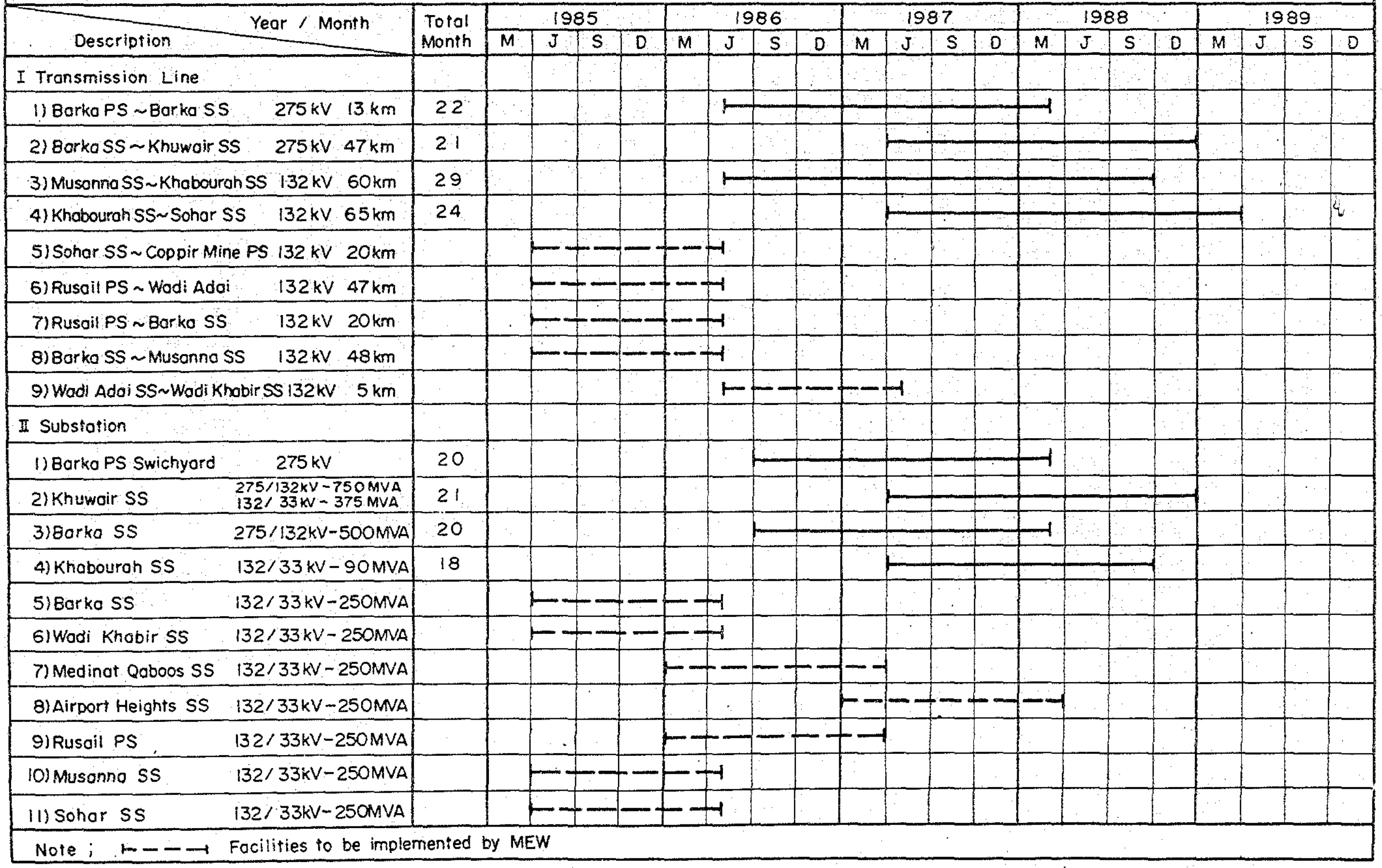
## Fig. 16.1 Construction Schedule for Power and Desalination Complex Plant.

| Description (Date. Year/Month) | Total Month |
|---|---|
| I. Civil Works | |
| 1) Field Investigation of Site | 4 |
| 2) Site Preparation & Others | 64 |
| 3) Sea Water Intake & Discharge Facilities | 23 |
| 4) Foundation for Equipment | 36 |
| 5) Buildings & Stack | 50 |
| II. Power Plants | |
| 1) Unit 1 ; $GT_1$ , Ge 1 , 80 MW | 26 |
| 2) Unit 2 ; $GT_2$ , Ge 2 , 80 MW | 26 |
| 3) Unit 3 ; $GT_3$ , Ge 3 , 80 MW | 26 |
| 4) Unit 4 ; $GT_4$ , Ge 4 , 80 MW | 26 |
| 5) Unit 5 ; $GT_5$ , Ge 5 , 80 MW | 26 |
| 6) Unit 6 ; $RH_{1-2}$, $ST_4$ , Ge 9 , 80 MW | 36 |
| 7) Unit 7 ; $RH_{3-4}$, $ST_5$ , Ge 10 , 80 MW | 36 |
| 8) Unit 8 ; $SG_1$ , $ST_1$ , Ge 6 , 60 MW | 40 |
| 9) Unit 9 ; $SG_2$ , $ST_2$ , Ge 7 , 60 MW | 40 |
| 10) Unit 10 ; $SG_3$ , $ST_3$ , Ge 8 , 60 MW | 40 |
| 11) Transmission Lines & Substation, 132 & 275kV | 35 |
| III. Desalination Plants | |
| 1) Unit 1 , 30,000 $m^3/D$ | 30 |
| 2) Unit 2 , 30,000 $m^3/D$ | 28 |
| 3) Unit 3 , 30,000 $m^3/D$ | 26 |
| 4) Unit 4 , 30,000 $m^3/D$ | 26 |
| 5) Unit 5 , 30,000 $m^3/D$ | 26 |
| 6) Unit 6 , 30,000 $m^3/D$ | 26 |
| 7) Auxiliary Boiler , No.1 & No.2 | 29 |
| 8) F.W. Reservoir & Conduit Pipe Line | 24 |




Note: ⊕ : Contract, May 1, 1986 (A) : Commencement of Erection (B) : Hydraulic Test; (C) : Test (D) : Completion of Erection or Commissioning

Fig. 16.2 Construction Schedule for Transmission Lines and Substations



# CHAPTER 17

# CONSTRUCTION COST ESTIMATE

# CHAPTER 17 CONSTRUCTION COST ESTIMATE

## 17.1 BASIC CONDITIONS

In Chapter 18 it is stated that seen from economic viewpoint Type-A combination of power plant and disalination plant is the most advantageous but when considering maintainability of equipment, stability of power supply and reliability of operation, Type-F combination is desirable. Construction cost of Type-F power plant is the largest in the six alternatives considered. Taking these conditions into account the selection of type of power plant will be made by MEW. In this Chapter the construction cost was estimated for Type-F combination in order to appropriate enough amount in the budget of the Government.

The construction cost estimate was broken down into local currency portion and foreign currency portion and detailed to cover the following facilities. (The amounts were expressed in terms of Rial Oman. For foreign currency portion, amounts converted to US$ were also given in parentheses).

Electric power sector:

- Generating facilities
- Transmission facilities
- Substation facilities

Desalination sector:

- Processing facilities
- Sea water intake and out-fall facilities
- Product water transportation facilities

Other costs

- Physical contingencies
- MEW's administration expenses
- Engineering fee

The annual disbursement of the construction cost was made according to the construction schedule described in Chapter 16. The estimate was made at

1985 prices, then price escalation of commodities was taken into consideration.

The foreign currency portion includes costs of imported equipment and materials, ocean freight and insurance, and salaries for foreign engineers and personnel, while the local currency portion includes costs for inland transportation, locally available construction machine and materials such as cement, aggregates, etc., as well as salaries and wages for local personnel and workers.

## 17.2 CONDITIONS FOR ESTIMATE

The physical contingencies, MEW's administration expenses, engineering fee, price escalation and exchange rates of currencies were estimated under the following conditions:

(1) Physical contingencies

Physical contingencies are to cover mainly unforeseen additional works. In the light of experiences in projects of similar nature, 10% for both civil works and electrical and mechanical equipment of their respective base direct cost was included as physical contingencies.

(2) MEW's administration expenses

In general, administration expenses of the owner are around 0.5% of the direct construction cost annually. Since the construction period of this project is 6 years, 3% of the base direct construction cost was included as MEW's administration expenses.

(3) Engineering fee

Engineering fee is the expense for engineering services such as definite design and preparation of tender documents, evaluation of bids, construction supervision, etc. In consideration of scale of this project, the amount was estimated at 2.5% of the base direct construction cost.

(4) Commodity price escalation rate

For price escalation of foreign currency portion the commodity price indexes in Japan for the period from 1980 to 1985 were referred to, while for price escalation of local currency portion the commodity price indexes in Oman for the period from 1978 to 1983 were referred to. According to these commodity price indexes, the average escalation rates are as follows:

Foreign currency portion:

Boiler 2%, generator 2.1%, transformer 1.9%, bringing to an average of about 2%.

Local currency portion:

Cement -2.3%, lumber 11.5% aggregates 3.2%, sand 10.6%, bringing to an average of about 5.8%.

When considering shares of local and foreign currency portions in the total construction cost, the weighted average price escalation rate of 2.5% is obtained. But it is difficult to foresee future trends of price rise both for local and foreign currency portions. Therefore, an average price escalation rate of 3% including margin was adopted for both local and foreign currency portions.

(5) Exchange rates of currencies

Currency exchange rates adopted in this study are as follows:

US$1.00 = 0.342 Rial Oman (R.O.)
US$1.00 = 250 Yen
1.00 R.O. = 731 Yen

## 17.3 CONDITIONS FOR ANNUAL DISBURSEMENT

The construction cost was disbursed annually under the following conditions:

(1) Equipment cost

Advance payment: ∘ 10% of the CIF price upon signing the contract.

∘ 80% of the CIF price upon shipment of the equipment.

Retention money: ∘ 10% of the CIF price to be released upon issuance of the acceptance certificate by MEW.

(2) Costs of civil works and buildings

Advance payment: ∘ 10% of the contract price upon signing the contract.

Monthly payment: ∘ According to works done.

Retention money: ∘ 10% of the cumulative total cost to be released upon issuance of the acceptance certificate by MEW.

(3) Erection and installation cost

Same conditions as for civil works.

## 17.4 ESTIMATED CONSTRUCTION COST

Based on the conditions stated above, the construction cost at 1985 prices including physical contingencies, MEW's administration expenses and engineering fee was estimated at 241.60 million R.O. for electric power sector and 101.68 million R.O. for desalination sector, a total of 343.28 million R.O. At the price escalation of 3% per annum, these amounts will increase to 264.12 million R.O. for electric power sector and 109.85 million R.O. for desalination sector, totalling 373.97 million R.O.

The construction cost, both at 1985 prices and escalated prices, is summarized in Tables 17.1, 17.2 and 17.3. The annual disbursement of the construction cost is shown in Tables 17.4 and 17.5.

Table 17.1 Summary of Construction Cost (Power and Desalination)

(Million R.O.)

| Item | Foreign Currency | (US$ million) | Local Currency | Total |
|---|---|---|---|---|
| Electric power sector | | | | |
| Generating facilities | 160.33 | (468.79) | 10.79 | 171.12 |
| Transmission facilities | 10.86 | ( 31.75) | 4.35 | 15.21 |
| Substation facilities | 19.22 | ( 56.20) | 3.64 | 22.86 |
| Sub-total (Base direct cost) | 190.41 | (556.74) | 18.78 | 209.19 |
| Contingencies | 19.04 | ( 55.67) | 1.86 | 20.90 |
| MEW's administration expenses | - | ( - ) | 6.28 | 6.28 |
| Engineering fee | 5.23 | ( 15.29) | - | 5.23 |
| Total (1985 prices) | 214.68 | (627.70) | 26.92 | 241.60 |
| Escalated price | 235.41 | (688.33) | 28.71 | 264.12 |
| Desalination sector | | | | |
| Processing facilities | 48.59 | (142.07) | 6.21 | 54.80 |
| Sea water intake and out-fall facilities | 2.93 | ( 8.57) | 2.95 | 5.88 |
| Product water distribution facilities | 17.88 | ( 52.28) | 9.48 | 27.36 |
| Sub-total (Base direct cost) | 69.40 | (202.92) | 18.64 | 88.04 |
| Contingencies | 6.94 | ( 20.29) | 1.86 | 8.80 |
| MEW's administration expenses | - | ( - ) | 2.64 | 2.64 |
| Engineering fee | 2.20 | ( 6.43) | - | 2.20 |
| Total (1985 prices) | 78.54 | (229.64) | 23.14 | 101.68 |
| Escalated price | 84.83 | (248.04) | 25.02 | 109.85 |
| Grand total | | | | |
| Cost at 1985 prices | 293.22 | (857.34) | 50.06 | 343.28 |
| Escalated price | 320.24 | (936.37) | 53.73 | 373.97 |

Table 17.2 Summary of Construction Cost (Electric Power Sector)

(Million R.O.)

| Item | Foreign Currency | (US$ million) | Local Currency | Total |
|---|---|---|---|---|
| A. Generating facilities | 160.33 | (468.79) | 10.79 | 171.12 |
| 1. Equipment | 145.10 | (424.27) | 1.30 | 146.40 |
| a) Gas turbine-generator | 70.17 | (205.18) | 0.42 | 70.59 |
| Equipment cost | 58.94 | (172.34) | - | 58.94 |
| Erection work | 11.23 | ( 32.84) | 0.42 | 11.65 |
| b) Steam turbine-generator | 74.93 | (219.09) | 0.88 | 75.81 |
| Equipment cost | 62.94 | (184.03) | - | 62.94 |
| Erection work | 11.99 | ( 35.06) | 0.88 | 12.87 |
| 2. Civil works | 4.19 | ( 12.24) | 4.74 | 8.93 |
| Foundation works | 1.25 | ( 3.65) | 1.26 | 2.51 |
| Land reclatimation (50%) | 0.50 | ( 1.46) | 0.50 | 1.00 |
| Water intake and out-fall (55%) | 2.44 | ( 7.13) | 2.98 | 5.42 |
| 3. Buildings | 5.38 | ( 15.73) | 3.60 | 8.98 |
| Buildings for power plant | 4.94 | ( 14.44) | 3.26 | 8.20 |
| Buildings for common use (50%) | 0.44 | ( 1.29) | 0.34 | 0.78 |
| 4. Switchyard | 5.66 | ( 16.55) | 1.15 | 6.81 |
| B. Transmission facilities | 10.86 | ( 31.75) | 4.35 | 15.21 |
| Barka PS - Barka SS | 1.14 | ( 3.33) | 0.46 | 1.60 |
| Barka SS - Khuwair SS | 4.13 | ( 12.08) | 1.65 | 5.78 |
| Musanna SS - Khabourah SS | 2.68 | ( 7.83) | 1.08 | 3.76 |
| Khabourah SS - Sohar SS | 2.91 | ( 8.51) | 1.16 | 4.07 |
| C. Substation facilities | 19.22 | ( 56.20) | 3.64 | 22.86 |
| Khuwair Substation | 9.42 | ( 27.54) | 1.09 | 10.51 |
| Barka substation (extension) | 5.43 | ( 15.88) | 0.74 | 6.17 |
| Khabourah substation | 2.49 | ( 7.28) | 0.29 | 2.78 |
| Buildings | 1.88 | ( 5.50) | 1.52 | 3.40 |
| Sub-total (base direct cost) | 190.41 | (556.74) | 18.78 | 209.19 |
| D. Other costs | | | | |
| Contingencies | 19.04 | ( 55.67) | 1.86 | 20.90 |
| MEW's administration expenses | - | ( - ) | 6.28 | 6.28 |
| Engineering fee | 5.23 | ( 15.29) | - | 5.23 |
| Total (1985 prices) | 214.68 | (627.70) | 26.92 | 241.60 |
| Escalated price | 235.41 | (688.33) | 28.71 | 264.12 |

Table 17.3 Summary of Construction Cost (Desalination Sector)

(Million R.O.)

| Item | Foreign Currency | (US$ million) | Local Currency | Total |
|---|---|---|---|---|
| A. Processing facilities | 48.59 | (142.07) | 6.21 | 54.80 |
| Equipment cost | 39.68 | (116.02) | - | 39.68 |
| Foundation works and reservoir | 3.84 | ( 11.23) | 2.45 | 6.29 |
| Buildings for desalination plant | 0.70 | ( 2.05) | 0.52 | 1.22 |
| Buildings for common use (50%) | 0.34 | ( 0.99) | 0.44 | 0.78 |
| Erection work | 4.03 | ( 11.78) | 2.80 | 6.83 |
| B. Water intake and out-fall facilities | 2.93 | ( 8.57) | 2.95 | 5.88 |
| Screen and other equipment | 0.45 | ( 1.32) | - | 0.45 |
| Land reclamation (50%) | 0.50 | ( 1.46) | 0.50 | 1.00 |
| Water intake and out-fall (45%) | 1.98 | ( 5.79) | 2.45 | 4.43 |
| C. Product water distribution facilities | 17.88 | ( 52.28) | 9.48 | 27.36 |
| Pumps, pipes and other materials | 15.73 | ( 46.00) | - | 15.73 |
| Civil and installation works | 2.15 | ( 6.28) | 9.48 | 11.63 |
| Sub-total (Base direct cost) | 69.40 | (202.92) | 18.64 | 88.04 |
| D. Other costs | | | | |
| Physical contingencies (10%) | 6.94 | ( 20.29) | 1.86 | 8.80 |
| MEW's administration expenses (3%) | - | ( - ) | 2.64 | 2.64 |
| Engineering fee (2.5%) | 2.20 | ( 6.43) | - | 2.20 |
| Total (1985 prices) | 78.54 | (229.64) | 23.14 | 101.68 |
| Excalated price | 84.83 | (248.04) | 25.02 | 109.85 |

Table-17.4 Annual Disbursement of Construction Cost (Electric Power Sector)

| Item | 1986 | | | 1987 | | | 1988 | | | 1989 | | | 1990 | | | 1991 | | | 1992 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total |
| A. Power plant | 5.02 | 2.00 | 7.02 | 34.19 | 4.10 | 38.29 | 53.36 | 1.66 | 55.02 | 50.50 | 1.42 | 51.92 | 12.43 | 0.74 | 13.17 | 4.83 | 0.87 | 5.70 | 160.33 | 10.79 | 171.12 |
| 1. Equipment | 2.37 | - | 2.37 | 26.86 | 0.07 | 26.93 | 51.15 | 0.22 | 51.37 | 48.92 | 0.43 | 49.35 | 11.91 | 0.48 | 12.39 | 3.89 | 0.10 | 3.99 | 145.10 | 1.30 | 146.40 |
| Gas turbine-generator | 2.35 | - | 2.35 | 22.99 | 0.07 | 23.06 | 27.80 | 0.20 | 28.00 | 14.72 | 0.11 | 14.83 | 2.31 | 0.04 | 2.35 | - | - | - | 70.17 | 0.42 | 70.59 |
| Steam turbine-generator | 0.02 | - | 0.02 | 3.87 | - | 3.87 | 23.35 | 0.02 | 23.37 | 34.20 | 0.32 | 34.52 | 9.60 | 0.44 | 10.04 | 3.89 | 0.10 | 3.99 | 74.93 | 0.88 | 75.81 |
| 2. Civil works | 0.99 | 1.12 | 2.11 | 1.96 | 2.12 | 4.08 | 0.64 | 0.72 | 1.36 | 0.19 | 0.31 | 0.50 | - | - | - | 0.41 | 0.47 | 0.88 | 4.19 | 4.74 | 8.93 |
| 3. Buildings | 0.80 | 0.53 | 1.33 | 1.05 | 1.16 | 2.21 | 1.09 | 0.67 | 1.76 | 1.39 | 0.68 | 2.07 | 0.52 | 0.26 | 0.78 | 0.53 | 0.30 | 0.83 | 5.38 | 3.60 | 8.98 |
| 4. Switchyard | 0.86 | 0.35 | 1.21 | 4.32 | 0.75 | 5.07 | 0.48 | 0.05 | 0.53 | | | | | | | | | | 5.66 | 1.15 | 6.81 |
| B. Transmission facilities | 3.82 | 0.46 | 4.28 | 7.04 | 1.66 | 8.70 | - | 2.11 | 2.11 | - | 0.12 | 0.12 | | | | | | | 10.86 | 4.35 | 15.21 |
| Barka PS - Barka SS | 1.14 | 0.14 | 1.28 | - | 0.27 | 0.27 | - | 0.05 | 0.05 | | | | | | | | | | 1.14 | 0.46 | 1.60 |
| Barka SS - Khuwair SS | | | | 4.13 | 0.50 | 4.63 | - | 1.15 | 1.15 | | | | | | | | | | 4.13 | 1.65 | 5.78 |
| Musanna SS - Khabourah SS | 2.68 | 0.32 | 3.00 | - | 0.43 | 0.43 | - | 0.33 | 0.33 | | | | | | | | | | 2.68 | 1.08 | 3.76 |
| Khabourah SS - Sohar SS | | | | 2.91 | 0.46 | 3.37 | - | 0.58 | 0.58 | - | 0.12 | 0.12 | | | | | | | 2.91 | 1.16 | 4.07 |
| C. Substation facilities | 1.03 | 0.49 | 1.52 | 6.66 | 1.67 | 8.33 | 11.53 | 1.48 | 13.01 | | | | | | | | | | 19.22 | 3.64 | 22.86 |
| Khuwair substation | 0.02 | 0.01 | 0.03 | 1.07 | 0.25 | 1.32 | 8.33 | 0.83 | 9.16 | | | | | | | | | | 9.42 | 1.09 | 10.51 |
| Barka substation | 0.68 | 0.21 | 0.89 | 4.22 | 0.47 | 4.69 | 0.53 | 0.06 | 0.59 | | | | | | | | | | 5.43 | 0.74 | 6.17 |
| Khabourah substation | - | - | - | 0.30 | 0.08 | 0.38 | 2.19 | 0.21 | 2.40 | | | | | | | | | | 2.49 | 0.29 | 2.78 |
| Buildings | 0.33 | 0.27 | 0.60 | 1.07 | 0.87 | 1.94 | 0.48 | 0.38 | 0.86 | | | | | | | | | | 1.88 | 1.52 | 3.40 |
| Sub-total (1985 prices) | 9.87 | 2.95 | 12.82 | 47.89 | 7.43 | 55.32 | 64.89 | 5.25 | 70.14 | 50.50 | 1.54 | 52.04 | 12.43 | 0.74 | 13.17 | 4.83 | 0.87 | 5.70 | 190.41 | 18.78 | 209.19 |
| D. Other costs | | | | | | | | | | | | | | | | | | | | | |
| Physical contingencies (10%) | 0.99 | 0.29 | 1.28 | 4.79 | 0.74 | 5.53 | 6.49 | 0.52 | 7.01 | 5.05 | 0.15 | 5.20 | 1.24 | 0.07 | 1.31 | 0.48 | 0.09 | 0.57 | 19.04 | 1.86 | 20.90 |
| MEW's administration expenses (3%) | - | 0.38 | 0.38 | - | 1.66 | 1.66 | - | 2.11 | 2.11 | - | 1.56 | 1.56 | - | 0.40 | 0.40 | - | 0.17 | 0.17 | - | 6.28 | 6.28 |
| Engineering fee (2.5%) | 2.00 | - | 2.00 | 0.70 | - | 0.70 | 0.70 | - | 0.70 | 0.70 | - | 0.70 | 0.70 | - | 0.70 | 0.43 | - | 0.43 | 5.23 | - | 5.23 |
| Total (1985 prices) | 12.86 | 3.62 | 16.48 | 53.38 | 9.83 | 63.21 | 72.08 | 7.88 | 79.96 | 56.25 | 3.25 | 59.50 | 14.37 | 1.21 | 15.58 | 5.74 | 1.13 | 6.87 | 214.68 | 26.92 | 241.60 |
| Escalated price | 13.24 | 3.73 | 16.97 | 56.63 | 10.42 | 67.05 | 78.76 | 8.16 | 86.92 | 63.28 | 3.65 | 66.93 | 16.65 | 1.40 | 18.05 | 6.85 | 1.35 | 8.20 | 235.41 | 28.71 | 264.12 |

Table 17.5 Annual Disbursement of Construction Cost (Desalination Sector)

(Million R.O.)

| Item | 1986 | | | 1987 | | | 1988 | | | 1989 | | | 1990 | | | 1991 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total |
| 1. Land reclamation, water intake and out-fall works | 0.69 | 0.89 | 1.58 | 1.27 | 1.47 | 2.74 | 0.27 | 0.30 | 0.57 | | | | | | | 0.25 | 0.29 | 0.54 | 2.48 | 2.95 | 5.43 |
| 2. Screen and other equipment | 0.05 | - | 0.05 | 0.36 | - | 0.36 | 0.04 | - | 0.04 | | | | | | | | | | 0.45 | - | 0.45 |
| 3. Buildings for desalination plant | 0.07 | 0.05 | 0.12 | 0.42 | 0.32 | 0.74 | 0.14 | 0.10 | 0.24 | | | | | | | 0.07 | 0.05 | 0.12 | 0.70 | 0.52 | 1.22 |
| 4. Buildings for common use | 0.03 | 0.05 | 0.08 | 0.18 | 0.24 | 0.42 | 0.09 | 0.12 | 0.21 | | | | | | | 0.04 | 0.03 | 0.07 | 0.34 | 0.44 | 0.78 |
| 5. Desalination equipment | 2.96 | - | 2.96 | 12.32 | 0.59 | 12.91 | 14.14 | 1.72 | 15.86 | 10.02 | 1.23 | 11.25 | 4.06 | 1.26 | 5.32 | | | | 43.50 | 4.80 | 48.30 |
| Plant No. 1 | 2.13 | - | 2.13 | 3.20 | 0.35 | 3.55 | 1.92 | 0.45 | 2.37 | | | | | | | | | | 7.25 | 0.80 | 8.05 |
| Plant No. 2 | 0.83 | - | 0.83 | 4.50 | 0.24 | 4.74 | 1.92 | 0.56 | 2.48 | | | | | | | | | | 7.25 | 0.80 | 8.05 |
| Plant No. 3 | | | | 4.62 | - | 4.62 | 2.13 | 0.71 | 2.84 | 0.50 | 0.09 | 0.59 | | | | | | | 7.25 | 0.80 | 8.05 |
| Plant No. 4 | | | | | | | 3.67 | - | 3.67 | 2.51 | 0.45 | 2.96 | 1.07 | 0.35 | 1.42 | | | | 7.25 | 0.80 | 8.05 |
| Plant No. 5 | | | | | | | 3.67 | - | 3.67 | 2.51 | 0.45 | 2.96 | 1.07 | 0.35 | 1.42 | | | | 7.25 | 0.80 | 8.05 |
| Plant No. 6 | | | | | | | 0.83 | - | 0.83 | 4.50 | 0.24 | 4.74 | 1.92 | 0.56 | 2.48 | | | | 7.25 | 0.80 | 8.05 |
| 6. Auxiliary boilers | 0.71 | - | 0.71 | 2.04 | 0.21 | 2.25 | 1.30 | 0.24 | 1.54 | | | | | | | | | | 4.05 | 0.45 | 4.50 |
| 7. Product water transportation facilities | 5.92 | - | 5.92 | 10.66 | 7.11 | 17.77 | 1.30 | 2.37 | 3.67 | | | | | | | | | | 17.88 | 9.48 | 27.36 |
| Sub-total (Base direct cost) | 10.43 | 0.99 | 11.42 | 27.25 | 9.94 | 37.19 | 17.28 | 4.85 | 22.13 | 10.02 | 1.23 | 11.25 | 4.06 | 1.26 | 5.32 | 0.36 | 0.37 | 0.73 | 69.40 | 18.64 | 88.04 |
| 8. Other costs | | | | | | | | | | | | | | | | | | | | | |
| Physical contingencies (10%) | 1.04 | 0.10 | 1.14 | 2.72 | 1.00 | 3.72 | 1.73 | 0.48 | 2.21 | 1.00 | 0.12 | 1.12 | 0.41 | 0.13 | 0.54 | 0.04 | 0.03 | 0.07 | 6.94 | 1.86 | 8.80 |
| MEW's administration expenses (3%) | - | 0.33 | 0.33 | - | 1.09 | 1.09 | - | 0.66 | 0.66 | - | 0.34 | 0.34 | - | 0.16 | 0.16 | - | 0.06 | 0.06 | - | 2.64 | 2.64 |
| Engineering fee (2.5%) | 0.68 | - | 0.68 | 0.34 | - | 0.34 | 0.34 | - | 0.34 | 0.34 | - | 0.34 | 0.34 | - | 0.34 | 0.16 | - | 0.16 | 2.20 | - | 2.20 |
| Total (1985 prices) | 12.15 | 1.42 | 13.57 | 30.31 | 12.03 | 42.34 | 19.35 | 5.99 | 25.34 | 11.36 | 1.69 | 13.05 | 4.81 | 1.55 | 6.36 | 0.56 | 0.46 | 1.02 | 78.54 | 23.14 | 101.68 |
| Excalated price | 12.51 | 1.46 | 13.97 | 32.16 | 12.76 | 44.92 | 21.14 | 6.55 | 27.69 | 12.78 | 1.90 | 14.68 | 5.57 | 1.80 | 7.37 | 0.67 | 0.55 | 1.22 | 84.83 | 25.02 | 109.85 |

# CHAPTER 18

# ECONOMIC EVALUATION

# CHAPTER 18 ECONOMIC EVALUATION

## 18.1 METHOD OF EVALUATION

### 18.1.1 Dual purpose plant and single purpose plant

The steam extracted from dual purpose power plant is supplied to desalination plant at high temperature. Therefore, the thermal efficiency of dual purpose power plant is lower than that of single purpose power plant. However, to produce given quantities of electric power and desalinated water, dual purpose plant can do it with far smaller quantity of fuel than that of fuel used by two single purpose plants for power generation and desalination. Hence, costs of steam generators of the dual purpose plant are fairly less than those of the two single purpose plants for electricity and water. The economy in energy input, in construction cost and in operation and maintenance cost due to common use of facilities and maintenance staff of dual purpose plant is well known, so economic justification of the dual purpose plant as compared with combination of two single purpose plants is not necessary to describe here.

### 18.1.2 Method of evaluation

The objective of the economic evaluation is to select the most economical types for power plant and desalination plant. For this purpose, the total costs incurred from the beginning of construction up to the end of service life of each alternative plant are converted to the present worth and compared with each other in terms of "benefit/cost ratio" and "economic internal rate of return (equalizing discount rate)".

In the dual purpose plant, power plant and desalination plant is connected by steam cycle and operated to produce given quantities of electric power and desalinated water in accordance with respective demand patterns for electricity and water. Operations of the both plants are controlled by each other, but the plant optimization can be carried out by setting up conditions in the following manner:

(1) Conditions for selecting type of desalination plant

Influences exerted on the power plant by the desalination plant are as follows:

- Quantity of steam used by desalination plant which differs according to performance ratio.
- Electric energy used by desalination plant for its station service which differs according to performance ratio.

In this context, if some conditions are set up, the cost comparison of desalination plants for each performance ratio can be made independently to the type of power plant, hence the optimum type of desalination plant can be selected. When once the optimum type of desalination plant is selected, the cost comparison of alternative power plants can be made because influences exerted by desalination plant become the same for each type of power plant. For this purpose, the following conditions were set up:

a) Allocation of steam cost (fuel cost)

The steam cost (fuel cost) shall be allocated to power plant and desalination plant according to calorie of steam used by both plants respectively. For this purpose, the unit costs per ton of steam production are calculated for both plants. Thus, fuel cost of power plant and desalination plant was calculated based on the respective unit cost per ton of steam production and the respective quantity of steam used.

b) Cost of electric energy used by desalination plant for station service

The cost of electricity generated by Barka power plant cannot be calculated before selection of type of power plant. Therefore, the present electricity tariff shall be used as the unit cost of electricity used by desalination plant for its station service.

c) Under the conditions a) and b), the cost comparison of desalination plant for each performance ratio can be carried out.

(2) Conditions for selecting type of power plant

After selection of type of desalination plant, the problem arises what type of power plant should be selected. For this purpose, the following conditions were set up:

a) Construction cost of heat recovery steam generators

Although steam produced by heat recovery steam generators connected to 5 units of gas turbine-generator of Type-D power plant is not used by this power plant, the construction cost of these steam generators shall be included in the cost of Type-D power plant because the conditions must be the same for each type of desalination plant.

b) Cost of steam produced by heat recovery steam generators

The steam produced by the above 5 units of heat recovery steam generator does not necessitate additional fuel and can be regarded gratuitous. However, in order to make the same conditions for desalination sector, the same amount of steam cost as that of steam extracted from steam turbine shall be included in the cost of desalination plant. This means that a shadow price is used for steam produced by heat recovery steam generators.

c) Equalization of supply service by application of kW and kWh adjustment factors

Quantity of electric energy used for station service, as well as, installed capacity, sending-end capacity and sent-out energy are different by type of power plant. Consequently, kW and kWh adjustment factors shall be applied to each type of power plant in order to make adequate cost comparison of power plants.

## 18.2 BASIC CONDITIONS

Basic conditions adopted for economic evaluation are as follows:

### 18.2.1 Prices

Consistent with the principles of economic evaluation, all items are expressed in real terms of 1985, i.e. excluding any future inflation, and all costs are converted to present worth as of the beginning of 1986 which is the starting year of the construciton.

### 18.2.2 Service life of facilities

In general, the economic service life of facilities, except for gas turbine, is considered at 20 to 25 years for both power plant and desalination plant, so the discounted cash-flow calculation of fuel cost, operation and maintenance cost, administration cost, etc. shall be made over the period up to 2010. The life of gas turbine-generators was assumed to be the half of that of steam turbine-generators.

### 18.2.3 Discount rate to be used for economic evaluation

In the economic evaluation, the question arises what value should be used as the discount rate which reflects the opportunity cost of capital. In this context, it is to be noted that the Oman Development Bank applys an interest rate of 8%, while the export and import banks of industrial countries apply an interest rate of 8.5% to 9.3% as the guide-line. It is also found that in Oman some public projects have been financed from abroad at an interest rate of 5%. Taking these into account, a discount rate of 8% shall be used as the criteria in the economic evaluation.

### 18.2.4 Fuel used

The reserves of natural gas in Oman are not so abundant. Data and information are not available to know whether Barka power plant of the total installed capacity of more than 700 MW can depend completely upon natural gas for the required quantity of fuel. The quantity of gas to be allocated the Barka project is not indicated in the concrete by the government. However, the economic evaluation shall be carried out on the assumption that the required quantity of gas for the whole service life of the plant is to be piped up to the plant site and supplied at the current price.

In this context, sensitivity analysis will be carried out for fuel - at 2 times current price.

## 18.3 ECONOMIC EVALUATION OF POWER PLANT

### 18.3.1 Construction cost

The construction cost of the power plant at 1985 prices and the cost of gas turbine-generators included in the construction cost are as follows:

(Million R.O.)

| Plant type | Total | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|
| Type-A | | | | | | | |
| Total amount | 167.4 | 9.8 | 56.0 | 43.2 | 43.1 | 10.4 | 4.9 |
| Gas turbine | 48.9 | 2.7 | 25.3 | 18.5 | 2.4 | - | - |
| Type-B | | | | | | | |
| Total amount | 164.4 | 7.6 | 40.4 | 39.0 | 61.0 | 12.9 | 3.5 |
| Gas turbine | 114.1 | 2.7 | 26.6 | 35.1 | 41.6 | 8.1 | - |
| Type-C | | | | | | | |
| Total amount | 168.2 | 9.9 | 56.6 | 43.3 | 43.1 | 10.4 | 4.9 |
| Gas turbine | 48.9 | 2.7 | 25.3 | 18.5 | 2.4 | - | - |
| Type-D | | | | | | | |
| Total amount | 171.8 | 7.3 | 39.0 | 37.7 | 45.8 | 32.4 | 9.6 |
| Gas turbine | 130.4 | 2.7 | 26.6 | 33.7 | 32.1 | 29.9 | 5.4 |
| Type-E | | | | | | | |
| Total amount | 178.9 | 8.0 | 44.5 | 50.1 | 47.0 | 22.3 | 7.0 |
| Gas turbine | 81.5 | 2.7 | 26.6 | 31.0 | 6.3 | 12.2 | 2.7 |
| Type-F | | | | | | | |
| Total amount | 197.7 | 8.1 | 44.3 | 63.5 | 60.0 | 15.2 | 6.6 |
| Gas turbine | 81.5 | 2.7 | 26.6 | 32.3 | 17.2 | 2.7 | - |

Note: The above costs include physical contingencies (10%), administration expenses (3%) and engineering fee (2.5%).

The present worth of the above costs are as follows:

(Million R.O.)

| Plant type | Discount rate | | | |
|---|---|---|---|---|
| | 8% | 10% | 12% | 14% |
| Type-A | 152.1 | 141.0 | 131.8 | 123.5 |
| Type-B | 169.7 | 153.6 | 140.1 | 128.7 |
| Type-C | 152.7 | 141.7 | 132.5 | 124.1 |
| Type-D | 177.9 | 159.7 | 144.8 | 132.3 |
| Type-E | 169.2 | 155.1 | 142.7 | 132.3 |
| Type-F | 184.9 | 169.6 | 156.6 | 145.5 |

### 18.3.2 Operation and maintenance costs

Statistically, the operation and maintenance costs are about 4.0% of the construction cost for both steam power plant and gas turbine power plant. Therefore, the operation and maintenance costs for each alternative are estimated as follows:

Type-A power plant:
167.4 x 0.04 = 6.7 million R.O.

Type-B power plant:
164.4 x 0.04 = 6.6 million R.O.

Type-C power plant:
168.2 x 0.04 = 6.7 million R.O.

Type-D power plant:
171.8 x 0.04 = 6.9 million R.O.

Type-E power plant:
178.9 x 0.04 = 7.2 million R.O.

Type-F power plant:

197.7 x 0.04 = 7.9 million R.O.

It is considered that the annual disbursement of the operation and maintenance costs will increase in accordance with increase in generating capacity of the year. The capacity increase for each alternative is planned as follows:

(MW)

| Plant | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|
| Type-A, C | 160 | 360 | 600 | 720 |
| Type-B | 160 | 400 | 560 | 720 |
| Type-D | 160 | 360 | 600 | 760 |
| Type-E | 160 | 320 | 560 | 720 |
| Type-F | 160 | 320 | 600 | 740 |

As shown above, about 20% of the total capacity is planned to be put into operation in 1988, 50% in 1989, 80% in 1990 and 100% in 1991 and thereafter. Therefore, the operation and maintenance costs will be disbursed as follows:

(Million R.O.)

| Year | Type-A | Type-B | Type-C | Type-D | Type-E | Type-F |
|---|---|---|---|---|---|---|
| 1988 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| 1989 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 |
| 1990 | 5.4 | 5.3 | 5.4 | 5.5 | 5.8 | 6.3 |
| 1991 and thereafter | 6.7 | 6.6 | 6.7 | 6.9 | 7.2 | 7.9 |

### 18.3.3 Administration expenses

In general, the administration expenses of the owner are about 0.5% of the construction cost for both steam power plant and gas turbine power plant.

Therefore, these expenses for each alternative are estimated as follows:

Type-A Power plant: 167.4 x 0.005 = 0.8 million R.O.
Type-B Power plant: 164.4 x 0.005 = 0.8 million R.O.
Type-C Power plant: 168.2 x 0.005 = 0.8 million R.O.
Type-D Power plant: 171.8 x 0.005 = 0.9 million R.O.
Type-E Power plant: 178.9 x 0.005 = 0.9 million R.O.
Type-F Power plant: 197.7 x 0.005 = 1.0 million R.O.

The annual disbursement of these expenses will be made in the same manner as in the case of operation and maintenance costs. Therefore:

(Million R.O.)

| Year | Type-A | Type-B | Type-C | Type-D | Type-E | Type-F |
|---|---|---|---|---|---|---|
| 1988 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 1989 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| 1990 | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 |
| 1991 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 1.0 |
| and thereafter | | | | | | |

18.3.4 Fuel cost

(1) Price of fuel

The price and heat value of natural gas supplied to MEW by Petroleum Development Oman (PDO) are as follows:

Price: US\$2.83/$10^3$ft$^3$ ...... 0.0342 R.O./Nm$^3$
Heat value: 9,000 kcal/Nm$^3$ ...... 3.8 Baizas/1,000 kcal
(= US\$0.0111/1,000 kcal)

The above gas price is the half of the export price of crude oil in Oman, and it is not favoured by any subvention of the government. From long-term viewpoint the price of natural gas is considered to approach the oil price, but from medium-term viewpoint it is considered suitable for setting up its price on the LNG basis. The export price of LNG differs to some extent by producing country, but it is in general around the half of the oil price. In Canada, LNG is supplied at C$3.655 (US$2.836/million B.T.U. (252,000 kcal) - US$0.0113/1,000 kcal - which is almost comparable to PDO's selling price of US$0.0111 (3.8 Baizas/1,000 kcal). Therefore, there is no problem to use the PDO's selling in the economic evaluation.

(2) *Energy generation and fuel consumption*

The operation mode of Barka power plant is described in Chapter 7. Based on this operation mode, the energy generation and fuel consumption are calculated as shown in Tables 18.1.(a) and 18.1.(b), and summarized as follows:

| Plant type | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|
| Energy generation (GWh) | | | | | | | | |
| Type-A,C | 491 | 1,799 | 2,698 | 4,844 | 4,956 | 5,067 | 5,176 | 5,284 |
| Type-B | 491 | 1,962 | 2,780 | 4,701 | 4,786 | 4,872 | 4,957 | 5,042 |
| Type-D | 491 | 1,799 | 2,821 | 4,894 | 5,058 | 5,217 | 5,385 | 5,549 |
| Type-E | 491 | 1,635 | 2,576 | 4,803 | 4,934 | 5,064 | 5,195 | 5,325 |
| Type-F | 491 | 1,635 | 2,780 | 4,859 | 5,014 | 5,168 | 5,322 | 5,477 |
| Fuel consumption (Million $Nm^3$) | | | | | | | | |
| Type-A,C | 180 | 490 | 739 | 1,618 | 1,630 | 1,642 | 1,635 | 1,664 |
| Type-B | 180 | 607 | 751 | 1,526 | 1,529 | 1,532 | 1,535 | 1,539 |
| Type-D | 180 | 490 | 780 | 1,650 | 1,668 | 1,688 | 1,706 | 1,728 |
| Type-E | 180 | 601 | 872 | 1,645 | 1,669 | 1,693 | 1,717 | 1,741 |
| Type-F | 180 | 601 | 956 | 1,639 | 1,666 | 1,693 | 1,720 | 1,747 |

(3) Fuel cost of power plant

Based on the avobe-mentioned price and consumption, the fuel cost for power generation and desalination is estimated as follows:

(Million R.O.)

| Year | Type-A, C | Type-B | Type-D | Type-E | Type-F |
|---|---|---|---|---|---|
| 1988 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 |
| 1989 | 16.8 | 20.8 | 16.8 | 20.6 | 20.6 |
| 1990 | 25.3 | 25.7 | 26.7 | 29.8 | 32.7 |
| 1991 | 55.3 | 52.2 | 56.4 | 56.3 | 56.1 |
| 1992 | 55.7 | 52.3 | 57.0 | 57.1 | 57.0 |
| 1993 | 56.2 | 52.4 | 57.7 | 57.9 | 57.9 |
| 1994 | 56.5 | 52.5 | 58.3 | 58.7 | 58.8 |
| 1995 and thereafter | 56.9 | 52.7 | 59.1 | 59.5 | 59.7 |

To obtain fuel cost charged on the power plant, it is necessary to deduct fuel cost of the desalination plant from the above total fuel cost. As described later, it is judged that the desalination plant of a performance ratio of 8 is the most economical for both extraction turbine alternative and back pressure turbine alternative. The fuel cost of the desalination plant is shown in paragraph 18.4.2.(3). The fuel cost charged on the power plant is calculated as follows:

(Million R.O.)

| Plant type | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 and therafter |
|---|---|---|---|---|---|---|---|---|
| <u>Type-A, C</u> | | | | | | | | |
| Total amount | 6.2 | 16.8 | 25.3 | 55.3 | 55.7 | 56.2 | 56.5 | 56.9 |
| Desalination | – | – | -2.2 | -4.4 | -4.9 | -5.5 | -6.1 | -6.4 |
| Power plant | 6.2 | 16.8 | 23.1 | 50.9 | 50.8 | 50.7 | 50.4 | 50.5 |
| <u>Type-B</u> | | | | | | | | |
| Total amount | 6.2 | 20.8 | 25.7 | 52.2 | 52.3 | 52.4 | 52.5 | 52.7 |
| Desalination | – | – | -2.2 | -4.4 | -4.9 | -5.5 | -6.1 | -6.4 |
| Power plant | 6.2 | 20.8 | 23.5 | 47.8 | 47.4 | 46.9 | 46.4 | 46.3 |
| <u>Type-D</u> | | | | | | | | |
| Total amount | 6.2 | 16.8 | 26.7 | 56.4 | 57.0 | 57.7 | 58.3 | 59.1 |
| Desalination | – | – | -2.2 | -4.4 | -4.9 | -5.5 | -6.1 | -6.4 |
| Power plant | 6.2 | 16.8 | 24.5 | 52.0 | 52.1 | 52.2 | 52.2 | 52.7 |
| <u>Type-E</u> | | | | | | | | |
| Total amount | 6.2 | 20.6 | 29.8 | 56.3 | 57.1 | 57.9 | 58.7 | 59.5 |
| Desalination | – | – | -3.3 | -6.7 | -7.5 | -8.3 | -9.2 | -9.7 |
| Power plant | 6.2 | 20.6 | 26.5 | 49.6 | 49.6 | 49.6 | 49.5 | 49.8 |
| <u>Type-F</u> | | | | | | | | |
| Total amount | 6.2 | 20.6 | 32.7 | 56.1 | 57.0 | 57.9 | 58.8 | 59.7 |
| Desalination | – | – | -3.3 | -6.7 | -7.5 | -8.3 | -9.2 | -9.7 |
| Power plant | 6.2 | 20.6 | 29.4 | 49.4 | 49.5 | 49.6 | 49.6 | 50.0 |

18.3.5 Present worth of the total costs

The annual disbursement and present worths of the construction cost, operation and maintenance costs, administration expenses and fuel cost for each alternative are shown in Tables 18.2, 18.3, and 18.4, and summarized in Table 18.5.

18.3.6 KW and kWh adjustment factors

The economic evaluation of alternative power plants must be conducted on the same supply service, i.e. the same energy and capacity at sending-end. Since the constitution of power plant (sharing of steam turbine-generators and gas turbine-generators) is different by type of power plant, both energy and capacity at sending-end are also different by type of power plant.

Therefore, it is necessary to adjust the fixed cost (construction cost, operation and maintenance cost, administration expenses) and fuel cost of each alternative by kW and kWh adjustment factors. These adjustment factors are calculated in the following manner:

(1) KW adjustment factor

By taking the sending-end capacity of the Type-F power plant as the basis (= 1), kW adjustment factors to be applied to the other alternatives can be obtained as follows:

| Power Plant | Total installed capacity | Station service loss (MW) | | Capacity at sending-end | Adjustment factor |
|---|---|---|---|---|---|
| | | Power plant | Desalination plant | | |
| Type-A | 720 | 15 | 21 | 684 | 1.038 |
| Type-B | 720 | 6 | 21 | 693 | 1.025 |
| Type-C | 720 | 15 | 21 | 684 | 1.038 |
| Type-D | 760 | 6 | 21 | 733 | 0.969 |
| Type-E | 720 | 8 | 21 | 691 | 1.027 |
| Type-F | 740 | 9 | 21 | 710 | 1 (Basis) |

(2) KWh adjustment factor

It is appropriate for kWh adjustment factor to be calculated based on the energy sent-out in 1995. (From this year the energy generation becomes constant every year.) By taking the sent-out energy of the Type-F power plant as the basis (= 1), kWh adjustment factors to be applied to the other alternatives can be calculated as follows:

(Million R.O.)

| Plant type | Energy generation (GWh) | Energy for station service (GWh) | | Energy sent-out (GWh) | Adjustment factor |
|---|---|---|---|---|---|
| | | Power plant | Desalination plant | | |
| Type-A | 5,284 | 112 | 181 | 4,991 | 1.048 |
| Type-B | 5,042 | 40 | 181 | 4,821 | 1.085 |
| Type-C | 5,284 | 112 | 181 | 4,991 | 1.048 |
| Type-D | 5,549 | 45 | 181 | 5,323 | 0.983 |
| Type-E | 5,325 | 61 | 181 | 5,083 | 1.029 |
| Type-F | 5,477 | 64 | 181 | 5,232 | 1(Basis) |

### 18.3.7 Benefit/cost ratio

By multiplying fixed costs by kW adjustment factor and fuel cost by kWh adjustment factor, the present worth of the adjusted total costs of each alternative was calculated and shown in Table 18.5.

The above table shows that Type-A power plant is the most economical at the discount rate of 8%, and the second most economical is Type-D power plant. Between three alternatives of types-A, B and D there is no large economic difference. The rate of return (EIRR) of Type-A power plant against Type-D and Type-B power plants is 8.9% and 11.5% respectively.

Seen from economic viewpoint, Type-F power plant is the least advantageous of the six alternatives (Types-A, B, C, D, E and F).

In the economic evaluation of power development project, the "benefit" of the project under consideration is expressed by the cost of alternative project, i.e. the expenditure to be saved by the execution of that project under consideration.

When putting the present worth of the total costs of Type-A, Type-B, Type-C, Type-D, Type-E and Type-F power plants as PA, PB, PC, PD, PE and PF respectively, the benefit/cost ratio (B/C ratio) of Type-F power plant is calculated as follows (See Table 18.5):

| | | Discount rate | | | |
|---|---|---|---|---|---|
| B/C ratio of Type-F | | 8 % | 10 % | 12 % | 14 % |
| Against Type-A | PA/PF | 0.969 | 0.966 | 0.964 | 0.962 |
| Against Type-B | PB/PF | 0.974 | 0.969 | 0.963 | 0.958 |
| Against Type-C | PC/PF | 0.970 | 0.968 | 0.966 | 0.963 |
| Against Type-D | PD/PF | 0.973 | 0.963 | 0.953 | 0.943 |
| Against Type-E | PE/PF | 0.988 | 0.986 | 0.983 | 0.980 |

Table 18.1.(a) Energy generation and fuel consumption (1988-1990)

| Plant type | Year | Energy generation | Fuel consumption |
|---|---|---|---|
| A, C | 1988 | 160 MW (GT) x 8,760 hr x 6/12 x 0.7 (plant factor) = 490.6 GWh | 490.6 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 180.4 million Nm$^3$ |
| | 1989 | 160 MW (GT) x 8,760 hr x 4/12 x 0.7 = 327.0 GWh | 327.0 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 120.3 million Nm$^3$ |
| | | 360 MW (CC) x 8,760 hr x 8/12 x 0.7 = 1,471.7 GWh | 1,471.7 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 369.6 million Nm$^3$ |
| | | Total 1,798.7 GWh | Total 489.9 million Nm$^3$ |
| | 1990 | 360 MW (CC) x 8,760 hr x 1 x 0.7 = 2,207.5 GWh | 2,207.5 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 554.3 million Nm$^3$ |
| | | 120 MW (ST) x 8,760 hr x 7/12 x 0.7 = 429.2 GWh | 429.2 GWh x 3,390 Kcal/kWh (25.4%) ÷ 9,000 Kcal/Nm$^3$ 161.7 million Nm$^3$ |
| | | 120 MW (ST) x 8,760 hr x 1/12 x 0.7 = 61.3 GWh | 61.3 GWh x 3,390 Kcal/kWh (25.4%) ÷ 9,000 Kcal/Nm$^3$ = 23.1 million Nm$^3$ |
| | | Total 2,698.0 GWh | Total 739.1 million Nm$^3$ |
| B | 1988 | 160 MW (GT) x 8,760 hr x 6/12 x 0.7 (plant factor) = 490.6 GWh | 490.6 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 180.4 million Nm$^3$ |
| | 1989 | 160 MW (GT) x 8,760 hr x 4/12 x 0.7 = 327.0 GWh | 327.0 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 120.3 million Nm$^3$ |
| | | 240 MW (CC) x 8,760 hr x 8/12 x 0.7 = 981.1 GWh | 981.1 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 246.4 million Nm$^3$ |
| | | 160 MW (GT) x 8,760 hr x 8/12 x 0.7 = 654.1 GWh | 654.1 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 240.6 million Nm$^3$ |
| | | Total 1,962.2 GWh | Total 607.3 million Nm$^3$ |
| | 1990 | 240 MW (CC) x 8,760 hr x 1 x 0.7 = 1,471.7 GWh | 1,471.7 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 369.6 million Nm$^3$ |
| | | 160 MW (GT) x 8,760 hr x 5/12 x 0.7 = 408.8 GWh | 408.8 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 150.3 million Nm$^3$ |
| | | 240 MW (CC) x 8,760 hr x 7/12 x 0.7 = 858.5 GWh | 858.5 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 215.6 million Nm$^3$ |
| | | 80 MW (GT) x 8,760 hr x 1/12 x 0.7 = 40.9 GWh | 40.9 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 15.0 million Nm$^3$ |
| | | Total 2,779.9 GWh | Total 750.5 million Nm$^3$ |
| D | 1988 | 160 MW (GT) x 8,760 hr x 6/12 x 0.7 (plant factor) = 490.6 GWh | 490.6 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 180.4 million Nm$^3$ |
| | 1989 | 160 MW (GT) x 8,760 hr x 4/12 x 0.7 = 327.0 GWh | 327.0 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ 120.3 million Nm$^3$ |
| | | 360 MW (CC) x 8,760 hr x 8/12 x 0.7 = 1,471.7 GWh | 1,471.7 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 369.6 million Nm$^3$ |
| | | Total 1,798.7 GWh | Total 489.9 million Nm$^3$ |
| | 1990 | 360 MW (CC) x 8,760 hr x 1 x 0.7 = 2,207.5 GWh | 2,207.5 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 554.3 million Nm$^3$ |
| | | 160 MW (GT) x 8,760 hr x 7/12 x 0.7 = 572.3 GWh | 572.3 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 210.5 million Nm$^3$ |
| | | 80 MW (GT) x 8,760 hr x 1/12 x 0.7 = 40.9 GWh | 40.9 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 15.0 million Nm$^3$ |
| | | Total 2,820.7 GWh | Total 779.8 million Nm$^3$ |
| E | 1988 | 160 MW (GT) x 8,760 hr x 6/12 x 0.7 (plant factor) = 490.6 GWh | 490.6 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 180.4 million Nm$^3$ |
| | 1989 | 160 MW (GT) x 8,760 hr x 4/12 x 0.7 = 327.0 GWh | 327.0 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 120.3 million Nm$^3$ |
| | | 320 MW (GT) x 8,760 hr x 8/12 x 0.7 = 1,308.2 GWh | 1,308.2 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 481.1 million Nm$^3$ |
| | | Total 1,635.2 GWh | Total 601.4 million Nm$^3$ |
| | 1990 | 160 MW (GT) x 8,760 hr x11/12 x 0.7 = 899.4 GWh | 899.4 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 330.8 million Nm$^3$ |
| | | 160 MW (GT) x 8,760 hr x 5/12 x 0.7 = 408.8 GWh | 408.8 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 150.4 million Nm$^3$ |
| | | 240 MW (CC) x 8,760 hr x 7/12 x 0.7 = 858.5 GWh | 858.5 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 215.6 million Nm$^3$ |
| | | 240 MW (CC) x 8,760 hr x 1/12 x 0.7 = 122.6 GWh | 122.6 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 30.8 million Nm$^3$ |
| | | 80 MW (ST) x 8,760 hr x 7/12 x 0.7 = 286.2 GWh | 286.2 GWh x 4,530 Kcal/kWh (19%) ÷ 9,000 Kcal/Nm$^3$ = 144.1 million Nm$^3$ |
| | | Total 2,575.5 GWh | Total 871.7 million Nm$^3$ |
| F | 1988 | 160 MW (GT) x 8,760 hr x 6/12 x 0.7 (plant factor) = 490.6 GWh | 490.6 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 180.4 million Nm$^3$ |
| | 1989 | 160 MW (GT) x 8,760 hr x 4/12 x 0.7 = 327.0 GWh | 327.0 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 120.3 million Nm$^3$ |
| | | 320 MW (GT) x 8,760 hr x 8/12 x 0.7 = 1,308.2 GWh | 1,308.2 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 481.1 million Nm$^3$ |
| | | Total 1,635.2 GWh | Total 601.4 million Nm$^3$ |
| | 1990 | 160 MW (GT) x 8,760 hr x 1 x 0.7 = 981.1 | 981.1 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 360.8 million Nm$^3$ |
| | | 160 MW (GT) x 8,760 hr x 5/12 x 0.7 = 408.8 | 408.8 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 150.3 million Nm$^3$ |
| | | 240 MW (CC) x 8,760 hr x 7/12 x 0.7 = 858.5 | 858.5 GWh x 2,260 Kcal/kWh (38%) ÷ 9,000 Kcal/Nm$^3$ = 215.6 million Nm$^3$ |
| | | 80 MW (GT) x 8,760 hr x 7/12 x 0.7 = 286.2 | 286.2 GWh x 3,310 Kcal/kWh (26%) ÷ 9,000 Kcal/Nm$^3$ = 105.3 million Nm$^3$ |
| | | 60 MW (ST) x 8,760 hr x 7/12 x 0.7 = 214.6 | 214.6 GWh x 4,530 Kcal/kWh (19%) ÷ 9,000 Kcal/Nm$^3$ = 108.0 million Nm$^3$ |
| | | 60 MW (ST) x 8,760 hr x 1/12 x 0.7 = 30.7 | 30.7 GWh x 4,530 Kcal/kWh (19%) ÷ 9,000 Kcal/Nm$^3$ = 15.5 million Nm$^3$ |
| | | Total 2,779.9 | Total 955.5 million Nm$^3$ |

Table 18.1.(b) Energy generation and fuel consumption (up to 1995)

| Power Plant | Capacity (MW) | Item | Unit | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Type-A and Type-C Steam turbine | 360 | Es: Energy at sending-end | GWh | | | | 2,583 | 2,587 | 2,589 | 2,590 | 2,590 |
| | | Eh: Energy for station service | GWh | | | | 91 | 91 | 91 | 91 | 91 |
| | | Eg: Energy at generator-terminal | GWh | | | | 2,674 | 2,678 | 2,680 | 2,681 | 2,681 |
| | | F : Fuel consumption | $10^6Nm^3$ | | | | 1,006 | 1,007 | 1,008 | 1,009 | 1,009 |
| Combined cycle | 360 | Es: Energy at sending-end | GWh | | | | 2,153 | 2,260 | 2,351 | 2,475 | 2,582 |
| | | Eh: Energy for station service | GWh | | | | 17 | 18 | 19 | 20 | 21 |
| | | Eg: Energy at generator-terminal | GWh | | | | 2,170 | 2,278 | 2,387 | 2,495 | 2,603 |
| | | F : Fuel consumption | $10^6Nm^3$ | | | | 612 | 623 | 634 | 644 | 655 |
| Total | 720 | Es: Energy at sending-end | GWh | 488 | 1,759 | 2,638 | 4,736 | 4,847 | 4,940 | 5,061 | 5,172 |
| | | Eh: Energy for station service | GWh | 3 | 40 | 60 | 108 | 109 | 110 | 111 | 112 |
| | | Eg: Energy at generator-terminal | GWh | 491 | 1,799 | 2,698 | 4,844 | 4,956 | 5,067 | 5,176 | 5,284 |
| | | F : Fuel consumption | $10^6Nm^3$ | 180 | 490 | 739 | 1,618 | 1,630 | 1,641 | 1,653 | 1,664 |
| Type-B Combined cycle | 720 | Es: Energy at sending-end | GWh | | | | 4,633 | 4,747 | 4,833 | 4,917 | 5,002 |
| | | Eh: Energy for station service | GWh | | | | 38 | 39 | 39 | 40 | 40 |
| | | Eg: Energy at generator-terminal | GWh | | | | 4,701 | 4,786 | 4,872 | 4,957 | 5,042 |
| | | F : Fuel consumption | $10^6Nm^3$ | | | | 1,523 | 1,527 | 1,531 | 1,535 | 1,539 |
| Auxiliary boiler | | F : Fuel consumption | | | | | 3 | 2 | 1 | 0 | 0 |
| Total | 720 | Es: Energy at sending-end | GWh | 488 | 1,944 | 2,757 | 4,663 | 4,747 | 4,833 | 4,917 | 5,002 |
| | | Eh: Energy for station service | GWh | 3 | 18 | 23 | 38 | 39 | 39 | 40 | 40 |
| | | Eg: Energy at generator-terminal | GWh | 491 | 1,962 | 2,780 | 4,701 | 4,786 | 4,872 | 4,957 | 5,042 |
| | | F : Fuel consumption | $10^6Nm^3$ | 180 | 607 | 751 | 1,526 | 1,529 | 1,532 | 1,535 | 1,539 |
| Type-D Combined cycle | 360 | Es: Energy at sending-end | GWh | | | | 1,960 | 2,093 | 2,236 | 2,388 | 2,550 |
| | | Eh: Energy for station service | GWh | | | | 16 | 17 | 18 | 19 | 21 |
| | | Eg: Energy at generator-terminal | GWh | | | | 1,976 | 2,110 | 2,254 | 2,407 | 2,571 |
| | | F : Fuel consumption | $10^6Nm^3$ | | | | 566 | 586 | 607 | 628 | 650 |
| Gas turbine | 400 | Es: Energy at sending-end | GWh | | | | 2,895 | 2,924 | 2,939 | 2,954 | 2,954 |
| | | Eh: Energy for station service | GWh | | | | 23 | 24 | 24 | 24 | 24 |
| | | Eg: Energy at generator-terminal | GWh | | | | 2,918 | 2,948 | 2,963 | 2,978 | 2,978 |
| | | F : Fuel consumption | $10^6Nm^3$ | | | | 1,063 | 1,071 | 1,075 | 1,078 | 1,078 |
| Auxiliary boiler | | F : Fuel consumption | | | | | 21 | 11 | 6 | 0 | 0 |
| Total | 760 | Es: Energy at sending-end | GWh | 488 | 1,785 | 2,798 | 4,855 | 5,017 | 5,175 | 5,342 | 5,504 |
| | | Eh: Energy for station service | GWh | 3 | 14 | 23 | 39 | 41 | 42 | 43 | 45 |
| | | Eg: Energy at generator-terminal | GWh | 491 | 1,799 | 2,821 | 4,894 | 5,058 | 5,217 | 5,385 | 5,549 |
| | | F : Fuel consumption | $10^6Nm^3$ | 180 | 490 | 780 | 1,650 | 1,668 | 1,688 | 1,706 | 1,728 |
| Type-E Steam turbine (Back pressure) | 160 | Es: Energy at sending-end | GWh | | | | | 1,161 | 1,161 | 1,161 | 1,161 |
| | | Eh: Energy for station service | GWh | | | | | 30 | 30 | 30 | 30 |
| | | Eg: Energy at generator-terminal | GWh | | | | | 1,191 | 1,191 | 1,191 | 1,191 |
| | | F : Fuel consumption | $10^6Nm^3$ | | | | | 677 | 677 | 677 | 677 |
| Combined cycle | 480 | Es: Energy at sending-end | GWh | | | | | 3,314 | 3,390 | 3,466 | 3,541 |
| | | Eh: Energy for station service | GWh | | | | | 27 | 27 | 28 | 29 |
| | | Eg: Energy at generator-terminal | GWh | | | | | 3,341 | 3,417 | 3,494 | 3,570 |
| | | F : Fuel consumption | $10^6Nm^3$ | | | | | 840 | 846 | 852 | 858 |
| Gas turbine | 80 | Es: Energy at sending-end | GWh | | | | | 400 | 454 | 508 | 562 |
| | | Eh: Energy for station service | GWh | | | | | 2 | 2 | 2 | 2 |
| | | Eg: Energy at generator-terminal | GWh | | | | | 402 | 456 | 510 | 564 |
| | | F : Fuel consumption | $10^6Nm^3$ | | | | | 152 | 170 | 188 | 206 |
| Total | 720 | Es: Energy at sending-end | GWh | 488 | 1,624 | 2,545 | | 4,875 | 5,005 | 5,135 | 5,264 |
| | | Eh: Energy for station service | GWh | 3 | 11 | 31 | | 59 | 59 | 60 | 61 |
| | | Eg: Energy at generator-terminal | GWh | 491 | 1,635 | 2,576 | | 4,934 | 5,064 | 5,195 | 5,325 |
| | | F : Fuel consumption | $10^6Nm^3$ | 180 | 601 | 872 | | 1,669 | 1,693 | 1,717 | 1,741 |

Table 18.1.(b) Energy generation and fuel consumption (up to 1995) - Continued -

| Power Plant | Capacity (MW) | Item | Unit | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Type-F | | | | | | | | | | | |
| Steam turbine (Back pressure) | 180 | Es: Energy at sending-end | GWh | | | | 1,306 | 1,306 | 1,306 | 1,306 | 1,306 |
| | | Eh: Energy for station service | GWh | | | | 34 | 34 | 34 | 34 | 34 |
| | | Eg: Energy at generator-terminal | GWh | | | | 1,340 | 1,340 | 1,340 | 1,340 | 1,340 |
| | | F : Fuel consumption | $10^6 Nm^3$ | | | | 674 | 674 | 674 | 674 | 674 |
| Combined cycle | 480 | Es: Energy at sending-end | GWh | | | | 3,182 | 3,269 | 3,354 | 3,439 | 3,526 |
| | | Eh: Energy for station service | GWh | | | | 26 | 26 | 27 | 28 | 28 |
| | | Eg: Energy at generator-terminal | GWh | | | | 3,208 | 3,295 | 3,381 | 3,467 | 3,554 |
| | | F : Fuel consumption | $10^6 Nm^3$ | | | | 831 | 838 | 845 | 852 | 859 |
| Gasaturbine | 80 | Es: Energy at sending-end | GWh | | | | 310 | 377 | 445 | 513 | 581 |
| | | Eh: Energy for station service | GWh | | | | 1 | 2 | 2 | 2 | 2 |
| | | Eg: Energy at generator-terminal | GWh | | | | 311 | 379 | 447 | 515 | 583 |
| | | F : Fuel consumption | $10^6 Nm^3$ | | | | 134 | 154 | 174 | 194 | 214 |
| Total | 740 | Es: Energy at sending-end | GWh | 488 | 1,624 | 2,745 | 4,798 | 4,952 | 5,105 | 5,258 | 5,413 |
| | | Eh: Energy for station service | GWh | 3 | 11 | 35 | 61 | 62 | 63 | 64 | 64 |
| | | Eg: Energy at generator-terminal | GWh | 491 | 1,635 | 2,780 | 4,859 | 5,014 | 5,168 | 5,322 | 5,477 |
| | | F : Fuel consumption | $10^6 Nm^3$ | 180 | 601 | 956 | 1,639 | 1,666 | 1,693 | 1,720 | 1,747 |

Table 18.2 Construction cost converted to present worth (Power plant)

(Million R.O.)

| Power plant | Total | 1<br>1986 | 2<br>1987 | 3<br>1988 | 4<br>1989 | 5<br>1990 | 6<br>1991 | | 11<br>1996 | 12<br>1997 | 13<br>1998 | 14<br>1999 | 15<br>2000 | 16<br>2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type-A | | | | | | | | | | | | | | |
| | (167.4) | | | | | | | | | | | | | |
| 1985 prices | 216.3 | 9.8 | 56.0 | 43.2 | 43.1 | 10.4 | 4.9 | | 2.7 | 25.3 | 18.5 | 2.4 | | |
| Discount rate 8% | 152.1 | 9.1 | 48.0 | 34.3 | 31.7 | 7.1 | 3.1 | | 1.2 | 10.0 | 6.8 | 0.8 | | |
| " 10% | 141.0 | 8.9 | 46.3 | 32.4 | 29.4 | 6.4 | 2.8 | | 0.9 | 8.0 | 5.3 | 0.6 | | |
| " 12% | 131.8 | 8.7 | 44.6 | 30.7 | 27.4 | 5.9 | 2.5 | | 0.8 | 6.5 | 4.2 | 0.5 | | |
| " 14% | 123.5 | 8.6 | 43.1 | 29.1 | 25.5 | 5.4 | 2.2 | | 0.6 | 5.2 | 3.4 | 0.4 | | |
| Type-B | | | | | | | | | | | | | | |
| | (164.4) | | | | | | | | | | | | | |
| 1985 prices | 278.5 | 7.6 | 40.4 | 39.0 | 61.0 | 12.9 | 3.5 | | 2.7 | 26.6 | 35.1 | 41.6 | 8.1 | |
| Discount rate 8% | 169.7 | 7.0 | 34.6 | 30.9 | 44.8 | 8.8 | 2.2 | | 1.2 | 10.6 | 12.9 | 14.1 | 2.6 | |
| " 10% | 153.6 | 6.9 | 33.4 | 29.3 | 41.7 | 8.0 | 2.0 | | 0.9 | 8.5 | 10.1 | 10.9 | 1.9 | |
| " 12% | 140.1 | 6.8 | 32.2 | 27.7 | 38.7 | 7.3 | 1.8 | | 0.8 | 6.8 | 8.0 | 8.5 | 1.5 | |
| " 14% | 128.7 | 6.7 | 31.1 | 26.3 | 36.1 | 6.7 | 1.6 | | 0.6 | 5.5 | 6.4 | 6.6 | 1.1 | |
| Type-C | | | | | | | | | | | | | | |
| | (168.2) | | | | | | | | | | | | | |
| 1985 prices | 217.1 | 9.9 | 56.6 | 43.3 | 43.1 | 10.4 | 4.9 | | 2.7 | 25.3 | 18.5 | 2.4 | | |
| Discount rate 8% | 152.7 | 9.2 | 48.5 | 34.3 | 31.7 | 7.1 | 3.1 | | 1.2 | 10.0 | 6.8 | 0.8 | | |
| " 10% | 141.7 | 9.0 | 46.8 | 32.5 | 29.4 | 6.4 | 2.8 | | 0.9 | 8.0 | 5.3 | 0.6 | | |
| " 12% | 132.5 | 8.8 | 45.1 | 30.8 | 27.4 | 5.9 | 2.5 | | 0.8 | 6.5 | 4.2 | 0.5 | | |
| " 14% | 124.1 | 8.7 | 43.5 | 29.2 | 25.5 | 5.4 | 2.2 | | 0.6 | 5.2 | 3.4 | 0.4 | | |
| Type-D | | | | | | | | | | | | | | |
| | (171.8) | | | | | | | | | | | | | |
| 1985 prices | 302.2 | 7.3 | 39.0 | 37.7 | 45.8 | 32.4 | 9.6 | | 2.7 | 26.6 | 33.7 | 32.1 | 29.9 | 5.4 |
| Discount rate 8% | 177.9 | 6.8 | 33.4 | 29.9 | 33.7 | 22.0 | 6.0 | | 1.2 | 10.6 | 12.4 | 10.9 | 9.4 | 1.6 |
| " 10% | 159.7 | 6.6 | 32.2 | 28.3 | 31.3 | 20.1 | 5.4 | | 0.9 | 8.5 | 9.7 | 8.4 | 7.1 | 1.2 |
| " 12% | 144.8 | 6.5 | 31.1 | 26.8 | 29.0 | 18.4 | 4.9 | | 0.8 | 6.8 | 7.7 | 6.5 | 5.4 | 0.9 |
| " 14% | 132.3 | 6.4 | 30.0 | 25.4 | 27.1 | 16.8 | 4.4 | | 0.6 | 5.5 | 6.1 | 5.1 | 4.2 | 0.7 |
| Type-E | | | | | | | | | | | | | | |
| | (178.9) | | | | | | | | | | | | | |
| 1985 prices | 260.4 | 8.0 | 44.5 | 50.1 | 47.0 | 22.3 | 7.0 | | 2.7 | 26.6 | 31.0 | 6.3 | 12.2 | 2.7 |
| Discount rate 8% | 169.2 | 7.4 | 38.1 | 39.7 | 34.5 | 15.2 | 4.4 | | 1.2 | 10.6 | 11.4 | 2.1 | 3.8 | 0.8 |
| " 10% | 155.1 | 7.3 | 36.8 | 37.6 | 32.1 | 13.8 | 3.9 | | 0.9 | 8.5 | 9.0 | 1.7 | 2.9 | 0.6 |
| " 12% | 142.7 | 7.1 | 35.5 | 35.6 | 29.8 | 12.6 | 3.5 | | 0.8 | 6.8 | 7.1 | 1.3 | 2.2 | 0.4 |
| " 14% | 132.3 | 7.0 | 34.2 | 33.8 | 27.8 | 11.6 | 3.2 | | 0.6 | 5.5 | 5.6 | 1.0 | 1.7 | 0.3 |
| Type-F | | | | | | | | | | | | | | |
| | (197.7) | | | | | | | | | | | | | |
| 1985 prices | 279.2 | 8.1 | 44.3 | 63.5 | 60.0 | 15.2 | 6.6 | | 2.7 | 26.6 | 32.3 | 17.2 | 2.7 | |
| Discount rate 8% | 184.9 | 7.5 | 38.0 | 50.4 | 44.1 | 10.3 | 4.2 | | 1.2 | 10.6 | 11.9 | 5.8 | 0.9 | |
| " 10% | 169.6 | 7.4 | 36.6 | 47.7 | 41.0 | 9.4 | 3.7 | | 0.9 | 8.5 | 9.3 | 4.5 | 0.6 | |
| " 12% | 156.6 | 7.2 | 35.3 | 45.1 | 38.1 | 8.6 | 3.3 | | 0.8 | 6.8 | 7.4 | 3.5 | 0.5 | |
| " 14% | 145.5 | 7.1 | 34.1 | 42.8 | 35.5 | 7.9 | 3.0 | | 0.6 | 5.5 | 5.9 | 2.7 | 0.4 | |

Note: Figures in parentheses show initial investment.

Table 18.3 Operation and mantenance costs, and administration expenses converted to present worths (Power plant)

(Million R.O.)

| Power plant | Total | 3<br>1988 | 4<br>1989 | 5<br>1990 | 6<br>1991 | 1991 - 2010 (20 years)<br>(CPWCP) | <br>Total | Remarks |
|---|---|---|---|---|---|---|---|---|
| Type-A, C | | | | | | | | Cumulative present worth covertion factor (CPWCF) for the period of 20 years from 1991 to 2010 is obtained by the following equation: |
| 1985 prices | 161.4 | 1.6 | 3.8 | 6.0 | 7.5 | | 150.0 | $\frac{(1+i)^{20}-1}{i\,(1+i)^{20}} \cdot \frac{1}{(1+i)^{6}}$ |
| Discount rate 8% | 58.3 | 1.3 | 2.8 | 4.1 | | 6,68206 | 50.1 | i: Discount rate |
| " 10% | 47.1 | 1.2 | 2.6 | 3.7 | | 5.28625 | 39.6 | |
| " 12% | 38.7 | 1.1 | 2.4 | 3.4 | | 4.23836 | 31.8 | |
| " 14% | 32.2 | 1.1 | 2.2 | 3.1 | | 3.43984 | 25.8 | |
| Type-B | | | | | | | | |
| 1985 prices | 159.3 | 1.6 | 3.8 | 5.9 | 7.4 | | 148.0 | |
| Discount rate 8% | 57.6 | 1.3 | 2.8 | 4.0 | | 6,68206 | 49.5 | |
| " 10% | 46.6 | 1.2 | 2.6 | 3.7 | | 5.28625 | 39.1 | |
| " 12% | 38.2 | 1.1 | 2.4 | 3.3 | | 4.23836 | 31.4 | |
| " 14% | 31.9 | 1.1 | 2.2 | 3.1 | | 3.43984 | 25.5 | |
| Type-D | | | | | | | | |
| 1985 prices | 167.6 | 1.6 | 3.8 | 6.2 | 7.8 | | 156.0 | |
| Discount rate 8% | 60.4 | 1.3 | 2.8 | 4.2 | | 6.68206 | 52.1 | |
| " 10% | 48.8 | 1.2 | 2.6 | 3.8 | | 5.28625 | 41.2 | |
| " 12% | 40.1 | 1.1 | 2.4 | 3.5 | | 4.23836 | 33.1 | |
| " 14% | 33.3 | 1.1 | 2.2 | 3.2 | | 3.43984 | 26.8 | |
| Type-E | | | | | | | | |
| 1985 prices | 173.9 | 1.6 | 3.8 | 6.5 | 8.1 | | 162.0 | |
| Discount rate 8% | 62.6 | 1.3 | 2.8 | 4.4 | | 6.68206 | 54.1 | |
| " 10% | 50.6 | 1.2 | 2.6 | 4.0 | | 5.28625 | 42.8 | |
| " 12% | 41.5 | 1.1 | 2.4 | 3.7 | | 4.23836 | 34.3 | |
| " 14% | 34.6 | 1.1 | 2.2 | 3.4 | | 3.43984 | 27.9 | |
| Type-F | | | | | | | | |
| 1985 prices | 190.5 | 1.6 | 3.8 | 7.1 | 8.9 | | 178.0 | |
| Discount rate 8% | 68.4 | 1.3 | 2.8 | 4.8 | | 6.68206 | 59.5 | |
| " 10% | 55.2 | 1.2 | 2.6 | 4.4 | | 5.28625 | 47.0 | |
| " 12% | 45.2 | 1.1 | 2.4 | 4.0 | | 4.23836 | 37.7 | |
| " 14% | 37.6 | 1.1 | 2.2 | 3.7 | | 3.43984 | 30.6 | |

Table 18.4 Fuel cost converted to present worth (Power plant)

(Million R.O.)

| Power plant | Total | 3<br>1988 | 4<br>1989 | 5<br>1990 | 6<br>1991 | 7<br>1992 | 8<br>1993 | 9<br>1994 | 10<br>1995 | 1995 - 2010 (16 years)<br>CPWCF | <br>Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Type-A, C | | | | | | | | | | | |
| 1985 prices | 1,056.9 | 6.2 | 16.8 | 23.1 | 50.9 | 50.8 | 50.7 | 50.4 | 50.5 | | 808.0 |
| Discount rate 8% | 370.8 | 4.9 | 12.3 | 15.7 | 32.1 | 29.6 | 27.4 | 25.2 | | 4.42789 | 223.6 |
| " 10% | 297.8 | 4.7 | 11.5 | 14.3 | 28.7 | 26.0 | 23.6 | 21.4 | | 3.31801 | 167.6 |
| " 12% | 242.5 | 4.4 | 10.7 | 13.1 | 25.8 | 23.0 | 20.4 | 18.1 | | 2.51489 | 127.0 |
| " 14% | 200.1 | 4.2 | 9.9 | 12.0 | 23.2 | 20.3 | 17.7 | 15.5 | | 1.92656 | 97.3 |
| Type-B | | | | | | | | | | | |
| 1985 prices | 979.8 | 6.2 | 20.8 | 23.5 | 47.8 | 47.4 | 46.9 | 46.4 | 46.3 | | 740.8 |
| Discount rate 8% | 347.4 | 4.9 | 15.3 | 16.0 | 30.1 | 27.6 | 25.3 | 23.2 | | 4.42789 | 205.0 |
| " 10% | 280.0 | 4.7 | 14.2 | 14.6 | 27.0 | 24.3 | 21.9 | 19.7 | | 3.31801 | 153.6 |
| " 12% | 228.5 | 4.4 | 13.2 | 13.3 | 24.2 | 21.4 | 18.9 | 16.7 | | 2.51489 | 116.4 |
| " 14% | 189.1 | 4.2 | 12.3 | 12.2 | 21.7 | 18.9 | 16.4 | 14.2 | | 1.92656 | 89.2 |
| Type-D | | | | | | | | | | | |
| 1985 prices | 1,099.2 | 6.2 | 16.8 | 24.5 | 52.0 | 52.1 | 52.2 | 52.2 | 52.7 | | 843.2 |
| Discount rate 8% | 384.7 | 4.9 | 12.3 | 16.7 | 32.8 | 30.4 | 28.2 | 26.1 | | 4.42789 | 233.3 |
| " 10% | 308.7 | 4.7 | 11.5 | 15.2 | 29.3 | 26.7 | 24.3 | 22.1 | | 3.31801 | 174.9 |
| " 12% | 251.1 | 4.4 | 10.7 | 13.9 | 26.3 | 23.5 | 21.0 | 18.8 | | 2.51489 | 132.5 |
| " 14% | 207.1 | 4.2 | 9.9 | 12.7 | 23.7 | 20.8 | 18.3 | 16.0 | | 1.92656 | 101.5 |
| Type-E | | | | | | | | | | | |
| 1985 prices | 1,048.4 | 6.2 | 20.6 | 26.5 | 49.6 | 49.6 | 49.6 | 49.5 | 49.8 | | 796.8 |
| Discount rate 8% | 370.2 | 4.9 | 15.1 | 18.0 | 31.2 | 28.9 | 26.8 | 24.8 | | 4.42789 | 220.5 |
| " 10% | 297.9 | 4.7 | 14.1 | 16.4 | 28.0 | 25.4 | 23.1 | 21.0 | | 3.31801 | 165.2 |
| " 12% | 243.0 | 4.4 | 13.1 | 15.0 | 25.1 | 22.4 | 20.0 | 17.8 | | 2.51489 | 125.2 |
| " 14% | 201.1 | 4.2 | 12.2 | 13.8 | 22.6 | 19.8 | 17.4 | 15.2 | | 1.92656 | 95.9 |
| Type-F | | | | | | | | | | | |
| 1985 prices | 1,054.3 | 6.2 | 20.6 | 29.4 | 49.4 | 49.5 | 49.6 | 49.6 | 50.0 | | 800.0 |
| Discount rate 8% | 373.0 | 4.9 | 15.1 | 20.0 | 31.1 | 28.9 | 26.8 | 24.8 | | 4.42789 | 221.4 |
| " 10% | 300.3 | 4.7 | 14.1 | 18.2 | 27.9 | 25.4 | 23.1 | 21.0 | | 3.31801 | 165.9 |
| " 12% | 245.2 | 4.4 | 13.1 | 16.7 | 25.0 | 22.4 | 20.0 | 17.9 | | 2.51489 | 125.7 |
| " 14% | 202.9 | 4.2 | 12.2 | 15.3 | 22.5 | 19.8 | 17.4 | 15.2 | | 1.92656 | 96.3 |

Remarks

Cumulative present worth convertion factor (CPWCF) for the period of 16 years from 1995 to 2010 is obtained by the following equation:

$$\frac{(1 + i)^{16} - 1}{i\,(1 + i)^{16}} \cdot \frac{1}{(1 + i)^{9}}$$

i: Discount rate

Table 18.5 Total costs converted to present worth and Benefit/cost ratio of Type-F power plant

(Million R.O.)

| Plant type | Discount rate | Fixed cost | Fuel cost | Total | B/C |
|---|---|---|---|---|---|
| Type-A | 8% | (152.1 + 58.3) x 1.038 = 218.4 | 370.8 x 1.048 = 388.6 | 607.0 | 0.969 |
| | 10% | (141.0 + 47.1) x 1.038 = 195.2 | 297.8 x 1.048 = 312.1 | 507.3 | 0.966 |
| | 12% | (131.8 + 38.7) x 1.038 = 177.0 | 242.5 x 1.048 = 254.1 | 431.1 | 0.964 |
| | 14% | (123.5 + 32.2) x 1.038 = 161.6 | 200.1 x 1.048 = 209.7 | 371.3 | 0.962 |
| Type-B | 8% | (169.7 + 57.6) x 1.025 = 233.0 | 347.4 x 1.085 = 376.9 | 609.9 | 0.974 |
| | 10% | (153.6 + 46.6) x 1.025 = 205.2 | 280.0 x 1.085 = 303.8 | 509.0 | 0.969 |
| | 12% | (140.1 + 38.2) x 1.025 = 182.8 | 228.5 x 1.085 = 247.9 | 430.7 | 0.963 |
| | 14% | (128.7 + 31.9) x 1.025 = 164.6 | 189.1 x 1.085 = 205.2 | 369.8 | 0.958 |
| Type-C | 8% | (152.7 + 58.3) x 1.038 = 219.0 | 370.8 x 1.048 = 388.6 | 607.6 | 0.970 |
| | 10% | (141.7 + 47.1) x 1.038 = 196.0 | 297.8 x 1.048 = 312.1 | 508.1 | 0.968 |
| | 12% | (132.5 + 38.7) x 1.038 = 177.7 | 242.5 x 1.048 = 254.1 | 431.8 | 0.966 |
| | 14% | (124.1 + 32.2) x 1.038 = 162.2 | 200.1 x 1.048 = 209.7 | 371.9 | 0.963 |
| Type-D | 8% | (177.9 + 60.4) x 0.969 = 230.9 | 384.7 x 0.983 = 378.2 | 609.1 | 0.973 |
| | 10% | (159.7 + 48.8) x 0.969 = 202.0 | 308.7 x 0.983 = 303.5 | 505.5 | 0.963 |
| | 12% | (144.8 + 40.1) x 0.969 = 179.2 | 251.1 x 0.983 = 246.8 | 426.0 | 0.953 |
| | 14% | (132.3 + 33.3) x 0.969 = 160.5 | 207.1 x 0.983 = 203.6 | 364.1 | 0.943 |
| Type-E | 8% | (169.2 + 62.6) x 1.027 = 238.1 | 370.2 x 1.029 = 380.9 | 619.0 | 0.988 |
| | 10% | (155.1 + 50.6) x 1.027 = 211.3 | 297.9 x 1.029 = 306.5 | 517.8 | 0.986 |
| | 12% | (142.7 + 41.5) x 1.027 = 189.2 | 243.0 x 1.029 = 250.0 | 439.2 | 0.983 |
| | 14% | (132.3 + 34.6) x 1.027 = 171.4 | 201.1 x 1.029 = 206.9 | 378.3 | 0.980 |
| Type-F | 8% | 184.9 + 68.4 = 253.3 | 373.0 | 626.3 | |
| | 10% | 169.6 + 55.2 = 224.8 | 300.3 | 525.1 | |
| | 12% | 156.6 + 45.2 = 201.8 | 245.2 | 447.0 | |
| | 14% | 145.5 + 37.6 = 183.1 | 202.9 | 386.0 | |

## 18.4 ECONOMIC EVALUATION OF DESALINATION PLANT

### 18.4.1 Construction cost

The construction cost of the desalination plant (not including product water distribution facilities) at 1985 prices is estimated as follows:

(Million R.O.)

| Plant type | Total | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|
| Performance ratio 6 | 58.0 | 5.5 | 18.8 | 17.4 | 10.5 | 5.0 | 0.8 |
| " 8 | 69.9 | 6.3 | 22.4 | 21.3 | 13.0 | 6.1 | 0.8 |
| " 10 | 83.2 | 7.3 | 26.3 | 25.6 | 15.7 | 7.4 | 0.9 |

Note: The above costs include physical contingencies, administration expenses and engineering fee (total: 15.5% of the construction cost).

Conversion of the above cost into present worth is shown in Table 18.7 and summarized below.

(Million R.O.)

| Plant type | Discount rate | | | |
|---|---|---|---|---|
| | 8% | 10% | 12% | 14% |
| Performance ratio 6 | 46.6 | 44.4 | 42.2 | 40.2 |
| " 8 | 56.1 | 53.4 | 50.9 | 48.4 |
| " 10 | 66.7 | 63.3 | 60.4 | 57.4 |

### 18.4.2 Annual costs

The annual costs of desalination plant include steam cost, power cost, chemicals cost, personnel expenses and materials cost and administration expenses.

(1) Unit cost of steam production

Extraction turbine is used for Type-A, Type-B and Type-C power plants, while back pressure turbine for Type-E and Type-F power plants. General characteristics of steam generators of these turbines and unit costs of steam production are as follows: (The required steam production for Type-E is slightly different from that for Type-F. But the difference is almost negligible, so the same figure was used for Type-E and Type-F for the purpose of simplification.)

| Item | Types-A, B, C (Extraction turbine) | Types-E and F (Back pressure turbine) |
|---|---|---|
| Required steam production: | 1,800 ton/hr | 1,200 ton/hr |
| Steam conditions: | 131 kg/cm$^2$<br>541°C | 81 kg/cm$^2$<br>505°C |
| Entropy: | 822.6 kcal/kg | 812.2 kcal/kg |
| Steam temperature at boiler inlet: | 240°C | 200°C |
| Entropy of steam obtained in boiler: | 582.6 kcal/kg | 612.2 kcal/kg |
| Boiler efficiency: | 85% | 85% |
| Price of natural gas: | 3.8 Baizas/10$^3$ kcal | |
| Fuel cost per ton of steam production: | 2.6046 R.O./ton | 2.7369 R.O./ton |
| Fixed cost of boiler: | 0.1573 R.O/ton | 2.8737 R.O./ton |

The power plant and desalination plant are operated at the same load factor. Therefore, when allocating steam cost (fuel cost) to the power plant and desalination plant in accordance with calories of steam used by these plants, the following steam costs can be calculated:

| Steam production cost | Types-A, B, C | Types-E and F |
|---|---|---|
| Desalination plant | 0.8408 R.O./ton | 1.2773 R.O./ton |
| Power plant | 2.8854 R.O./ton | 1.7879 R.O./ton |

(2) Quantity of product water to be supplied by Barka desalination plant

As shown in Table 5.8, the capacity of the existing water supply facilities including wells and Ghubrah desalination plant is 119,500 $m^3/d$, but the quantity of water actually supplied by these facilities is estimated at about 119,500 $m^3/d$ x 0.85 = 101,790 $m^3/d$ assuming a plant factor of 85%. Hence, the quantity of water supplied by Barka desalination plant is estimated as follows:

| Year | Demand for water ($m^3/d$) | Water supplied by existing facilities ($m^3/d$) | Shortage ($m^3/d$) | Water supplied by Barka desalination plant | | Note for Barka plant |
|---|---|---|---|---|---|---|
| | | | | Daily production ($m^3/d$) | Annual production ($m^3$) | |
| 1989 | 174,071 | 101,790 | -72,281 | 72,281 | 26,383,000 | (1) |
| 1990 | 193,596 | " | -91,806 | 91,806 | 30,754,000 | (2) |
| 1991 | 206,877 | " | -105,087 | 105,087 | 38,357,000 | (3) |
| 1992 | 220,158 | " | -118,368 | 118,368 | 43,204,000 | |
| 1993 | 233,438 | " | -131,649 | 131,649 | 48,052,000 | |
| 1994 | 246,719 | " | -144,929 | 144,929 | 52,899,000 | |
| 1995 and thereafter | 260,000 | " | -158,210 | 153,000 | 55,845,000 | |

Note: (1) 90,000 $m^3/d$ x 0.85 = 76,500 $m^3/d$
(2) 150,000 $m^3/d$ x 0.85 = 127,500 $m^3/d$
(3) 180,000 $m^3/d$ x 0.85 = 153,000 $m^3/d$

The first and the second units of each 30,000 $m^3/d$ of Barka desalination plant are planned to enter service at the end of November and the end of December 1988, respectively, but their water production in that year is almost negligible.

(3) *Steam cost (Fuel cost)*

Quantity of steam used for producing 1 $m^3$ of product water is 0.181 ton in case of performance ratio 6, 0.136 ton in case of performance ratio 8 and 0.109 ton in case of performance ratio 10.

To meet water demand and supply balance, Barka desalination plant will be operated to produce 72,281 $m^3/d$ in 1989 by using auxiliary steam generator, and in 1990 the plant will produce 76,500 $m^3/d$ by using auxiliary steam generator during the first 5 months and 91,806 $m^3/d$ by using steam supplied by power plant during the last 7 months.

Therefore, steam cost (fuel cost) of the desalination plant is estimated as follows:

(Million R.O.)

| Item | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|
| <u>Extraction turbine</u> | | | | | | | |
| Performance ratio 6 | 2.4 | 4.0 | 5.8 | 6.6 | 7.3 | 8.1 | 8.5 |
| Performance ratio 8 | 2.4 | 3.3 | 4.4 | 4.9 | 5.5 | 6.1 | 6.4 |
| Performance ratio 10 | 2.4 | 2.9 | 3.5 | 4.0 | 4.4 | 4.9 | 5.1 |
| <u>Back pressure turbine</u> | | | | | | | |
| Performance ratio 6 | 2.4 | 5.6 | 8.9 | 10.0 | 11.1 | 12.2 | 12.9 |
| Performance ratio 8 | 2.4 | 4.4 | 6.7 | 7.5 | 8.3 | 9.2 | 9.7 |
| Performance ratio 10 | 2.4 | 3.8 | 5.3 | 6.0 | 6.7 | 7.4 | 7.8 |

(4) Power cost

Quantity of electric energy used for producing 1 $m^3$ of product water is 3.10 kWh in case of performance ratio 6, 3.24 kWh in case of performance ratio 8 and 3.56 kWh in case of performance ratio 10. Therefore, when using the present tariff of 20 Baizas/kWh the power cost of the desalination plant is estimated as follows:

(Million R.O.)

| Year | Performance ratio | | |
|---|---|---|---|
| | 6 | 8 | 10 |
| 1989 | 1.6 | 1.7 | 1.9 |
| 1990 | 1.9 | 2.0 | 2.2 |
| 1991 | 2.4 | 2.5 | 2.7 |
| 1992 | 2.7 | 2.8 | 3.1 |
| 1993 | 3.0 | 3.1 | 3.4 |
| 1994 | 3.3 | 3.4 | 3.8 |
| 1995 and thereafter | 3.5 | 3.6 | 4.0 |

(5) Chemicals cost

The chemicals used, their specific consumption, unit price and total cost for producing 1 $m^3$ of product water are as follows:

| Kinds of chemicals | Consumption ($kg/m^3$) | Unit price ($R.O./m^3$) | Total cost ($R.O./m^3$) |
|---|---|---|---|
| Scale inhibitor | 0.0133 | 1.8 | 0.0239 |
| Anti-foam agent | 0.0001 | 1.19 | 0.0001 |
| Limestone | 0.06 | 1.104 | 0.0063 |
| Soda ash | 0.0015 | 1.324 | 0.0005 |
| Chlorine (Product water treatment) | 0.0011 | 1.1 | 0.0012 |
| Chlorine (Sea water intake) | 0.008 | 1.1 | 0.0088 |
| | | Total | 0.0408 |

Therefore, annual disbursement of the chemicals cost will be the following:

(Million R.O.)

| Year | Performance ratio | | |
|---|---|---|---|
| | 6 | 8 | 10 |
| 1989 | 1.1 | 1.1 | 1.1 |
| 1990 | 1.3 | 1.3 | 1.3 |
| 1991 | 1.6 | 1.6 | 1.6 |
| 1992 | 1.8 | 1.8 | 1.8 |
| 1993 | 2.0 | 2.0 | 2.0 |
| 1994 | 2.2 | 2.2 | 2.2 |
| 1995 and thereafter | 2.3 | 2.3 | 2.3 |

(6) Personnel expenses, materials cost for maintenance and administration expenses

Statistically, personnel expenses, materials cost for maintenance and administration expenses are 0.42%, 0.5% and also 0.5% of the construction cost, respectively. Therefore, at the full load operation of the desalination plant these costs will amount to:

Performance ratio 6 : 58.0 x 0.0142 = 0.8 million R.O.
Performance ratio 8 : 69.9 x 0.0142 = 1.0 million R.O.
Performance ratio 10: 83.2 x 0.0142 = 1.2 million R.O.

These costs will be in proportion to the capacity of the desalination plant, so their annual disbursement will be as follows:

(Million R.O.)

| Year | Performance ratio 6 | 8 | 10 |
|---|---|---|---|
| 1989 | 0.4 | 0.5 | 0.6 |
| 1990 | 0.7 | 0.8 | 1.0 |
| 1991 and there-after | 0.8 | 1.0 | 1.2 |

(7) Total of the annual costs

Annual disbursement of the steam cost, power cost, chemicals cost, personnel expenses, materials cost for maintenance and administration expenses will amount to the following:

(Million R.O.)

| Plant type | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 and there-after |
|---|---|---|---|---|---|---|---|
| Extraction turbine alternative | | | | | | | |
| Performance ratio 6 | 5.5 | 7.9 | 10.6 | 11.9 | 13.1 | 14.4 | 15.1 |
| " 8 | 5.7 | 7.4 | 9.5 | 10.5 | 11.6 | 12.7 | 13.3 |
| " 10 | 6.0 | 7.4 | 9.0 | 10.1 | 11.0 | 12.1 | 12.6 |
| Back pressure turbine alternative | | | | | | | |
| Performance ratio 6 | 5.5 | 9.5 | 13.7 | 15.3 | 16.9 | 18.5 | 19.5 |
| " 8 | 5.7 | 8.5 | 11.8 | 13.1 | 14.4 | 15.8 | 16.6 |
| " 10 | 6.0 | 8.3 | 10.8 | 12.1 | 13.3 | 14.6 | 15.3 |

Conversion of the above costs into present worth over the period of 20 years is shown in Table 18.8 and summarized as follows:

(Million R.O.)

| Plant type | Discount rate | | | |
|---|---|---|---|---|
| | 8% | 10% | 12% | 14% |
| Extraction turbine alternative | | | | |
| Performance ratio 6 | 104.2 | 83.1 | 67.3 | 55.0 |
| " 8 | 92.9 | 74.2 | 60.0 | 49.3 |
| " 10 | 88.8 | 71.0 | 57.7 | 47.4 |
| Back pressure turbine alternative | | | | |
| Performance ratio 6 | 132.7 | 105.6 | 85.2 | 69.7 |
| " 8 | 114.2 | 91.1 | 73.5 | 60.3 |
| " 10 | 106.1 | 84.7 | 68.7 | 56.3 |

### 18.4.3 Change in capacity sharing for Type-E and Type-F power plants by performance ratio, and construction cost adjustment

The steam condition in the back pressure turbine alternative described in paragraph 18.4.2.(1) is to produce desalinated water of 180,000 $m^3/d$ at performance ratio 8. Under this condition the turbine-generators combined with desalination plant can generate power of 160 MW for Type-E power plant and 180 MW for Type-F power plant. If performance ratio is changed from 8 into 6 or 10, the above power generating capacity will be changed into the following:

| Performance ratio | Type-E power plant | Type-F power plant |
|---|---|---|
| 6 | 213 MW | 240 MW |
| 8 | 160 MW | 180 MW |
| 10 | 128 MW | 144 MW |

Therefore, when adopting performance ratio 6 or 10, the sharing of capacity of Type-E and Type-F power plants will have to be changed as follows for the total capacity of 720 MW and 740 MW respectively:

| | Type-E power plant | Type-F power plant |
|---|---|---|
| For performance ratio 6: | | |
| Increase in capacity of back pressure turbine-generators: | +53 MW (213 - 160) | +60 MW (240 - 180) |
| Decrease in capacity of gas turbine generators: | -53 MW | -60 MW |
| For performance ratio 10: | | |
| Decrease in capacity of back pressure turbine-generators: | -32 MW (128 - 160) | -36 MW (144 - 180) |
| Increase in capacity of gas generators: | +32 MW | +36 MW |

The above change results in change in the construction cost which must be considered in the optimization of performance ratio.

The construction cost per kW of back pressure turbine-generator is higher than that of gas turbine-generator, and the difference between the two is estimated at about 55 R.O./kW. Therefore, the above change will result in change in the construction cost as follows:

| | Type-E power plant | Type-F power plant |
|---|---|---|
| For performance ratio 6: | | |
| Increase in the construction cost: | 2.92 million R.O. | 3.30 million R.O. |
| For performance ratio 10: | | |
| Decrease in the construction cost: | 1.76 million R.O. | 1.98 million R.O. |

The annual disbursement of the above costs are converted to present worths and shown in Table 18.9 as "Construction cost adjustment".

### 18.4.4 Benefit/cost ratio and optimum performance ratio

As stated in paragraph 18.4.2.(3), the unit cost of steam production in the extraction turbine alternative is different from that in the back pressure turbine alternative. The present worth of the total costs including construction cost, steam cost, power cost, chemicals cost, personnel expenses, materials cost for maintenance and administration expenses of each type of desalination plant is shown in Table 18.9.

The above table shows that both in the extraction turbine alternative and in the back pressure turbine alternative the desalination plant of a performance ratio 8 is the most economical. Therefore, it is suggested that the performance ratio 8 be adopted for the desalination plant to be jointly operated with Barka power plant.

The benefit/cost ratio (B/C ratio) of the desalination plant of a performance ratio 8 is calculated as follows:

| | Discount rate | | | |
|---|---|---|---|---|
| B/C ratio of P.ratio 8 | 8% | 10% | 12% | 14% |
| Extraction turbine alternative | | | | |
| Against performance ratio 6: | 1.012 | 0.999 | 0.987 | 0.974 |
| Against performance ratio 10: | 1.044 | 1.053 | 1.065 | 1.073 |
| Back pressure turbine alternative | | | | |
| (Type-E) | | | | |
| Against performance ratio 6: | 1.066 | 1.053 | 1.033 | 1.029 |
| Against performance ratio 10: | 1.006 | 1.015 | 1.027 | 1.035 |
| (Type-F) | | | | |
| Against performance ratio 6: | 1.068 | 1.055 | 1.043 | 1.032 |
| Against performance ratio 10: | 1.005 | 1.014 | 1.027 | 1.033 |

Table 18.6 General characteristics of steam generators and unit costs of steam production
(Power generation and desalination)

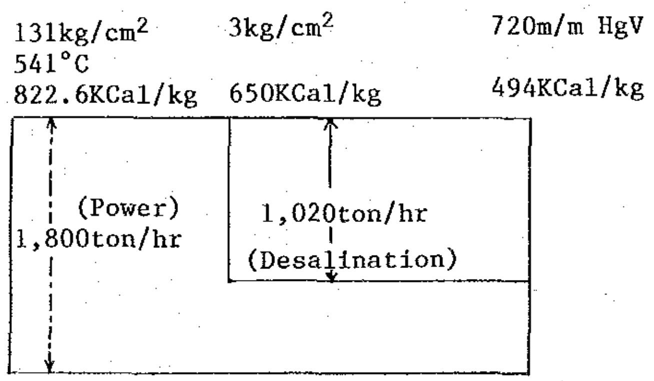
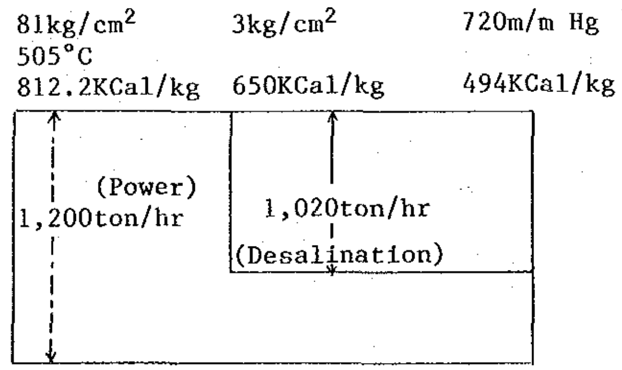
| Item | Steam generator for extraction turbine (Types-A, B, and C power plants) | Steam generator for back pressure turbine (Types-E and F power plants) |
|---|---|---|
| Required steam production | 1,800 ton/hr | 1,200 ton/hr |
| Steam conditions: | | |
| Pressure | 131 kg/cm$^2$ | 81 kg/cm$^2$ |
| Temperature | 541°C | 505°C |
| Entropy | 822.6 kcal/kg | 812.2 kcal/kg |
| Steam temperature at boiler inlet | 240°C | 200°C |
| Entropy obtained by steam in boiler | 582.6 kcal/kg | 612.2 kcal/kg |
| Boiler efficiency | 85% | 85% |
| Price of natural gas | 3.8 Baizas/1,000 kcal | 3.8 Baizas/1,000 kcal |
| Fuel cost: | $3.8\ \text{Baizas} \times \frac{582.6 \times 1{,}000}{1{,}000\ \text{kcal} \times 0.85 \times 1{,}000}$ = 2.6046 R.O./ton | $3.8\ \text{Baizas} \times \frac{612.2 \times 1{,}000}{1{,}000\ \text{kcal} \times 0.85 \times 1{,}000}$ = 2.7369 R.O./ton |
| Fixed cost of boiler | 0.1573 R.O./ton | 0.1368 R.O./ton |
| Unit cost of steam production | Total 2.7619 R.O./ton | Total 2.8737 R.O./ton |
| Allocation of steam used: On the condition that power plant and desalination plant be operated at the same plant factor. |   |   |
| Total calorie used by power plant and desalination plant | (822.6 - 494) x 1,000 x 1,800 kcal/hr = 591.5 million kcal/hr | (812.2 - 494) x 1,000 x 1,200 kcal/hr = 381.8 million kcal/hr |
| Calorie used by desalination | (650 - 494) x 1,000 x 1,020 kcal/hr = 159.1 million kcal/hr | (650 - 494) x 1,000 x 1,020 kcal/hr = 159.1 million kcal/hr |
| Calorie used by power plant | 591.5 - 159.1 = 432.4 million kcal/hr | 381.8 - 159.1 = 222.7 million kcal/hr |
| Steam production cost per ton: | | |
| Desalination plant | 0.8408 R.O./ton | 1.2773 R.O./ton |
| Power plant | 2.8854 R.O./ton | 1.7879 R.O./ton |

Table 18.7 Construction cost converted to present worth (Desalination)

(Million R.O.)

| Desalination plant | Total | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|
| Performance ratio: 6 | | | | | | | |
| 1985 prices | 58.0 | 5.5 | 18.8 | 17.4 | 10.5 | 5.0 | 0.8 |
| Discount rate 8% | 46.6 | 5.1 | 16.1 | 13.8 | 7.7 | 3.4 | 0.5 |
| " 10% | 44.4 | 5.0 | 15.5 | 13.1 | 7.2 | 3.1 | 0.5 |
| " 12% | 42.2 | 4.9 | 15.0 | 12.4 | 6.7 | 2.8 | 0.4 |
| " 14% | 40.2 | 4.8 | 14.5 | 11.7 | 6.2 | 2.6 | 0.4 |
| Performance ratio: 8 | | | | | | | |
| 1985 prices | 69.9 | 6.3 | 22.4 | 21.3 | 13.0 | 6.1 | 0.8 |
| Discount rate 8% | 56.1 | 5.8 | 19.2 | 16.9 | 9.6 | 4.1 | 0.5 |
| " 10% | 53.4 | 5.7 | 18.5 | 16.0 | 8.9 | 3.8 | 0.5 |
| " 12% | 50.9 | 5.6 | 17.9 | 15.1 | 8.3 | 3.5 | 0.5 |
| " 14% | 48.4 | 5.5 | 17.2 | 14.4 | 7.7 | 3.2 | 0.4 |
| Performance ratio: 10 | | | | | | | |
| 1985 prices | 83.2 | 7.3 | 26.3 | 25.6 | 15.7 | 7.4 | 0.9 |
| Discount rate 8% | 66.7 | 6.8 | 22.5 | 20.3 | 11.5 | 5.0 | 0.6 |
| " 10% | 63.3 | 6.6 | 21.7 | 19.2 | 10.7 | 4.6 | 0.5 |
| " 12% | 60.4 | 6.5 | 21.0 | 18.2 | 10.0 | 4.2 | 0.5 |
| " 14% | 57.4 | 6.4 | 20.2 | 17.3 | 9.3 | 3.8 | 0.4 |

Table 18.8 Present worth of annual costs including steam cost, power cost, chemical costs, personnel expenses, material costs and administration expenses (Desalination)

(Million R.O.)

| Performance ratio | Grand total | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1995-2010 (16 years) | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | LPWCF | Total | |
| Extraction turbine alternative | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 1985 prices | 305.0 | 5.5 | 7.7 | 10.6 | 11.9 | 13.1 | 14.4 | 15.1 | | 241.6 | Cumulative present worth conversion factor (CPWCF) for the period of 16 years from 1995 to 2010 is obtained by the following equation: |
| Discount rate 8% | 104.2 | 4.0 | 5.4 | 6.7 | 6.9 | 7.1 | 7.2 | | 4.42789 | 66.9 | $\frac{(1 + i)^{16} - 1}{i(1 + i)^{16}} \cdot \frac{1}{(1 + i)^{9}}$ |
| " 10% | 83.1 | 3.8 | 4.9 | 6.0 | 6.1 | 6.1 | 6.1 | | 3.31801 | 50.1 | i: Discount rate |
| " 12% | 67.3 | 3.5 | 4.5 | 5.4 | 5.4 | 5.3 | 5.2 | | 2.51489 | 38.0 | |
| " 14% | 55.0 | 3.3 | 4.1 | 4.8 | 4.7 | 4.6 | 4.4 | | 1.92656 | 29.1 | |
| 8 | | | | | | | | | | | |
| 1985 prices | 270.2 | 5.7 | 7.4 | 9.5 | 10.5 | 11.6 | 12.7 | 13.3 | | 212.8 | |
| Discount rate 8% | 92.9 | 4.2 | 5.0 | 6.0 | 6.1 | 6.3 | 6.4 | | 4.42789 | 58.9 | |
| " 10% | 74.2 | 3.9 | 4.6 | 5.4 | 5.4 | 5.4 | 5.4 | | 3.31801 | 44.1 | |
| " 12% | 60.0 | 3.6 | 4.2 | 4.8 | 4.7 | 4.7 | 4.6 | | 2.51489 | 33.4 | |
| " 14% | 49.3 | 3.4 | 3.8 | 4.3 | 4.2 | 4.1 | 3.9 | | 1.92656 | 25.6 | |
| 10 | | | | | | | | | | | |
| 1985 prices | 257.2 | 6.0 | 7.4 | 9.0 | 10.1 | 11.0 | 12.1 | 12.6 | | 201.6 | |
| Discount rate 8% | 88.8 | 4.4 | 5.0 | 5.7 | 5.9 | 5.9 | 6.1 | | 4.42789 | 55.8 | |
| " 10% | 71.0 | 4.1 | 4.6 | 5.1 | 5.2 | 5.1 | 5.1 | | 3.31801 | 41.8 | |
| " 12% | 57.7 | 3.8 | 4.2 | 4.6 | 4.6 | 4.4 | 4.4 | | 2.51489 | 31.7 | |
| " 14% | 47.4 | 3.6 | 3.8 | 4.1 | 4.0 | 3.9 | 3.7 | | 1.92656 | 24.3 | |
| Back pressure turbine alternative | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 1985 prices | 391.4 | 5.5 | 9.5 | 13.7 | 15.3 | 16.9 | 18.5 | 19.5 | | 312.0 | |
| Discount rate 8% | 132.7 | 4.0 | 6.5 | 8.6 | 8.9 | 9.1 | 9.3 | | 4.42789 | 86.3 | |
| " 10% | 105.6 | 3.8 | 5.9 | 7.7 | 7.8 | 7.9 | 7.8 | | 3.31801 | 64.7 | |
| " 12% | 85.2 | 3.5 | 5.4 | 6.9 | 6.9 | 6.8 | 6.7 | | 2.51489 | 49.0 | |
| " 14% | 69.7 | 3.3 | 4.9 | 6.2 | 6.1 | 5.9 | 5.7 | | 1.92656 | 37.6 | |
| 8 | | | | | | | | | | | |
| 1985 prices | 334.9 | 5.7 | 8.5 | 11.8 | 13.1 | 14.4 | 15.8 | 16.6 | | 265.6 | |
| Discount rate 8% | 114.2 | 4.2 | 5.8 | 7.4 | 7.6 | 7.8 | 7.9 | | 4.42789 | 73.5 | |
| " 10% | 91.1 | 3.9 | 5.3 | 6.7 | 6.7 | 6.7 | 6.7 | | 3.31801 | 55.1 | |
| " 12% | 73.5 | 3.6 | 4.8 | 6.0 | 5.9 | 5.8 | 5.7 | | 2.51489 | 41.7 | |
| " 14% | 60.3 | 3.4 | 4.4 | 5.4 | 5.2 | 5.0 | 4.9 | | 1.92656 | 32.0 | |
| 10 | | | | | | | | | | | |
| 1985 prices | 309.9 | 6.0 | 8.3 | 10.8 | 12.1 | 13.3 | 14.6 | 15.3 | | 244.8 | |
| Discount rate 8% | 106.1 | 4.4 | 5.6 | 6.8 | 7.1 | 7.2 | 7.3 | | 4.42789 | 67.7 | |
| " 10% | 84.7 | 4.1 | 5.1 | 6.1 | 6.2 | 6.2 | 6.2 | | 3.31801 | 50.8 | |
| " 12% | 68.7 | 3.8 | 4.7 | 5.5 | 5.5 | 5.4 | 5.3 | | 2.51489 | 38.5 | |
| " 14% | 56.3 | 3.6 | 4.3 | 4.9 | 4.8 | 4.7 | 4.5 | | 1.92656 | 29.5 | |

Table 18.9 Present worth of the total costs and Benefit/Cost ratio (Desalination)

(Million R.O.)

| Performance ratio | Discount rate | Construction cost | Annual cost | Construction cost adjustment | Total | B/C ratio (Base: Performance ratio 8) |
|---|---|---|---|---|---|---|
| Extraction turbine alternative | | | | | | |
| 6 | 8% | 46.6 | 104.2 | - | 150.8 | 1.012 |
| | 10% | 44.4 | 83.1 | - | 127.5 | 0.999 |
| | 12% | 42.2 | 67.3 | - | 109.5 | 0.987 |
| | 14% | 40.2 | 55.0 | - | 95.2 | 0.974 |
| 8 | 8% | 56.1 | 92.9 | - | 149.0 | - |
| | 10% | 53.4 | 74.2 | - | 127.6 | - |
| | 12% | 50.9 | 60.0 | - | 110.9 | - |
| | 14% | 48.4 | 49.3 | - | 97.7 | - |
| 10 | 8% | 66.7 | 88.8 | - | 155.5 | 1.044 |
| | 10% | 63.3 | 71.0 | - | 134.3 | 1.053 |
| | 12% | 60.4 | 57.7 | - | 118.1 | 1.065 |
| | 14% | 57.4 | 47.4 | - | 104.8 | 1.073 |
| Back pressure turbine alternative (Combined with Type-E power plant) | | | | | | |
| 6 | 8% | 46.6 | 132.7 | +2.3 | 181.6 | 1.066 |
| | 10% | 44.4 | 105.6 | +2.2 | 152.2 | 1.053 |
| | 12% | 42.2 | 85.2 | +2.1 | 129.5 | 1.033 |
| | 14% | 40.2 | 69.7 | +2.0 | 111.9 | 1.029 |
| 8 | 8% | 56.1 | 114.2 | - | 170.3 | - |
| | 10% | 53.4 | 91.1 | - | 144.5 | - |
| | 12% | 50.9 | 73.5 | - | 124.4 | - |
| | 14% | 48.4 | 60.3 | - | 108.7 | - |
| 10 | 8% | 66.7 | 106.1 | -1.4 | 171.4 | 1.006 |
| | 10% | 63.3 | 84.7 | -1.3 | 146.7 | 1.015 |
| | 12% | 60.4 | 68.7 | -1.3 | 127.8 | 1.027 |
| | 14% | 57.4 | 56.3 | -1.2 | 112.5 | 1.035 |
| (Combined with Type-F power plant) | | | | | | |
| 6 | 8% | 46.6 | 132.7 | +2.6 | 181.9 | 1.068 |
| | 10% | 44.4 | 105.6 | +2.5 | 152.5 | 1.055 |
| | 12% | 42.2 | 85.2 | +2.4 | 129.8 | 1.043 |
| | 14% | 40.2 | 69.7 | +2.3 | 112.2 | 1.032 |
| 8 | 8% | 56.1 | 114.2 | - | 170.3 | - |
| | 10% | 53.4 | 91.1 | - | 144.5 | - |
| | 12% | 50.9 | 73.5 | - | 124.4 | - |
| | 14% | 48.4 | 60.3 | - | 108.7 | - |
| 10 | 8% | 66.7 | 106.1 | -1.6 | 171.2 | 1.005 |
| | 10% | 63.3 | 84.7 | -1.5 | 146.5 | 1.014 |
| | 12% | 60.4 | 68.7 | -1.4 | 127.7 | 1.027 |
| | 14% | 57.4 | 56.3 | -1.4 | 112.3 | 1.033 |

## 18.5 OVERALL ECONOMIC EVALUATION

### 18.5.1 Basic considerations

In principle, the purpose of feasibility study is to formulate the most economical project. Therefore, the project which meets the least cost solution is recommended as the optimum project.

However, when equipment considered has not proven operation record or there is a special condition in demand pattern, these conditions should be taken into account.

In spite of the fact that in the desalination sector RO process is more economical than MSF process, MSF process was recommended in this study, considering that MSF process is predominant for large scale desalination plant in commercial operation while RO process has almost no performance record for power and desalination dual purpose plant. Also in the desalination sector it was planned to adopt the performance ratio 8 because this ratio is the most economical both in the extraction turbine alternative and in the back pressure turbine alternative.

The special condition in the demand pattern is for power generation sector, and this problem has a close relation with stability of electricity supply and reliability of plant operation.

The overall evaluation of the project including considerations on the economy and on the stability of electricity supply is described below.

### 18.5.2 Benefit/cost ratio and economic internal rate of return

The steam production cost in the extraction turbine alternative is different from that in the back pressure turbine alternative. Therefore, the economic evaluations carried out separately for each of the power plant (Section 18.3) and the desalination plant (Section 18.4) are not sufficient, and it is necessary for the overall economic evaluation to be conducted on the combination of power plant and desalination plant.

The present worth of the total costs of each type of combination (combination of power plant and desalination plant), as well as, the benefit/cost ratio (B/C ratio) of Type-F combination are shown in Table 18.10, and summarized as follows:

Present Worth of the Total Costs and Costs Economized against Type-F Combination

(Million R.O.)

| | Discount rate 8% | | Discount rate 10% | |
|---|---|---|---|---|
| | Present worth of the total costs | Costs economized against Type-F combination | Present worth of the total costs | Costs economized against Type-F combination |
| Type-A | 756.0 | 40.6 | 634.9 | 34.7 |
| Type-B | 758.9 | 37.7 | 636.6 | 33.0 |
| Type-C | 756.6 | 40.0 | 635.7 | 33.9 |
| Type-D | 758.1 | 38.5 | 633.1 | 36.5 |
| Type-E | 789.3 | 7.3 | 662.3 | 7.3 |
| Type-F | 796.6 | | 669.6 | |

B/C ratio of Type-F combination

| | Discount rate 8% | Discount rate 10% |
|---|---|---|
| Against Type-A | 0.949 | 0.948 |
| Against Type-B | 0.953 | 0.951 |
| Against Type-C | 0.950 | 0.949 |
| Against Type-D | 0.952 | 0.945 |
| Against Type-E | 0.991 | 0.989 |

Note: C: Cost of Type-F combination

B: Cost of other type of combination. This cost is regarded as the benefit of Type-F combination because it is the expenditure to be saved by the execution of Type-F combination

As shown in the above table, the most economical solution is Type-A combination when using a discount rate of 8%. The economic ranking of projects can be clarified by the economic internal rate of return (EIRR) which is the discount rate equalizing present worths of the total costs of two projects. When taking Type-A combination as the basis, the EIRR of this alternative is calculated as follows (See Fig. 18.1):

| | | |
|---|---|---|
| Against Type-B combination | : | 11.5% |
| Against Type-D combination | : | 8.9% |
| Against Type-E combination | : | Meaningless to calculate because EIRR will be more than 30%. |
| Against Type-F combination | : | |

Seen from economic viewpoint, the least advantageous solution is Type-F combination. This alternative is higher-costed than Type-A combination by more than 5% (89 million R.O. at 1985 prices which is converted to the present worth of 41 million R.O. at the discount rate of 8%).

### 18.5.3 Sensitivity analysis

It is appropriate for sensitivity analysis to be carried out for price rise of fuel. From long-term viewpoint the price of natural gas is considered to approach the oil price. At present the price of natural gas in Oman is determined at the half of oil price. Therefore, sensitivity analysis was carried out to see how about the change in the benefit/cost ratio of Type-F combination for price rise of fuel at 2 times current prise at the discount rate of 8%. The result obtained is as follows:

| | B/C Ratio of Type-F combination | |
|---|---|---|
| | For fuel at current price | For fuel at 2 times current price |
| Against Type-A combination | 0.949 | 0.962 |
| Against Type-B combination | 0.953 | 0.955 |
| Against Type-D combination | 0.952 | 0.956 |
| Against Type-E combination | 0.991 | 1.005 |

The above result shows that the price rise of fuel will have an effect of improving slightly the relative economy of Type-F combination.

### 18.5.4 Conclusion

As stated above, Type-A combination is the most economical. In this combination, the power plant adopts turbine-generators of a unit capacity of 120 MW. When fault occurs on the 120 MW turbine-generator at the minimum load time in January and February, it is necessary to execute partial load shedding in order to prevent overall failure of the power system. Such a countermeasure is needed for only several years after commissioning of the power plant, and probability of occurrence of fault at the minimum load time in the winter season is extremely low. Therefore, when importance is attached to the long-term economy, it is suggested that Type-A power plant be adopted as the optimum solution.

Stability of electricity supply is also very important for electric utility. Since Barka power plant is planned to play the most important role in the integrated grid system covering the Capital area and the Batinah coast, the stability of supply and reliability of operation are especially required for this power station. When standing on this viewpoint, any type of power plant giving fears of load shedding is not desirable, and it is rather suitable for adopting a power plant which is, though less economic, more reliable in operation and electricity supply. Type-F power plant is the most suitable to meet requirements of stability of supply and reliability of operation.

The selection of type of power plant should be made considering economic aspect on one hand and stability of supply on the other hand. As for economy, the degree of difference between alternatives is shown in this study. Therefore, it is suggested that the selection be made by MEW taking into account probability of load shedding when adopting Type-A power plant and loss of economy when adopting Type-F power plant.

## 18.6 TYPE OF POWER PLANT USED IN THIS REPORT FOR CONCEPTUAL DESIGN, COST ESTIMATE AND FINANCIAL ANALYSIS

The final selection of type of power plant is to be made by MEW. However, conceptual design of power plant (Chapter 8), cost estimate (Chapter 17) and financial analysis (Chapter 19) in this report shall be conducted by using Type-F combination taking into consideration the budget to be appropriated in the Third 5-Year Plan.

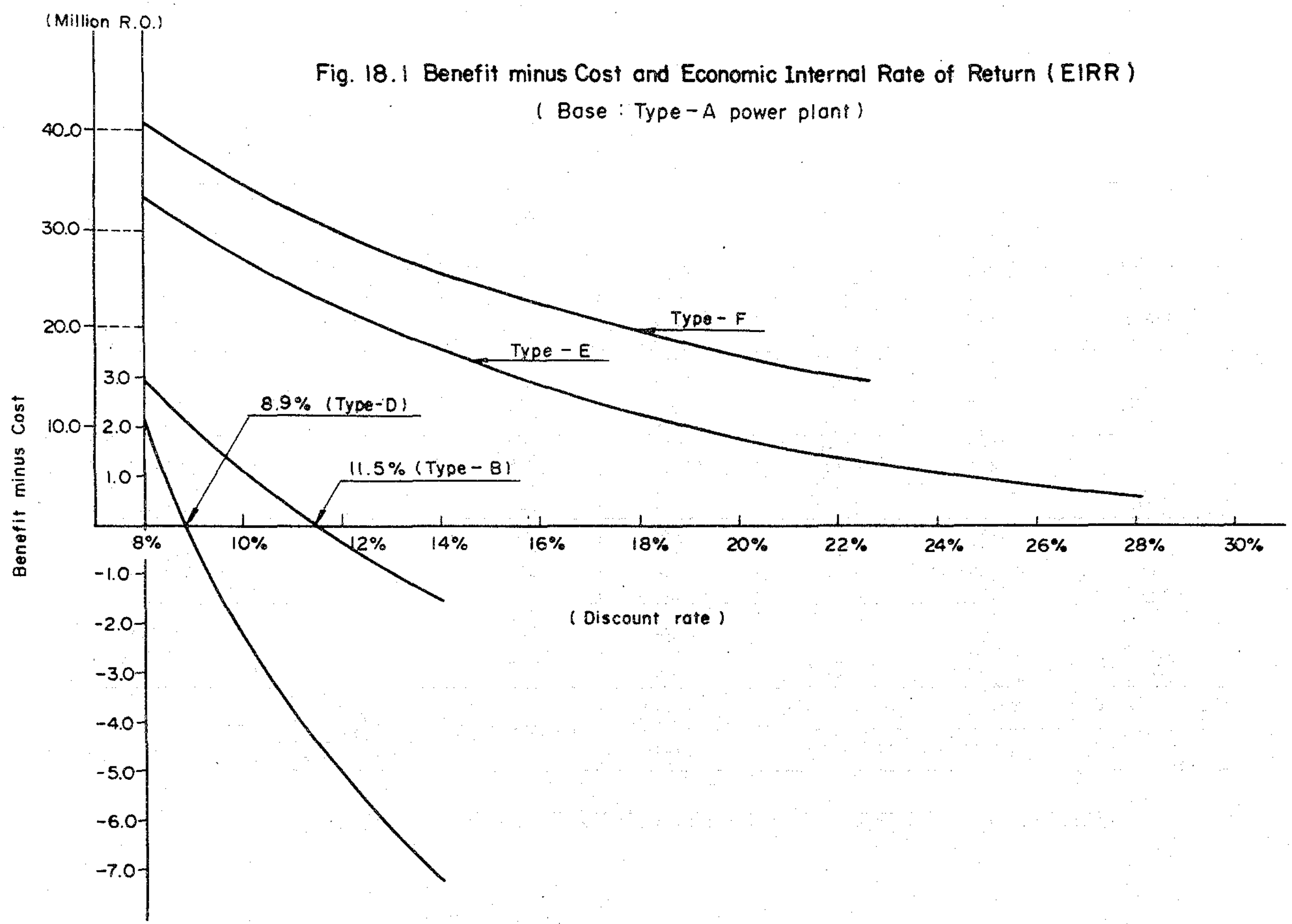
Table 18.10 Overall cost comparison and Benefit/Cost ratio (Power and desalination)

(Million R.O.)

| Turbine used | Combination of power plant and desalination plant | Discount rate | Total costs converted to present worth | | | B/C ratio (Base:Type-F power plant) |
|---|---|---|---|---|---|---|
| | | | Power plant | Desalination | Total | |
| Extraction turbine | Type-A | 8% | 607.0 | 149.0 | 756.0 | 0.949 |
| | | 10% | 507.3 | 127.6 | 634.9 | 0.948 |
| | | 12% | 431.1 | 110.9 | 542.0 | |
| | | 14% | 371.3 | 97.7 | 469.0 | |
| Extraction turbine | Type-B | 8% | 609.9 | 149.0 | 758.9 | 0.953 |
| | | 10% | 509.0 | 127.6 | 636.6 | 0.951 |
| | | 12% | 430.7 | 110.9 | 541.6 | |
| | | 14% | 369.8 | 97.7 | 467.5 | |
| Extraction turbine | Type-C | 8% | 607.6 | 149.0 | 756.6 | 0.950 |
| | | 10% | 508.1 | 127.6 | 635.7 | 0.949 |
| | | 12% | 431.8 | 110.9 | 542.7 | |
| | | 14% | 371.9 | 97.7 | 469.6 | |
| | Type-D | 8% | 609.1 | 149.0 | 758.1 | 0.952 |
| | | 10% | 505.5 | 127.6 | 633.1 | 0.945 |
| | | 12% | 426.0 | 110.9 | 536.9 | |
| | | 14% | 364.1 | 97.7 | 461.8 | |
| Back pressure turbine | Type-E | 8% | 619.0 | 170.3 | 789.3 | 0.991 |
| | | 10% | 517.8 | 144.5 | 662.3 | 0.989 |
| | | 12% | 439.2 | 124.4 | 563.6 | |
| | | 14% | 378.3 | 108.7 | 487.0 | |
| Back pressure turbine | Type-F | 8% | 626.3 | 170.3 | 796.6 | |
| | | 10% | 525.1 | 144.5 | 669.6 | |
| | | 12% | 447.0 | 124.4 | 571.4 | |
| | | 14% | 386.0 | 108.7 | 494.7 | |

Fig. 18.1 Benefit minus Cost and Economic Internal Rate of Return ( EIRR )

( Base : Type - A power plant )



# CHAPTER 19

# FINANCIAL ANALYSIS

# CHAPTER 19 FINANCIAL ANALYSIS

## 19.1 CONDITIONS AND METHOD OF ANALYSIS

For the reasons described in the beginning of Chapter 17, this financial analysis shall be conducted based on the Type-F combination of power plant and desalination plant.

The analysis shall be carried out in the following manner:

a) To set up loan conditions deemed most reasonable.

b) To estimate operating expenses for both electric power sector and desalination sector.

c) To estimate reasonable new selling prices of electricity and water on the cost basis.

d) To estimate operating revenues for both electric power sector and desalination sector based on the above new selling prices of electricity and water.

e) To prepare repayment schedule of the borrowings, profit and loss statement and cash-flow sheet.

f) To calculate rate of return (ratio of operating income to fixed assets in operation) and rate of net income (ratio of net income to fixed assets in operation) to evaluate financial performance of the project.

The financial analysis shall also be carried out for the period up to 2010 as in the case of economic evaluation of Chapter 18. Construction costs of facilities used in this analysis are of escalated prices estimated by using price escalation rate of 3% per annum, but all revenues and expenses after commissioning of the project shall be assumed constant excluding any future inflation.

## 19.2 PROCUREMENT OF FUNDS, INTEREST DURING CONSTRUCTION AND TOTAL CONSTRUCTION COSTS

In Chapter 17, the construction costs of the project are estimated as follows at a price escalation rate of 3% per annum for both foreign currency portion and local currency portion:

(Million R.O.)

| Year | Power sector | | | Desalination sector | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | F.C. | L.C. | Total | F.C. | L.C. | Total | F.C. | L.C. | Total |
| 1986 | 13.24 | 3.73 | 16.97 | 12.51 | 1.46 | 13.97 | 25.75 | 5.19 | 30.94 |
| 1987 | 56.63 | 10.42 | 67.05 | 32.16 | 12.76 | 44.92 | 88.79 | 23.18 | 111.97 |
| 1988 | 78.76 | 8.16 | 86.92 | 21.14 | 6.55 | 27.69 | 99.90 | 14.71 | 114.61 |
| 1989 | 63.28 | 3.65 | 66.93 | 12.78 | 1.90 | 14.68 | 76.06 | 5.55 | 81.61 |
| 1990 | 16.65 | 1.40 | 18.05 | 5.57 | 1.80 | 7.37 | 12.22 | 3.20 | 25.42 |
| 1991 | 6.85 | 1.35 | 8.20 | 0.67 | 0.55 | 1.22 | 7.52 | 1.90 | 9.42 |
| Total | (683.33)<br>235.41 | 28.71 | 264.12 | (248.04)<br>84.83 | 25.05 | 109.85 | (936.37)<br>320.24 | 53.73 | 373.97 |

Note: Costs of foreign currency portion are converted to US$ million and shown in parentheses.

Since the above amounts are very large, the project will have to be financed by plural financial institutions.

The policy of the government for procurement of funds is not made clear, but it is to be noted that the export and import banks of industrial countries apply an interest rate of 8.5% (low interest countries) to 9.3% (high interest rate countries) as guidelines, while in Oman some public projects have been financed by a foreign government at an interest rate of 5%. Taking these into consideration, the following loan conditions were assumed in this financial analysis:

For foreign currency portion:

Repayment period: 15 years after commissioning

Compounded interest rate: 7.3% (Assuming Ex-Im bank's loan of 8.5% x 2/3 and government base loan of 5% x 1/3)

For local currency portion:

Repayment period: 10 years after commissioning
Interest rate: 8% (Oman Development Bank)

In fact, the local currency portion of the construction costs will be financed by the budget of the government, so there will be no local interest charged on the project. However, in order to calculate adequate new prices of electricity and water the interest rate of the Oman Development Bank was used in this financial analysis as the opportunity cost of capital in Oman.

Based on the above loan conditions, the total construction costs of the project including interests during construction are estimated as follows:

(Million R.O.)

| Sector | Currency | Construction cost | Interest during construction | Total construction costs |
|---|---|---|---|---|
| Electric power | Foreign<br>Local<br>Total | 235.41<br>28.71<br>264.12 | 57.61<br>8.61<br>66.22 | 293.02<br>37.32<br>330.34 |
| Desalination | Foreign<br>Local<br>Total | 84.83<br>25.02<br>109.85 | 23.93<br>7.68<br>31.61 | 108.76<br>30.70<br>141.46 |
| Total | Foreign<br>Local<br>Total | 320.24<br>53.73<br>373.97 | 81.54<br>16.29<br>97.83 | 401.78<br>70.02<br>471.80 |

## 19.3 DEBT FINANCE OF THE ELECTRIC POWER SECTOR

### 19.3.1 Operating expenses

Statistically, the operation and maintenance cost is 4.0% of the construction cost in case of power generating facilities, 2.1% in case of transmission facilities and 2.9% in case of substation facilities. Therefore, based on the direct construction costs by facility at 1985 prices the weighted cost ratio of the electric power sector is calculated at 3.74% as shown below:

| Facility | Construction cost (Million R.O.) | Share | Weighted cost ratio |
|---|---|---|---|
| Generation | 171.12 | 81.8% | 4.0% x 0.818 = 3.27% |
| Transmission | 15.21 | 7.3% | 2.1% x 0.073 = 0.15% |
| Substation | 22.86 | 10.9% | 2.9% x 0.109 = 0.32% |
| Total | 209.19 | 100% | 3.74% |

Note: *Construction costs at 1985 prices are shown in* Chapter 17.

The construction costs of the electric power sector will amount to 264.12 million R.O. in total, therefore the operation and maintenance cost of this sector is estimated as follows:

264.12 million R.O. x 0.0374 = 9.88 million R.O.

Annual disbursement of the above cost will be made in accordance with capacity in operation, i.e. *20% in 1988, 50% in 1989, 80% in 1990 and 100% in* 1991 and thereafter.

(2) MEW's administration expenses

The administration expenses are *0.5%* of the construction cost *in all cases* of power generation, transmission and transformation. Therefore, MEW's *administration expenses are estimated as follows:*

264.12 million R.O. x 0.005 = 1.32 million R.O.

Annual disbursement of the above expenses will be made in the same manner as in the case of operation and maintenance cost.

(3) Fuel cost

In paragraph 18.3.4 (3) of Chapter 18, the fuel cost charged on the electric power sector is estimated as follows:

| | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 and thereafter |
|---|---|---|---|---|---|---|---|---|
| Fuel cost (Million R.O.) | 6.20 | 20.60 | 29.40 | 49.40 | 49.50 | 49.60 | 49.60 | 50.00 |

(4) Depreciation cost

Depreciation period differs according to kinds of facilities, but for the purpose of simplification depreciation on the fixed assets was calculated on the straight line method to write off (without scrap value) the costs of fixed assets of all kinds of power facilities over the period of 20 years. Therefore, the depreciation cost is:

330.34 million R.O./20 years = 16.52 million R.O.

19.3.2 Operating revenues

(1) Energy sold

As stated in paragraph 4.3.1 (3) of Chapter 4, the transmission and distribution losses are estimated at about 15% of the energy sent-out. Therefore, by deducting these losses from energy at sending-end of Barka power station, estimated in Table 18.1 (b), the following energy is expected to be available at consumers-end:

| | | | (GWh) |
|---|---|---|---|
| Year | Energy at sending-end | Transmission and distribution losses | Energy at consumers-end |
| 1988 | 488 | 73 | 415 |
| 1989 | 1,624 | 244 | 1,380 |
| 1990 | 2,745 | 412 | 2,333 |
| 1991 | 4,798 | 720 | 4,078 |
| 1992 | 4,952 | 743 | 4,209 |
| 1993 | 5,105 | 766 | 4,339 |
| 1994 | 5,258 | 789 | 4,469 |
| 1995 | 5,413 | 812 | 4,601 |
| Average for 20 years | | | 4,536 |

(2) Calculation of new tariff rate of electricity

It is generally admitted in the public utilities that electricity tariff should be established on the cost basis including fair return.

As described in Chapter 4, the total demand for electricity in 1991 is forecasted to grow to some 1,300 MW in 1991. This load will be supplied for the most part by Barka power station because this power station is destined, by its nature, to supply base load and middle load of the power system. The peak load will be supplied by Rusail power station (498 MW after extension in 1976/77) and small scale gas turbine power plants at Ghubrah. Therefore, it will be appropriate for present electricity tariff to be adjusted based on the electricity supply costs of Barka power station and gas turbine power stations. These supply costs are calculated as follows:

a) Electricity supply cost of Barka power station

The overall costs (annual costs) of Barka power project including power station, transmission lines and substations are estimated as follows:

(Million R.O.)

| Item | Amount |
|---|---|
| ∘ Operation and maintenance cost | 9.88 |
| ∘ Administration expenses | 1.32 |
| ∘ Fuel cost | 50.00 |
| ∘ Depreciation cost | 16.52 |
| ∘ Interest on foreign loan: (235.41 x 0.11188 (Note 1) x 15 years - 235.41)/20 years = | 7.98 |
| ∘ Interest on local loan: (28.71 x 0.14903 (Note 2) x 10 years - 28.71)/20 years = | 0.70 |
| Total (Overall costs) | 86.40 |

Note 1: Capital recovery factor for interest rate of 7.3% and repayment period of 15 years.

Note 2: Capital recovery factor for interest rate of 8% and repayment period of 10 years.

Annual average of energy sold is 4,536 GWh as shown in paragraph 19.3.2.(1). Therefore, the electricity supply cost of the project will be 19.05 Baizas/kWh at substation-end as shown below:

86.40 million R.O./4,536 GWh = 19.05 Baizas/kWh

In case that thermal power stations are predominant in the power system, shares of power generating sector, transmission and transformation sector and distribution sector in the total supply cost of electricity are generally as follows:

| | |
|---|---|
| Power generating sector | 70% |
| Transmission and transformation sector | 10% |
| Distribution sector | 20% |
| Total | 100% |

Therefore, supply cost of 19.05 Baizas/kWh at substation-end will increase to 23.81 Baizas/kWh at consumers-end.

19.05 Baizas/0.8 = 23.81 Baizas/kWh

b) Electricity supply cost of gas turbine power stations

Data on power generating cost of the existing Rusail power station are not available. However, based on prices and characteristics generally admitted, power generating cost of gas turbine power station can roughly be estimated as follows:

(R.O. kW)

| Item | | Amount |
|---|---|---|
| o Fixed costs/kW (Estimated unit construction cost: 120 R.O. (US$350)/kW) | | |
| o Depreciation cost | 120 R.O./10 years | = 12.00 |
| o Interest on loan: (120 x 0.14435 (Note 1) x 10 years - 120)/10 years | | = 5.32 |
| o Operation and maintenance cost<br>o Administration expenses | 120 R.O. x 0.0456 | = 5.47 |
| Sub-total | | 22.79 |

Note 1: Capital recovery factor for interest rate of 7.3% and repayment period of 10 years

When taking into account future industrialization of the country, the load factor in the integrated power system after commissioning of Barka power station is considered at around 55%. At this system load factor, gas turbine power stations are considered to be operated at a plant factor of less than 21%, seen from demand forecast given in Tables 4.12 and 18.1 (b). Thus, energy generation per kW installed of gas turbine power station is about 1,840 kWh (1 kW x 8,760 hr x 0.21 = 1,840 kWh). Therefore, the fixed costs per kWh installed is:

22.79 R.O./1,840 kWh = 12.38 Baizas/kWh

Since thermal efficiency of gas turbine is about 26.8% (3,209 kcal/kWh), fuel cost per kWh is calculated at 11.55 Baizas.

3.8 Baizas/$10^3$ kcal x 3,209 kcal/kWh = 12.19 Baizas/kWh

Therefore, generating cost per kWh is 24.55 Baizas.

12.38 + 12.19 = 24.57 Baizas/kWh

As stated before, power generating cost is considered to be about 70% of the total supply cost of electricity, and transmission and distribution loss factor is estimated at around 15%. Therefore, energy supply cost of gas turbine power station at consumers-end is calculated at 41.26 Baizas/kWh.

$$\frac{24.57 \text{ Baizas/kWh}}{0.70\ (1 - 0.15)} = 41.29 \text{ Baizas/kWh}$$

c) New electricity tariff

The electricity tariff should be established to cover all costs incurred from power generation to distribution.

Based on Tables 4.12 and 18.1 (b) and using a system load factor of 55%, it is calculated that in 1991 energy supplied by Barka power station will amount to about 78% of the total energy supplied, and the remaining 22% will be supplied by other power stations (mainly by gas turbine power stations).

The above shares will remain almost constant in the future as far as there will be no big change in the shape of annual load curve. Therefore, it will be appropriate to apply, after commissioning of Barka power station, new electricity tariff made on the cost basis as follows:

23.81 Baizas/kWh x 0.78 = 18.57 Baizas/kWh
41.29 Baizas/kWh x 0.22 = 9.08 Baizas/kWh

Weighted average: 27.65 Baizas/kWh (= 28 Baizas/kWh)

The above new rate of 28 Baizas/kWh is more than 40% higher than that of the present electricity tariff. However, when considering that the present tariff rate has been held unchanged during 12 years from 1973, the above price rise is not considered so large.

## 19.4 DEBT FINANCE OF DESALINATION SECTOR

### 19.4.1 Operating expenses

(1) Steam cost (fuel cost)

Paragraph 18.4.2 (3) shows the steam cost to be charged on desalination sector as follows:

| Year | Amount (Million R.O.) |
|---|---|
| 1989 | 2.40 |
| 1990 | 4.40 |
| 1991 | 6.70 |
| 1992 | 7.50 |
| 1993 | 8.30 |
| 1994 | 9.20 |
| 1991 and thereafter | 9.70 |

(2) Power cost

In the economic evaluation in Chapter 18, the power cost of desalination plant was calculated using the present tariff rate of 20 Baizas/kWh because type of Barka power plant cannot be selected prior to determination of type of desalination plant. In this financial analysis, however, the type of power plant is already selected, so the power cost of desalination plant shall be calculated based on the energy supply cost at sending-end of Barka power plant.

As described in paragraph 19.3.2 (2), the overall costs (annual costs) of Barka power project including power station, transmission lines and substations are estimated at 86.40 million R.O. If these costs are allocated according to direct cost of each sector, the share of power station in the overall costs is calculated at 70.68 million R.O.

86.40 million R.O. x 171.12/209.19 = 70.68 million R.O.

From 1995 Barka power station will enter full load operation with a sent-out energy of 5,413 GWh annually as indicated in 19.3.2 (1). Therefore, energy supply cost at sending-end of Barka power station will be:

70.68 million R.O./5,413 GWh = 13.06 Baizas/kWh

On the other hand, quantity of product water of desalination plant will be 55,845,000 $m^3$ annually.

180,000 $m^3$/day x 365 days x 0.85 = 55,845,000 $m^3$

Since power consumption for producing 1 $m^3$ of product water is estimated at 3.24 kWh, the power cost is calculated at 2.36 million R.O. as shown below:

13.06 Baizas/kWh x 3.24 kWh/$m^3$ x 55,845,000 $m^3$ = 2.36 million R.O.

The annual disbursement of the above cost will be made in the following manner according to capacity of desalination plant in operation:

| Year | Amount (Million R.O.) |
|---|---|
| 1989 | 1.12 |
| 1990 | 1.30 |
| 1991 | 1.62 |
| 1992 | 1.83 |
| 1993 | 2.03 |
| 1984 | 2.24 |
| 1995 and thereafter | 2.36 |

(3) Chemicals cost

Paragraph 18.4.2 (5) shows the chemicals cost as follows:

| Year | Amount (Million R.O.) |
|---|---|
| 1989 | 1.10 |
| 1990 | 1.30 |
| 1991 | 1.60 |
| 1992 | 1.80 |
| 1993 | 2.00 |
| 1994 | 2.20 |
| 1995 and thereafter | 2.30 |

(4) Personnel expenses, administration expenses and cost of materials for maintenance

Statistically, personnel expenses are 0.42% of the construction cost, and administration expenses and cost of materials for maintenance are 0.5% of the construction cost, respectively. In the economic evaluation in Chapter 18 the corresponding costs of product water transportation facilities were excluded, but in the financial analysis costs of these facilities must also be included. Since the total construction costs of desalination sector including product water transportation facilities are estimated at 109.85 million R.O., the captioned cost and expenses will amount to:

109.85 million R.O. x 0.0142 = 1.56 million R.O.

The annual disbursement of the above costs will be as follows:

| Year | Amount (Million R.O.) |
|---|---|
| 1989 | 0.78 |
| 1990 | 1.25 |
| 1991 and thereafter | 1.56 |

(5) Depreciation cost

Depreciation on the fixed assets shall be calculated on the straight line method to write off (without scrap value) the costs of fixed assets of all kinds of facilities over the period of 20 years. Therefore, the depreciation cost is:

141.46 million R.O./20 years = 7.07 million R.O.

19.4.2 Operating revenues

(1) Loss factor and quantity sold of product water

Data from early in 1970's to 1983 shows large variations by year in the loss factor of water transportation and distribution due to leakage and other reasons, i.e. about 20% up to 1979 and slightly more than 30% during the last 4 years from 1980 to 1993. In this financial analysis the loss factor after commissioning of Barka desalination plant shall be estimated at 20% including un-metered consumption, considering that maintenance of water pipelines be made in a good condition in the future.

Based on the above conditions, the quantity sold of product water of Barka desalination plant is estimated as follows:

| Year | Production ($m^3$) | Quantity sold ($m^3$) |
|---|---|---|
| 1989 | 26,383,000 | 21,106,400 |
| 1990 | 30,754,000 | 24,603,200 |
| 1991 | 38,357,000 | 30,685,600 |
| 1992 | 43,204,000 | 34,563,200 |
| 1993 | 48,052,000 | 38,441,600 |
| 1994 | 52,899,000 | 42,319,200 |
| 1995 and thereafter | 55,845,000 | 44,676,000 |
| Average for 20 years | | 43,041,000 |

(2) Calculation of new tariff rate of water

a) Product water supply cost of Barka desalination plant

The overall costs (annual costs) of Barka desalination plant are estimated as follows:

| Item | Amount |
|---|---|
| | (Million R.O.) |
| ∘ Steam cost | 9.70 |
| ∘ Power cost | 2.36 |
| ∘ Chemicals | 2.30 |
| ∘ Personnel expenses, administration expenses and cost of materials for maintenance | 1.56 |
| ∘ Depreciation cost | 7.07 |
| ∘ Interest on foreign loan: | |
| (84.83 x capital recovery factor 0.11188 x 15 years − 84.83)/20 years = | 2.88 |
| ∘ Interest on local loan: | |
| (25.02 x capital recovery factor 0.14903 x 10 years − 25.02)/20 years = | 0.61 |
| Total (Overall costs) | 26.48 |

Therefore, product water supply cost of Barka desalination plant is calculated to be 588 Baizas/$m^3$ at outlet of water conduit pipe.

26.48 million R.O./43,041,000 $m^3$ = 615 Baizas/$m^3$

Costs of distribution pipelines branched from the above conduit pipe are roughly estimated at about 10% of the total supply costs of water. Thus, product water supply cost of Barka desalination plant will increase to 683 Baizas/$m^3$ (2.9 Baizas/gallon) at consumers-end.

615 Baizas/0.9 = 683 Baizas/$m^3$
= 3.1 Baizas/gallon

b) New water tariff

At present, water is supplied at 2 Baizas/gallon to domestic consumers and at 3 Baizas/gallon to commercial and industrial consumers. Data to calculate the average rate are not available.

After commissioning of Barka desalination plant, the total water production capacity in the Capital area will increase to 300,000

$m^3$/day of which 60% is of Barka desalination plant as shown below:

| Supply sources | Capacity ($m^3$/day) |
|---|---|
| Wells | 22,000 ( 7.3%) |
| Ghubrah desalination plant | 98,000 (32.7%) |
| Barka desalination plant | 180,000 (60.0%) |
| Total | 300,000 ( 100%) |

The supply cost of product water of Ghubrah desalination plant is not informed, but this cost is considered almost comparable to the supply cost at the plant site of Barka desalination plant. The supply cost at the plant site of Barka desalination plant is estimated as follows:

683 Baizas/$m^3$ x 60.68 million R.O. (cost of plant)/88.04 million R.O. (cost including water distribution facilities) = 471 Baizas/$m^3$

Therefore, the average supply cost of product water including Barka and Ghubrah desalination plants is roughly estimated as follows:

(683 x 0.6) + (471 x 0.4) = 598 Baizas/$m^3$ (= 2.7 Baizas/gallon)

Therefore, it will be appropriate to apply, after commissioning of Barka desalination plant, new water tariff of an average rate of 2.7 Baizas/gallon (598 Baizas/$m^3$).

## 19.5 RESULTS OF FINANCIAL ANALYSIS

Based on the conditions shown in paragraph 19.2 for the procurement of funds and operating expenses and revenues estimated for both electric power and desalination sectors, the projection of financial performance of the project was made and shown in the following tables:

Table 19.1 Procurement of funds and repayment schedule
Table 19.2 Details of operating revenues

Table 19.3 Details of operation expenses
Table 19.4 Profit and loss statement
Table 19.5 Cash-flow sheet

Results of financial analysis are described as follows:

### 19.5.1 Profit and loss calculation

As seen in the profit and loss statement in Table 19.4, the annual balance will show slight deficit up to 1994 and keep black every year from 1995, and accumulated net income will ammount to 279.57 million R.O. by 2010.

### 19.5.2 Cash-flow balance

Due to interest during construction, deficit in the accumulated cash balance will continue up to 1999 and turn to black in 2000.

### 19.5.3 Rate of return

The operating income must cover interest and net income (or loss). The interest is a return on the capital invested and the net income is a return on the efforts of business operation.

The rate of return which is the ratio of operating income to the fixed assets in operation of the project is as follows:

Accumulated operating income: 523.10 million R.O.

Accumulated fixed assets in operation: 4,481.89 million R.O.

Rate of return:

- For the first 10 years after completion of the project:
  225.10 million R.O./3,707.18 million R.O. = 6.1%
- For the whole service life of 20 years:
  523.10 million R.O./4,481.89 million R.O. = 11.7%