2) Auxiliary steam generator

This study is based on the dual purpose of power plant and desalination plant, so electric power and steam for desalination plant are supplied from power plant. But at initial stage auxiliary steam generators are installed to supply steam for first 3 desalination plants (30,000 m^3/d x 3 units) which are to be constructed from the end of 1988 to the beginning of 1989, because the construction period of steam turbine power plant is longer than that of desalination plant.

After the completion of power plant, heating steam for desalination plant is supplied from power plant, so auxiliary steam generators are used as stand-by system in case of shutdown of the power plant.

3) Sea water intake and discharge facilities

Sea water intake and discharge facilities are common use with power plant. So, refer to chapter 10 in detail.

9.3.4 Equipment specification

(1) Desalination plant (6 units)

1) Evaporator (1/unit)

Heat Recovery Section

Type : Cross tube & rectangular box type

Number of Stages : 20 stages

Materials:

Shell & Partition Plate

Stage No.1 - No.6 : Carbon Steel + 316L SS cladding
Stage No.7 - No.20 : Carbon steel + Epoxy coating

Tube sheet : 90/10 Cu-Ni

Tube : Aluminium brass

Water box : Carbon Steel + 90/10 Cu-Ni cladding

Heat Rejection Section

Type : Cross tube & rectangular box type

Number of Stages : 3 stages

Materials:

Shell & Partition plate : Carbon steel + Epoxy coating
Tube sheet : 90/10 Cu-Ni
Tube : Titanium
Water box : Carbon steel + 90/10 Cu-Ni cladding

2) Brine Heater

Type : Horizontal, shell & tube type heat exchanger

Quantity : 1/unit

Materials:

Shell : Carbon steel
Tube : 90/10 Cu-Ni
Tube sheet : 90/10 Cu-Ni
Water box : Carbon steel + 90/10 Cu-Ni cladding

3) Deaerator

Type : Vacuum packed tower type

Quantity : 1/unit

Performance : Dissolved oxygen Max. 20 ppb

Materials:

Shell	:	Carbon steel + Neoprene rubber lining
Spray Nozzle	:	316 L stainless steel
Packing	:	Polypropylene

4) Venting System

Steam Ejector

Type	:	Twin 3 stages type
Quantity	:	1/unit

Vent Condenser

Type	:	Horizontal, shell & tube type heat exchanger
Quantity	:	1/unit

Ejector Condenser

Type	:	Horizontal, shell & tube type heat exchanger
Quantity	:	1/unit

5) Sponge ball tube cleaning system

Sponge ball catching screen	:	1/unit
Sponge ball collector	:	1/unit
Accessories	:	Sponge balls, pump & motor

6) Main process pumps

Brine Recycle Pump

Type	:	Vertical mixed flow pump with barrel
Quantity	:	1/unit
Capacity	:	13,150 m^3/hr
Total head	:	50 m
Driver	:	Electric motor
Materials:		
Casing	:	Ni-resist
Impeller	:	Stainless cast steel
Shaft	:	Stainless steel
Barrel	:	FRP

Brine Blow-down Pump

Type	:	Vertical mixed flow pump with barrel
Quantity	:	1/unit
Capacity	:	1,812 m^3/hr
Total head	:	20 m
Driver	:	Electric motor
Materials:		
Casing	:	Ni-resist
Impeller	:	Stainless cast steel
Shaft	:	Stainless steel
Barrel	:	FRP

Distillate Pump

Type	:	Vertical mixed flow pump with barrel
Quantity	:	2/unit (working: 1, stand-by: 1)
Capacity	:	1,500 m^3/hr
Total head	:	20 m
Driver	:	Electric motor
Materials:		
Casing	:	Stainless cast steel
Impeller	:	Stainless cast steel
Shaft	:	Stainless steel
Barrel	:	FRP

Condensate Pump

Type	:	Horizontal single suction volute
Quantity	:	2/unit (working: 1, stand-by: 1)
Capacity	:	198 m^3/hr
Total head	:	35 m
Driver	:	Electric motor
Materials:		
Casing	:	Cast steel
Impeller	:	Stainless cast steel
Shaft	:	Stainless steel

(2) Micellaneous equipments

1) Product water treatment system

Quantity: 1 (total)

Type: Limestone filter type using the extraction gas from the evaporator

Treated water capacity: 180,000 m^3/day
(The half of untreated total product water from the evaporators is to be mixed with the other half of treated water from the product water treatment system)

Total Hardness of Treated Water: 60 $\pm$ 10 mg/l (as $CaCO_3$)

Main Equipment (total plant)

CO_2 Absorber	2 units
Limestone Filter	8 units (1 unit stand-by)
Compressor	4 units (2 units stand-by)
pH Adjusting System	1 set
Limestone Storage & Feed System	1 set
Washing System for Limestone Filter	1 set

2) Auxiliary steam generator

Quantity : 2 (total)

Type : Natural circulation type

Capacity : 300 tons/h each

Steam Pressure : 10 kg/cm^2G

Steam Temperature : 183°C (saturated steam)

Fuel : Natural gas (or heavy fuel oil in an emergency case)

Components

Boiler Bank	:	2 nos
Fuel Firing Equipment	:	2 sets
Automatic control System	:	2 sets
Deaerator Lift	:	2 nos
Deaerator Pump & Motor	:	2 nos
Forced Draft Fan	:	2 nos
Stack	:	2 nos

3) Piping

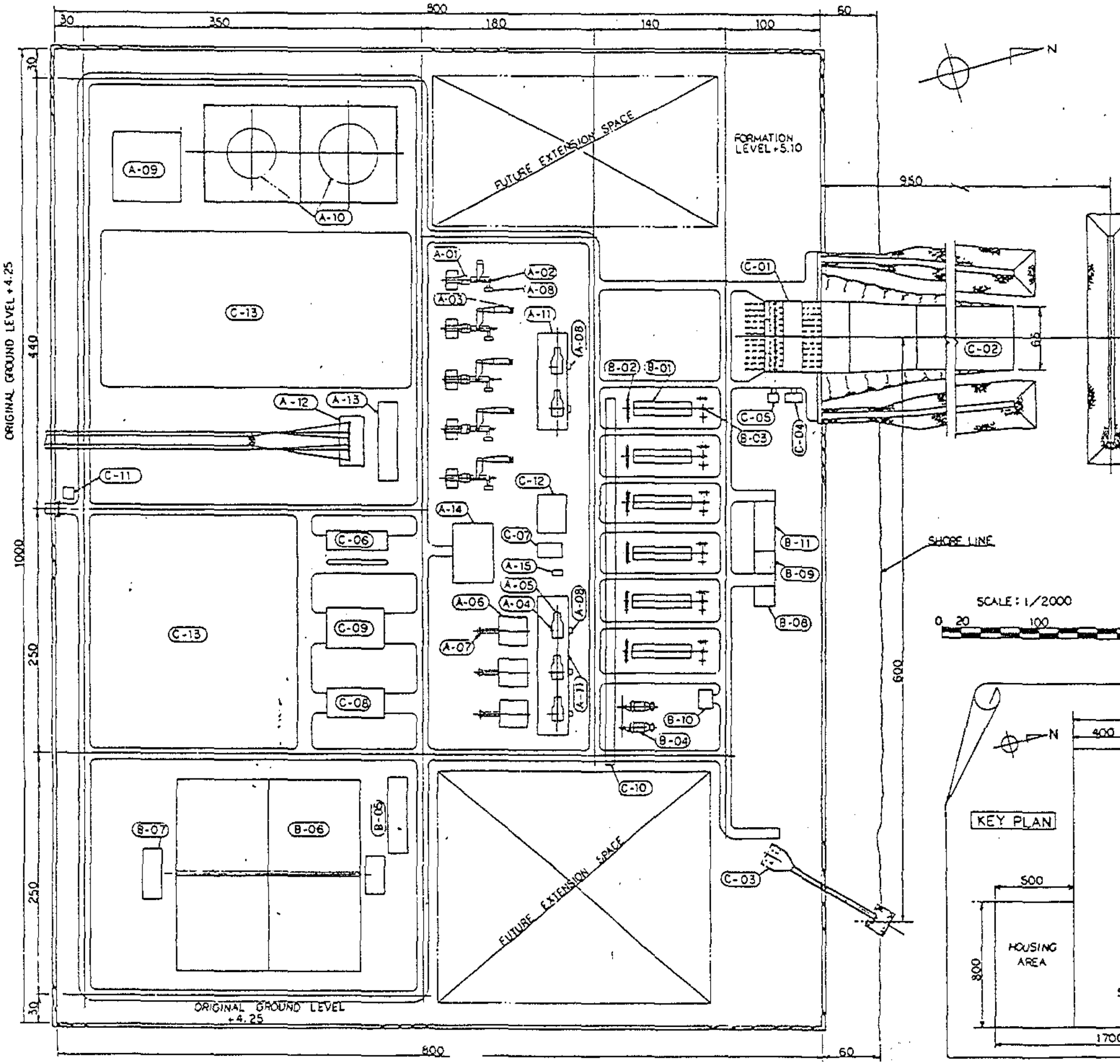
Service	Working Temp.	Material
Seawater & low temperature brine	≤ 80°C	Fiber reinforced plastic
High temp. brine	> 80°C	Carbon Steel + 90/10 Cu-Ni cladding
Distillate & fresh water	≤ 80°C	Fiber reinforced plastic
Condensate	120°C	Carbon steel
Steam	120 - 300°C	Carbon steel

9.3.5 Desalination plant arrangement

Whole plant plot plan is shown in Fig. 9.8. Required construction area of desalination plants and related equipments such as desalination plant units, product water treatment unit auxiliary steam generators, and water reservoirs and pumping station is approx. 132,500 m^2.

(1) Evaporator and associated auxiliary

General arrangement of desalination plant is shown in Fig. 9.4 considering easy maintenance and inspection.



ITEM NO	FACILITY	REMARKS
	POWER PLANT	
A-01	GAS TURBINE	
A-02	GENERATOR	
A-03	HEAT RECOVERY UNIT	
A-04	STEAM TURBINE	
A-05	GENERATOR	
A-06	STEAM GENERATOR	
A-07	STACK	
A-08	TRANSFORMER	
A-09	FUEL GAS RECEIVING UNIT	
A-10	FUEL OIL TANK	
A-11	TURBINE HALL	
A-12	SENDING OUT FACILITY	
A-13	SWITCH GEAR ROOM	
A-14	CENTRAL CONTROL BUILDING	
A-15	DAMP CONDENSER	
	DESALINATION PLANT	
B-01	EVAPORATOR	
B-02	BRINE HEATER	
B-03	DESAL PUMPS	
B-04	AUX. STEAM GENERATOR	
B-05	PRODUCT WATER TREATMENT	
B-06	PRODUCT WATER RESERVOIR	
B-07	PRODUCT WATER PUMPING STATION	
B-08	DESAL CONTROL BUILDING	
B-09	DESAL CHEMICAL INJECT BUILDING	
B-10	DESAL SWITCH GEAR BUILDING	
B-11	CHEMICAL STORE HOUSE	
	COMMON FACILITY	
C-01	SEA WATER INTAKE & PUMP PIT	
C-02	SEA WATER INTAKE CHANNEL	
C-03	SEA WATER OUTFALL	
C-04	CHLORINATION BUILDING	
C-05	SEA WATER PUMP CONTROL ROOM	
C-06	ADMINISTRATION BUILDING	
C-07	COMPRESSOR ROOM	
C-08	STORE	
C-09	WORK SHOP	
C-10	PIPE RACK	
C-11	GATE HOUSE	
C-12	UTILITY SPACE	
C-13	STORAGE YARD	

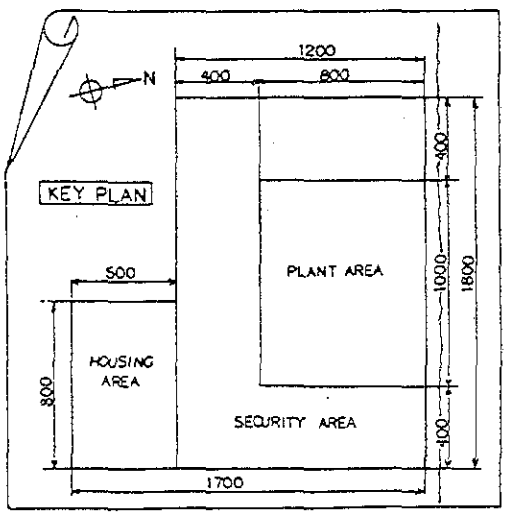


FIG. 9.8
PLOT PLAN

Brine heaters and condensate pumps are located at steam generator side and deaerator, main process pumps, ejector are so arranged in one group at sea-shore side that connecting pipes become short and simple and consequently, maintenance and inspection become easy.

In addition, there is space for withdrawing and re-inserting of evaporator tubes between each evaporator unit.

(2) Large process pumps

Large pumps such as brine recycle pump, brine blow down pump and distillate pumps are installed in a single row for easy maintenance.

(3) Auxiliary steam generator

Auxiliary steam generators installed exclusively for desalination plant are located adjacent to No.1 desalination plant considering desalination plant construction schedule order from No.1 unit to No.6 unit.

Because this steam generator will supply the steam exclusively to first three desalination plants, when the steam from power plant is not available at initial power construction stage.

(4) Chemical feed building and desalination control building

Chemical feed building and desalination control building are located near main process pump units, and auxiliary steam generators to operate desalination plants and auxiliary steam generators easily.

(5) Product water treatment system

Product water treatment system is located between evaporator units and water resorvoirs to minimize product water piping route.

CHAPTER 10

OUTLINES AND CONCEPTUAL DESIGNS OF CIVIL AND ARCHITECTURAL FACILITIES

CHAPTER 10 OUTLINES AND CONCEPTUAL DESIGNS OF CIVIL AND ARCHITECTURAL FACILITIES

10.1 LAYOUT AND OUTLINE OF CIVIL AND ARCHITECTURAL FACILITIES

The layout of the principal civil and architectural facilities related to construction of power and desalination complex plant is shown in Fig. 10.1.

The total land area required for this project, including plant-related facilities, storage yard for materials and equipment during construction, field offices of MEW and contractors, and land for laborers' quarters, is approximately 1,000,000 m^2 (1,000 x 1,000 m). As mentioned in 6.4, the elevation of the ground at this site is approximately 1 m above H.H.W.L. (highest predicted tide at Mina Quboos), so that an area of approximately 800,000 m^2 for plant-related facilities is to be raised at least 1 m from the original height to be H.H.W.L. + 2.00 m in consideration of the allowance for high waves due to strong wind (according to the observation data on wave height at Mina Qaboos, 5.9 m and 5.2 m of high waves were recorded on August, 1983 and on February, 1984), the dranage convenience for compounds and the gradient required for discharge of large volume of waste water from plant area to sea area. Gravel is to be laid at open spaces in the plant area where structures or equipment foundations are not to be installed, while greening is to be done with plants and lawns around buildings that will be constantly occupied by operation and maintenance personnel after start of plant operation such as the administration building and the control buildings. In order to prevent trespassing into the premises of the plant by third parties, a fence 2.00 m in height (the approximate construction cost of the fence would be 92,000 R.O.) is to be provided at the entire perimeter of the plant site.

The outlines of the principal civil and architectural facilities are as listed below.

(1) Access road to site
Length: 2,500 m
Width: 10.00 m
Surfacing: Concrete, thickness 7 cm
Gutter: Reinforced concrete open channel, 50 x 50 cm

(2) Plant internal roads

Length: 6,700 m

Width: 10.00 m

Surfacing: Concrete, thickness 7 cm

Gutter: Reinforced concrete open channel, 50 x 50 cm

(3) Seawater intake facility: Intake waterway, 1 system

Intake quantity: $40 m^3/sec$

Structure: Open channel with dredged waterway and dykes

Waterway: Length: 850 m, Width: 65.00 m

Dyke: Number: 2 lines, Length: 850 m x 2 + 210 m = 1,910 m

Max. height: 11.50 m

(4) Seawater intake facility: Intake and pump pit, 1 system

Structure: Reinforced concrete open channel, curtain-wall type

Length: 60.00 m

Width: 73.00 m

Height: 13.20 m

(5) Discharge facilities: Discharge pit and discharge channel, 1 system

Structure: Reinforced concrete open channel

Length: 130.00 m

Width: 8.00 - 21.00 m

Height: 2.80 - 8.50 m

(6) Gas turbine generator foundation: 80 MW x 5 units

Structure: Reinforced concrete mat, including soil stabilization

Length: 50.00 m

Width: 5.00 m

Average thickness: 2.00 m

(7) Steam turbine generator foundation: 80 MW x 2 units

Structure: Reinforced concrete double slab and mat

Length: 20.00 m

Width: 9.00 m

Thickness: 2.00 - 5.00 m

(8) Steam-turbine generator foundation: 60 MW x 3 units
Structure: Reinforced concrete double slab and mat
Length: 18.00 m
Width: 8.00 m
Thickness: 1.80 - 4.30 m

(9) Boiler foundation: 60 MW x 3 units
Structure: Reinforced concrete double slab
Length: 33.00 m
Width: 33.00 m
Average thickness: 6.10 m

(10) Exhaust gas heat recovery boiler foundation: single, 4 units
Structure: Reinforced concrete mat, including soil stabilization
Length: 40.00 m
Width: 10.00 m
Average thickness; 2.00 m

(11) Oil tank foundation: 15,000 kl x 1 unit and 23,000 kl x 1 unit
Structure: Ground improvement by sand replacement
Oil retaining wall: Reinforced concrete parapet wall
Parapet wall length: 100 m x 2 + 200 m x 2 = 600 m
Height: 2.00 m

(12) Desalination plant unit foundation: 30,000 m^3/day x 6 units
Structure: Reinforced concrete mat, including soil stabilization

(13) Auxiliary boiler foundation: 300 t/hr x 2 units
Structure: Reinforced concrete mat, including soil stabilization

(14) Reservoir foundation: 54,000 m^3 x 4 units
Structure: Reinforced concrete mat, including soil stabilization

(15) Two powerplant main buildings (for steam turbine generator 80 MW 2 units and 60 MW x 3 units)
Foundation: Reinforced concrete double slab and mat
Structure: Steel construction, 3 stories
Scale: Total building area 17,341 m^2
: Total building volume 138,000 m^3

(16) Administration building (joint use building)

Foundation: Reinforced concrete mat, including soil stabilization

Structure: Reinforced concrete construction, 2 stories

Floor area: 2,940 m^2

(17) Control buildings

1) Powerplant control building

Foundation: Reinforced concrete mat, including soil stabilization

Structure: Reinforced concrete construction, 2 stories, partially with mezzanine floor

Floor area: 8,183 m^2

2) Desalination plant control building

Foundation: Reinforced concrete mat, including soil stabilization

Structure: Reinforced concrete construction, one story

Floor area: 540 m^2

(18) Other buildings

1) Common use buildings

Repair shop: Steel construction, 1 story, 2,400 m^2

Warehouse: Steel construction, 1 story, 1,800 m^2

Chlorine treatment building: Reinforced concrete construction, 1 story, 220 m^2

Guardhouse: Reinforced concrete construction, 1 story, 80 m^2

Garage shed: Steel construction, 220 m^2

2) Desalination plant buildings

Chemical injection building: Reinforced concrete construction, 2 stories, 1,080 m^2

275-kV switchyard: Reinforced concrete construction, 1 story, 324 m^2

Product water treatment building: Reinforced concrete, 1 story, 200 m^2

Product water pumphouse: Steel construction, partially reinforced concrete construction, 1,226 m^2

(19) Self-standing stack (3 units)

Foundation: Reinforced concrete mat, including soil stabilization

Structure: Steel construction

Height: 80 m

Top diameter: 2.4 m

10.2 CONCEPTUAL DESIGN OF INTAKE FACILITIES

At this power and desalination complex plant a large volume of seawater totalling approximately 40 m^3/sec will be required that is, approximately 22 m^3/sec as cooling water for powerplant, and approximately 18 m^3/sec as raw water for the desalination plant. Needless to say, it is desirable for the seawater for cooling water of the powerplant to be of low temperature and contain as little quantities as possible of trash, dirt, sand, and marine life, and seawater for desalination plant to be of water quality suitable for desalination with regard to physical properties and chemical composition.

In carrying out design of intake facilities, in addition to topographical and geological conditions, it is necessary to consider various factors such as waves, littoral drift, seasonal variations of water temperature, recirculation of thermal effluent and siphon effect of circulating waterway system and ease of transportation and installation of materials and equipment required for construction works and ease of maintenance of the facilities after starting the plant operation, etc.

(1) Comparisons of Various Intake Systems of Seawater Intake Facilities

As described previously in 6.6, the sea-bottom slope of the sea area off this site is a gradual shelving bottom type of 1/110 to 1/280. When the beforementioned factors which are basic conditions for design of intake facilities are considered, it is conceivable from a technical viewpoint for three kinds of systems to be used that is open channel intake system, piled jetty-supported pipeline intake system and sea-bottom buried pipeline intake system. In order to select the intake systems for this site, the construction costs for the individual systems were roughly calculated and economic comparisons were made.

1) Open Channel Intake System

The outline of this intake system, as shown in Fig. 10.2, is that an open channel would be provided by excavation of the sea bottom and by constructing dikes. The flow velocity in the open channel would be made about 20 cm/sec in order to prevent traction of soil at the bottom of the channel. In case of this project, the design cooling seawater temperature for the powerplant equipment is assumed to be 30°C (Max. temp. 35°C), accordingly the intake is employed a deep-water type of 3.5 m below L.L.W.L. which would be enable to collect 27–28°C of seawater through the year, so that the length of the channel would be 850 m with the width 65 m. At the starting point of the channel a breakwater 210 m in length would be provided to prevent high waves at times of strong winds from entering the channel directly.

The crest of the dike is to be made the same elevation as the grounds for the plant. Tetrapods weighing 10 t are to be placed at the outer slopes of the dikes while the slopes on the channel sides would be lined with riprap, each piece weighing about 200 kg. Road passable by vehicles for inspection and maintenance of the channel would be provided at the crest of the dike. The approximate construction cost of this facility would be 7.63 million R.O.

2) Piled Jetty-supported Pipeline Intake System

The outline of this facility, as shown in Fig. 10.3, is the same as for the intake facility of the desalination and steam raising plant extension presently under construction by MEW at Ghubrah. Water is to be conveyed by three pipelines of steel pipes 2.40 m in diameter, and these pipes are to be mounted as pipe beams on a piled jetty composed of steel pipe piles and steel-concrete cross beams. A reinforced concrete intake and a pump pit are to be provided at the beginning point of the jetty, and seawater supplied to the pipelines by pumps. The flow velocity inside a pipeline is to be approximately 3 m/sec. Since intake will be by a deep-water system, the length of the pipelines will be 1,000 m. The crest elevation of the cross beams is to be L.L.W.L. + 9.00 m to minimize the effects of high waves on the pipelines at times of strong winds. The intake and pump pit at the beginning point of the jetty will involve underwater work, and as a cofferdam during construction, steel pipe sheet piles are to be driven around the structures to make possible concreting work in a dry condition. The outer and inner surfaces of the pipelines are to be coated with tar-base paint to prevent corrosion. For inspection and maintenance of the pipelines, tracks for bogie cars and a walkway are to be provided on the jetty. The approximate construction cost of this facility would be 8.45 million R.O.

3) Sea-bottom Buried Pipeline Intake System

In outline, as shown in Fig. 10.4, this facility would consist of three pipelines with pipe diameter of 2.80 m and steel intake heads provided at the beginning points of each pipeline. The intake is employed a deep-water type of 3 m below L.L.W.L. which whould be enable to collect 27-28°C of seawater through the year, so that the pipeline length is 1,000 m. The pipelines and the foundations of the intake heads are to be buried at the sea bottom so as not to be affected by waves. Intake velocities at the intake heads are to be about 20 cm/sec in order that warm layer of surface water will not be mixed in. The velocities in the pipelines are to be approximately 2 m/sec. The outer and inner surfaces of the pipelines are to be coated with tar-base paint to prevent corrosion, while cathodic protection devices are also to be attached. For inspection and maintenance of the pipelines, manholes from which it will be possible to enter the pipelines from the sea bottom are to be provided at intervals of 200 m. The approximate construction cost of this facility would be 5.64 million R.O.

Furthermore, comparison studies for construction costs on installing a reserve pipeline were made for the piled jetty-supported and the sea-bottom buried pipeline intake systems, and total construction costs will be estimated to be 10.39 million R.O. (against 8.45 million R.O.) for the former and 7.41 million R.O. (against 5.64 million R.O.) for the latter respectively. For the open channel intake system, it is not necessary to consider any reserve facility from its structural viewpoints.

As a result of comparison studies of construction costs of the individual types of intake facilities, the sea-bottom buried pipeline intake system would be the most economical at this site, however, in consideration of difficult situations in maintenance of the underwater pipelines after starting the plant operation in Oman, the open channel intake sytem will be adopted in this Feasibility study.

(2) Conceptual Design of Intake Facilities

Fig. 10.5 shows the outline of the intake and pump pit facilities. These facilities are to be of reinforced concrete construction and provided on sound foundation ground 10 m below the present ground surface. A curtain-wall type intake is employed to collect low temperature seawater through the year. The intake is to be provided with stop log facilities for drying inside the intake to carry out inspection and maintenance inside the waterway, while a bar screen and rotary screen are to be provided to remove trash and marine life. The size of the pump pit is to be large enough to install 13 pump units (including 3 reserve units) making it possible for separate supply of water to four generator units and six desalination units. The pump pit is to be equipped with one travelling crane for inspection and maintenance of pumping facilities.

(3) Conceptual Design of Discharge Facilities

The outline of discharge facilities is given in Fig. 10.6. In design of the discharge facilities it is particularly necessary to give consideration to recirculation of thermal effluent and siphon effect of the circulating water line system. As stated in 6.11.2, for this project, an ample distance of about 1,000 m horizontally was secured between the intake and discharge points, while further, since the intake system is based on deep-water intake and discharge on surface layer discharge, it is thought there will be no recirculation of thermal effluent. Waste water from the each plant would be collected at a discharge pit, and upon energy dissipation, the water is to flow down an open channel connected to the pit for discharge in the sea area near the present shoreline. Riprap is to be placed in the vicinity of the open channel outlet to prevent scouring of the original ground. At the field investigation by JICA study team, observation data on littoral drift and tidal current at vicinity of the site were not available, so that no study on the littoral drift was made in this stage. It is necessary to carry out field investigations and detail studies on the littoral drift at the stage of definite design.

Furthermore, construction cost of approximate 3.7 million R.O. is estimated for an alternative discharge facility comprising 3 underwater outfall pipelines of 730 m in length and 2.50 m in diameter which would make it possible to lead heated water to 1.00 m below L.L.W.L.

10.3 CONCEPTUAL DESIGNS OF POWER AND DESALINATION COMPLEX PLANT EQUIPMENT FOUNDATIONS

Euipment foundations of the principal facilities such as turbines, generators, boilers, and evaporators must be supported by ground that is thoroughly reliable with regard to strength. It is necessary for the foundation mat to safely transmit the loads of overlaying equipment and structures to the foundation ground while alleviating trouble due to vibration of equipment and possessing adequate rigidity and strength against uneven settlement.

As previously stated in 6.4, geological investigations were not carried out at the project site for the present study, with only a surface reconnaissance made, but in consideration of the results of geological investigations by boring at Ghubrah, boring logs in groundwater surveys carried out in the vicinity of Barka town, and construction experience at the existing desalination and steam raising plant at Ghubrah, it is estimated that N value in standard penetration test at around 5 to 6 m below the present ground surface at this site will be 20 or over. Therefore, in design of equipment foundations for this project, a level 6 m below the present ground surface was assumed to be the bearing layer and spread foundation structures were applied for the equipment foundations. The configurations and constructions of equipment foundations will differ depending on the weights of equipment, steel frames, and structures which will be the loads, and on the types of structures. The principal types of configurations and structures of foundations adopted for this project are as follows:

(1) Reinforced Concrete Double Slab Foundation

Excavation is done to bearing ground and a reinforced concrete double slab foundation is provided on the ground.

(2) Soil Stabilization and Reinforced Concrete Mat Foundation

Soft soil down to the bearing ground is removed, and river-run sand-gravel borrowed from a wadi is laid and compacted, on top of which a reinforced concrete mat foundation is provided.

Examples of foundation structures for a steam turbine generator and a boiler are shown in Fig. 10.7.

10.4 CONCEPTUAL DESIGN OF PRINCIPAL BUILDINGS AND SELF-STANDING STACK

(1) Powerplant Main Buildings (for Steam Turbine Generator)

The building is to be of dry construction in consideration of obtaining the merits of lightening of weight and shortening of construction time. That is, the building is to be of steel construction with the exterior wall clad with coated steel sheet. The roof is to be built by laying lightweight concrete panels on a steel frame, with asphalt waterproofing provided on top. The exterior wall up to the work floor is to be of reinforced concrete construction. The floor of each story is to be of reinforced concrete as a rule, but where openness is required for maintenance purposes, the floor is to be of removable steel grating. Indoor partitions are to be of reinforced concrete construction wall or precast concrete block construction wall depend on the degree of importance. Places where precision instruments and equipment are accomodated and rooms where plant personnel work at all times are to be provided with air-conditioning facilities.

As other building equipment, there are to be provided lighting facilities, water supply and drainage facilities, fire alarm facilities, fire extinguishing facilities, and sanitation facilities.

An elevation is shown in Fig. 10.7 and the second floor plan in Fig. 10.8.

(2) Administration Building (Common Use Building)

The administration building is to be two-storied and of reinforced concrete construction. The foundation is to be a reinforced concrete mat foundation built on ground where soil stabilization has been performed. The administration building is to be for use in common by the powerplant and the desalination plant, and out of the personnel of the two plants, all day workers except operating and maintenance personnel of the various pieces of equipment are to be accomodated.

As uses by function, a chemical analysis laboratory, office rooms, rest room, archives, locker room, and ventilating machinery room are to be provided on the ground floor, and office rooms, director's office, deputy director's office, conference room, and auxiliary room on the first floor. The office rooms are to be arranged rationally according to each work category.

As for building equipment, there are to be air-conditioning facilities, lighting facilities, water supply and drainage facilities, fire alarm facilities, fire extinguishing facilities, and sanitation facilities.

The plan of the administration building is as shown in Fig. 10.9.

(3) Control Buildings

1) Powerplant Control Building

This building is to accomodate the central nerve system of the powerplant such as the control panel, and is to be situated at a central location of the powerplant area.

It is to be a reinforced concrete building of two stories, with a reinforced concrete mat foundation on ground that has been subjected to soil stabilization work.

As uses by functions of this control building, the first floor would have a control room, computer room, relay room, telecommunication equipment room, operating personnel anteroom, and air-conditioning machinery room, while the mezzanine floor is to have a cable spreading room under the control room and relay room. The ground floor is to have an electricity room, control power supply room, battery room, archives, and office room.

Building equipment would be similar to the administration building.

The plan of this control building is as shown in Fig. 10.10.

2) Desalination Control Building

This building would accomodate the central nerve system equipment for desalination plant such as the control panel, and is to be on the seaward side at the center of desalination plant.

This is to be a reinforced concrete one-story building having a reinforced concrete mat foundation built on stabilized ground. A free access floor (height 500 mm) is to be adopted for cable works of the control panel in the control room.

Since equipment would be delivered from time to time in step with operating start times, shutters are to be provided for access at the back side of the panel.

Building equipment would be similar to the administration building.

The plan of this control building is as shown in Fig. 10.11.

(4) Self-standing Stack

Height: 80 m

Top diameter: 2.4 m

Lining: Acid-resistant, water-resistant castable refractory sprayed lining

Foundation: Reinforced concrete mat foundation

Details of Study

The types conceivable were a reinforced concrete stack and a steel stack. Both types have their merits and demerits from the standpoints of constructability and economics.

In general, reinforced concrete stacks are frequently adopted for heights up to about 100 m in case ground conditions are good, and are considered to pose no problems in regard to economics and safety. On the other hand, a drawback is that deterioration with time of concrete is greater than of steel, while it is difficult to carry out inspections and provide countermeasures. Centralization is difficult to achieve. Providing a lining directly to the stack shell is difficult. Earthquake resistance is poor where ground conditions are unfavorable, and this type is considered to be uneconomical.

The advantage of a steel stack is that an earthquake-resistant design can be made even where ground conditions are unfavorable because of the comparatively light weights of both the superstructure and the foundation. Unlike a concrete stack, it is possible for direct lining to be provided. Steel has little variance in quality, while parts worked on in the field can be inspected and tested. Damage due to time-dependent deterioration and corrosion is easy to discover and cope with. The drawbacks are that construction of a superstructure is generally complex and construction time required is somewhat long.

Based upon comprehensive judgment of the above and in view of the ground conditions in case of the project site and ease of future inspection and repairs, 3 units of self-standing steel stacks were planned.

Regarding lining of the inner surface of the stack shell, it was decided that an acid-resistant, water-resistant castable refractory is to be sprayed on to protect the inner surface from high concentrations of sulfurous substances. As for the foundation, it is to be reinforced concrete spread foundation mat with the space between the bearing ground and the foundation mat stabilized by excavating and replacing with river-run gravel from a wadi. The configuration is as shown in Fig. 10.7.

For comparison purpose, construction costs for different height of stacks are estimated roughly as follows;

Height 80 m	0.59 million R.O.
100 m	0.73 million R.O.
120 m	0.87 million R.O.

(5) Accommodation of Plant Personnel

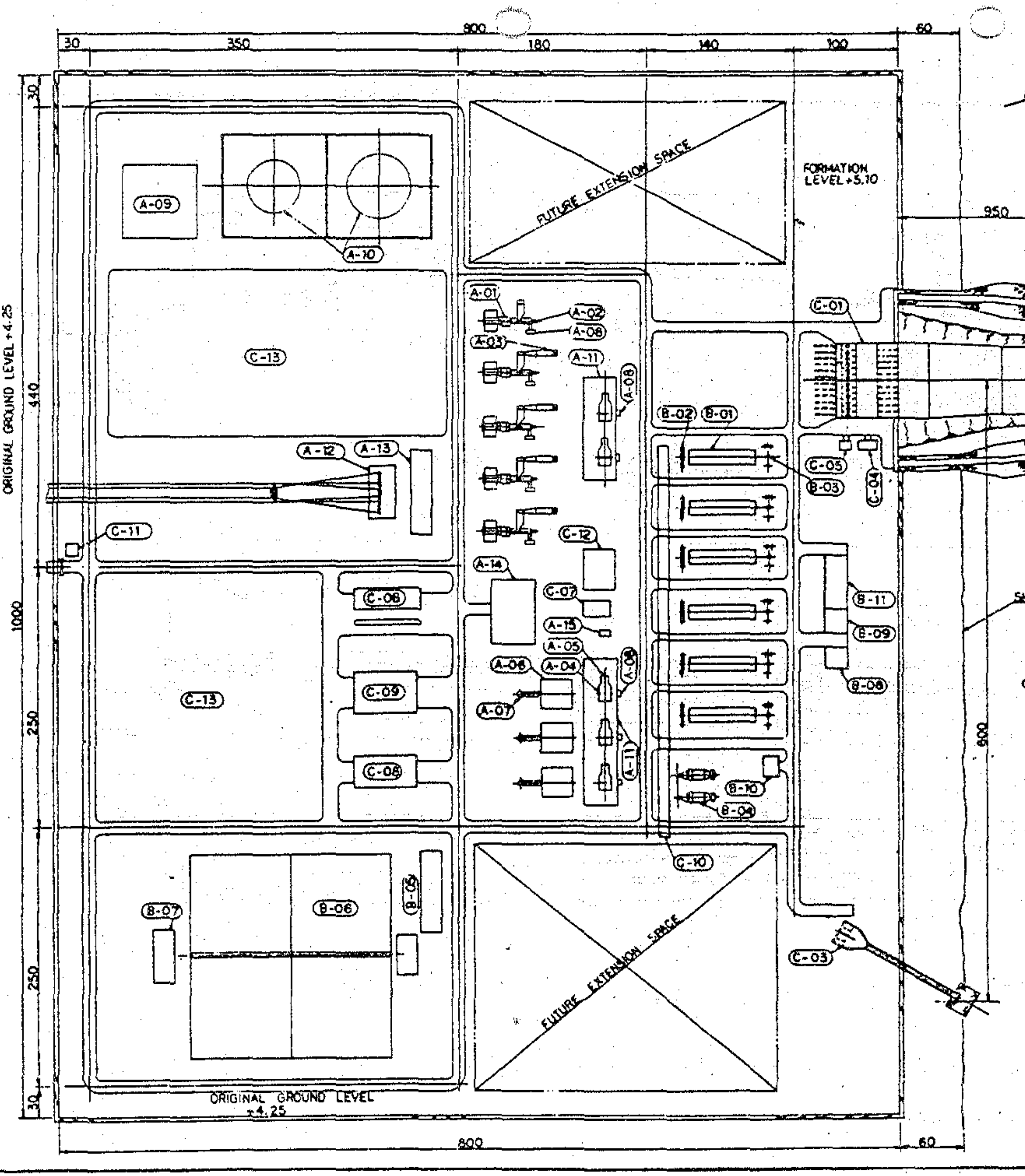
An accommodation lot for personnel of plant operation and maintenance is selected at the south end of the complex plant site with an area of approximate 40 ha. as shown in Fig. 10.1.

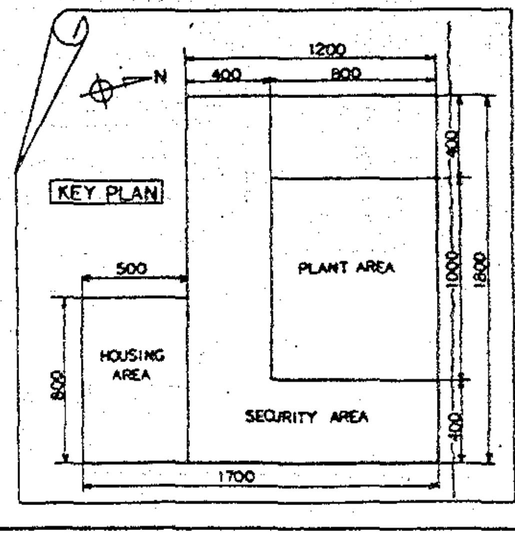
Types and numbers of accommodations are considered as follows;

A type	140 m^2/flat	20 flats
B type	120 m^2/flat	120 flats
C type	100 m^2/flat	150 flats
D type	80 m^2/flat	210 flats
		Total: 500 flats (Total Area: 49,000 m^2)

Public facilities such as mosque, school, clinic, market, gymnasium, club house for sports and recreation, bank and post office, kindergarden, restaurants, gate house, gasoline filling station and recreation facilities (swimming pool, soccer ground, tennis court, etc.) are to be considered.

Total floor area of public facilities would be approximate 6,500 m^2.
General layout is shown in Fig. 10.12.
Total construction cost of these accommodation facilities are estimated roughly 19.2 million R.O.





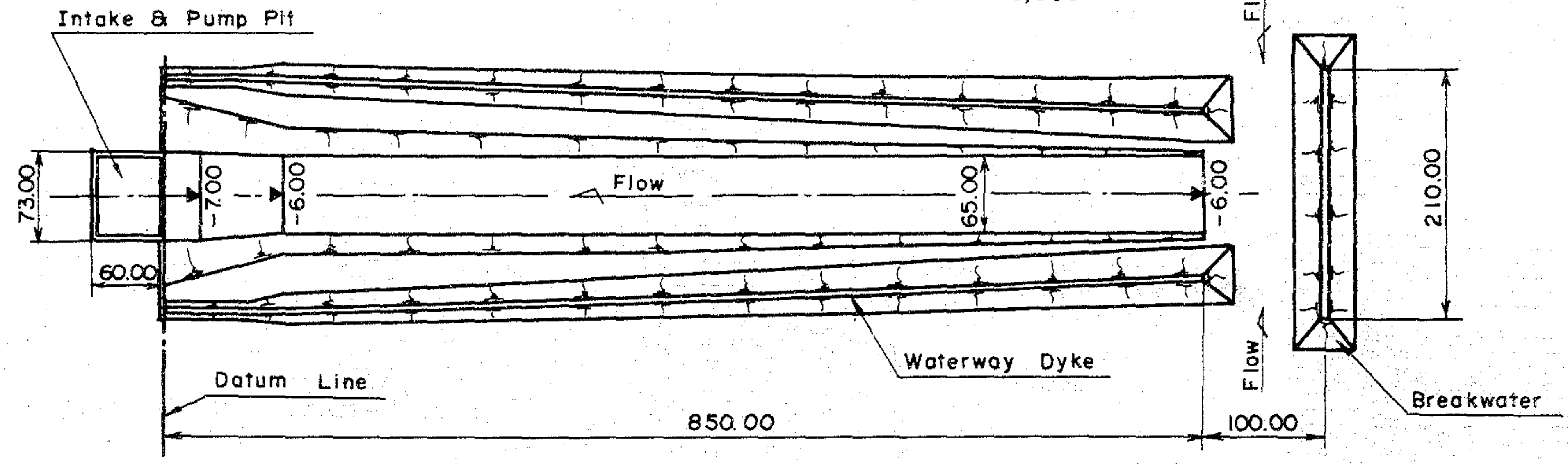
ITEM NO	FACILITY	REMARKS
	POWER PLANT	
A-01	GAS TURBINE	
A-02	GENERATOR	
A-03	HEAT RECOVERY UNIT	
A-04	STEAM TURBINE	
A-05	GENERATOR	
A-06	STEAM GENERATOR	
A-07	STACK	
A-08	TRANSFORMER	
A-09	FUEL GAS RECEIVING UNIT	
A-10	FUEL OIL TANK	
A-11	TURBINE HALL	
A-12	SENDING OUT FACILITY	
A-13	SWITCH GEAR ROOM	
A-14	CENTRAL CONTROL BUILDING	
A-15	DAMP CONDENSER	
	DESALINATION PLANT	
B-01	EVAPORATOR	
B-02	BRINE HEATER	
B-03	DESAL PUMPS	
B-04	AUX. STEAM GENERATOR	
B-05	PRODUCT WATER TREATMENT	
B-06	PRODUCT WATER RESERVOIR	
B-07	PRODUCT WATER PUMPING STATION	
B-08	DESAL CONTROL BUILDING	
B-09	DESAL CHEMICAL INJECT BUILDING	
B-10	DESAL SWITCH GEAR BUILDING	
B-11	CHEMICAL STORE HOUSE	
	COMMON FACILITY	
C-01	SEA WATER INTAKE & PUMP PIT	
C-02	SEA WATER INTAKE CHANNEL	
C-03	SEA WATER OUTFALL	
C-04	CHLORINATION BUILDING	
C-05	SEA WATER PUMP CONTROL ROOM	
C-06	ADMINISTRATION BUILDING	
C-07	COMPRESSOR ROOM	
C-08	STORE	
C-09	WORK SHOP	
C-10	PIPE RACK	
C-11	GATE HOUSE	
C-12	UTILITY SPACE	
C-13	STORAGE YARD	

FIG 10.1
PLOT PLAN

Fig. 10.2 SEA WATER INTAKE : OPEN CHANNEL

PLAN

Scale : 1/5,000



SECTION OF CHANNEL

Scale : 1/1,000

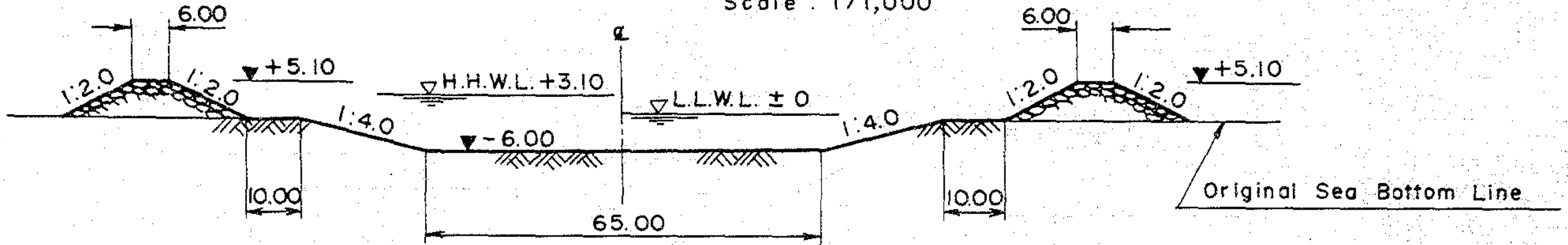


Fig. 10.3 SEA WATER INTAKE : JETTY TYPE

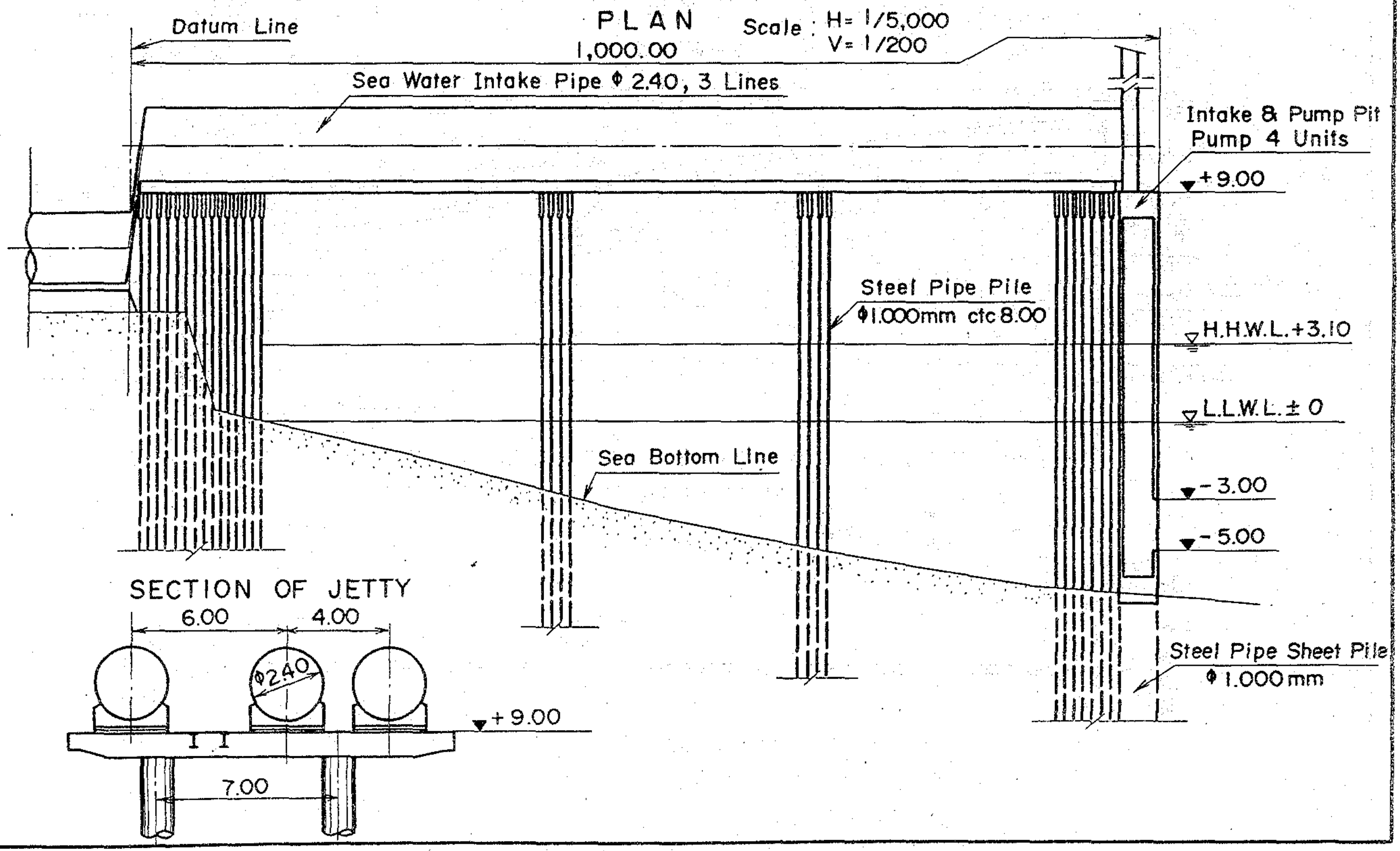


Fig. 10.4 SEA WATER INTAKE PIPE

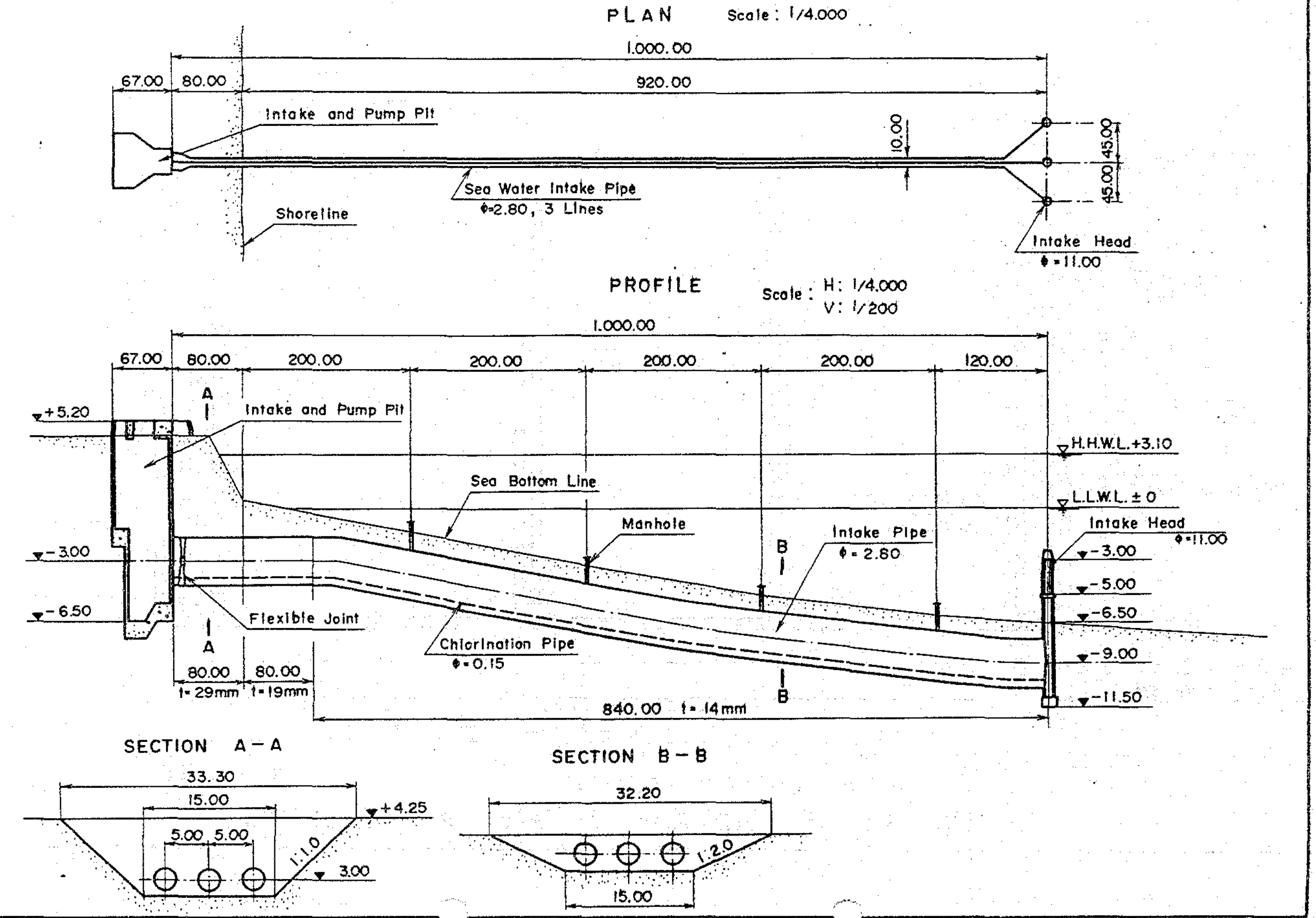


Fig. 10.5 SEA WATER INTAKE AND PUMP PIT

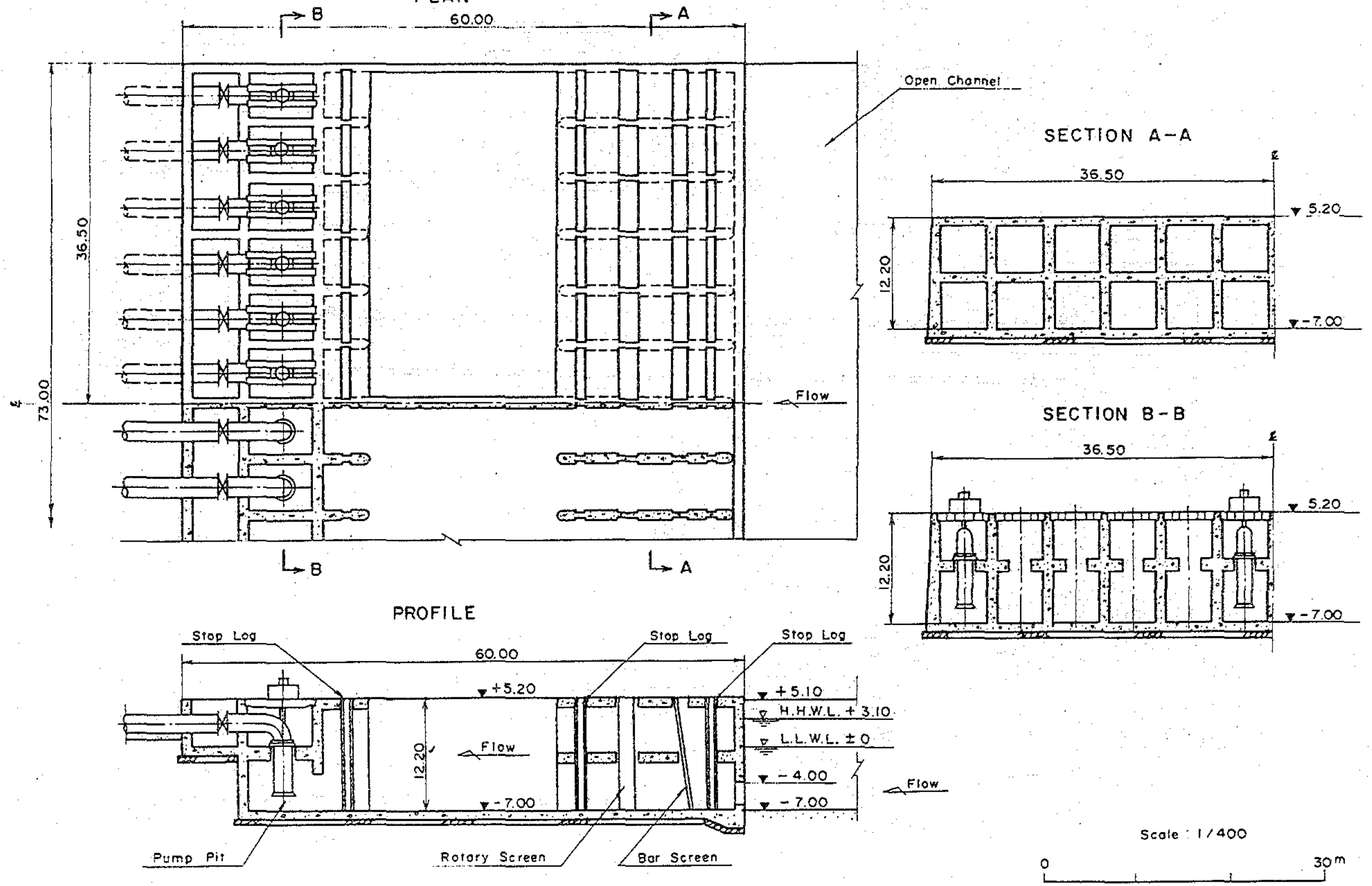


Fig. 10.6 DISCHARGE PIT AND CHANNEL

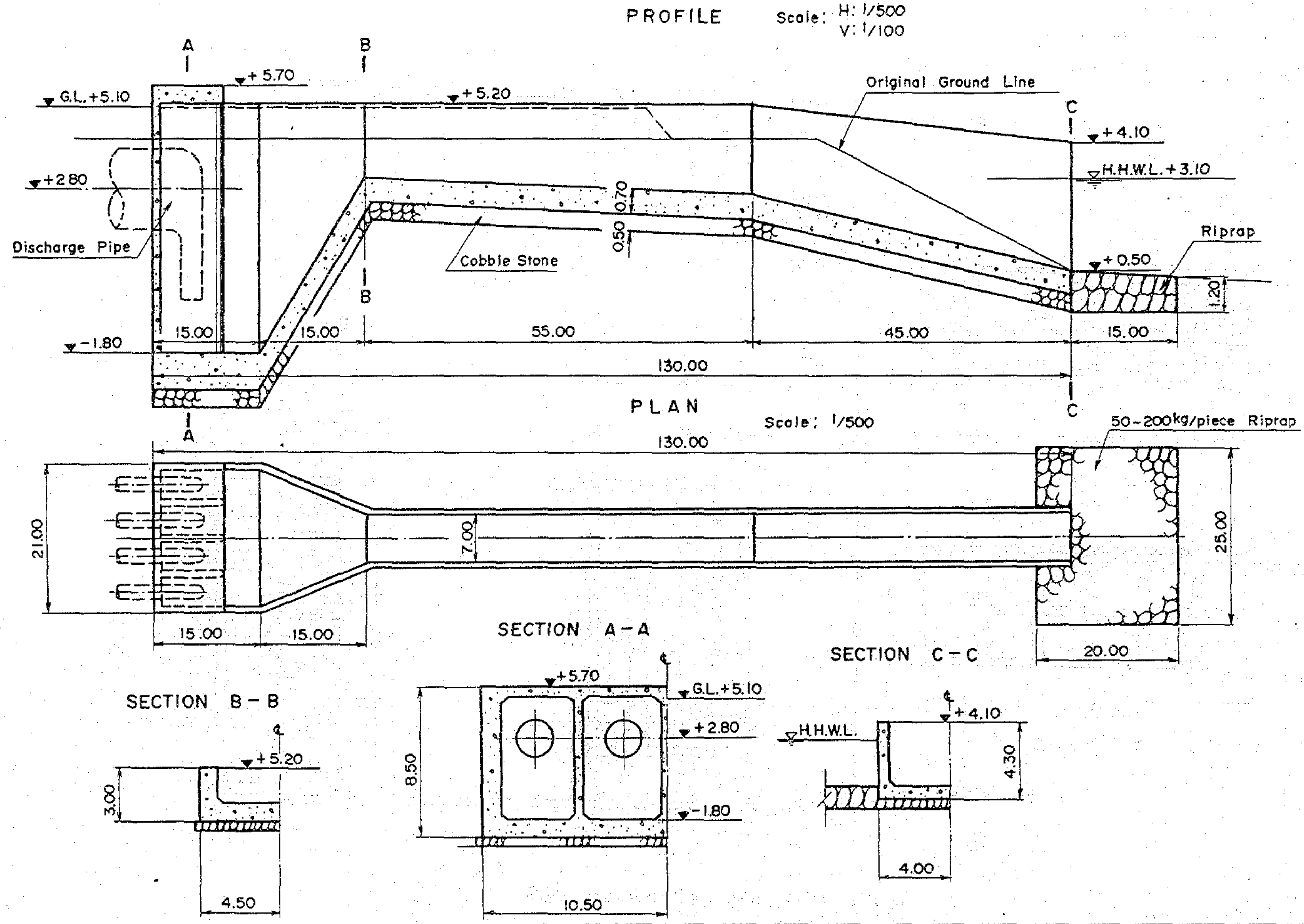


Fig. 10-7 SECTION OF POWER STATION

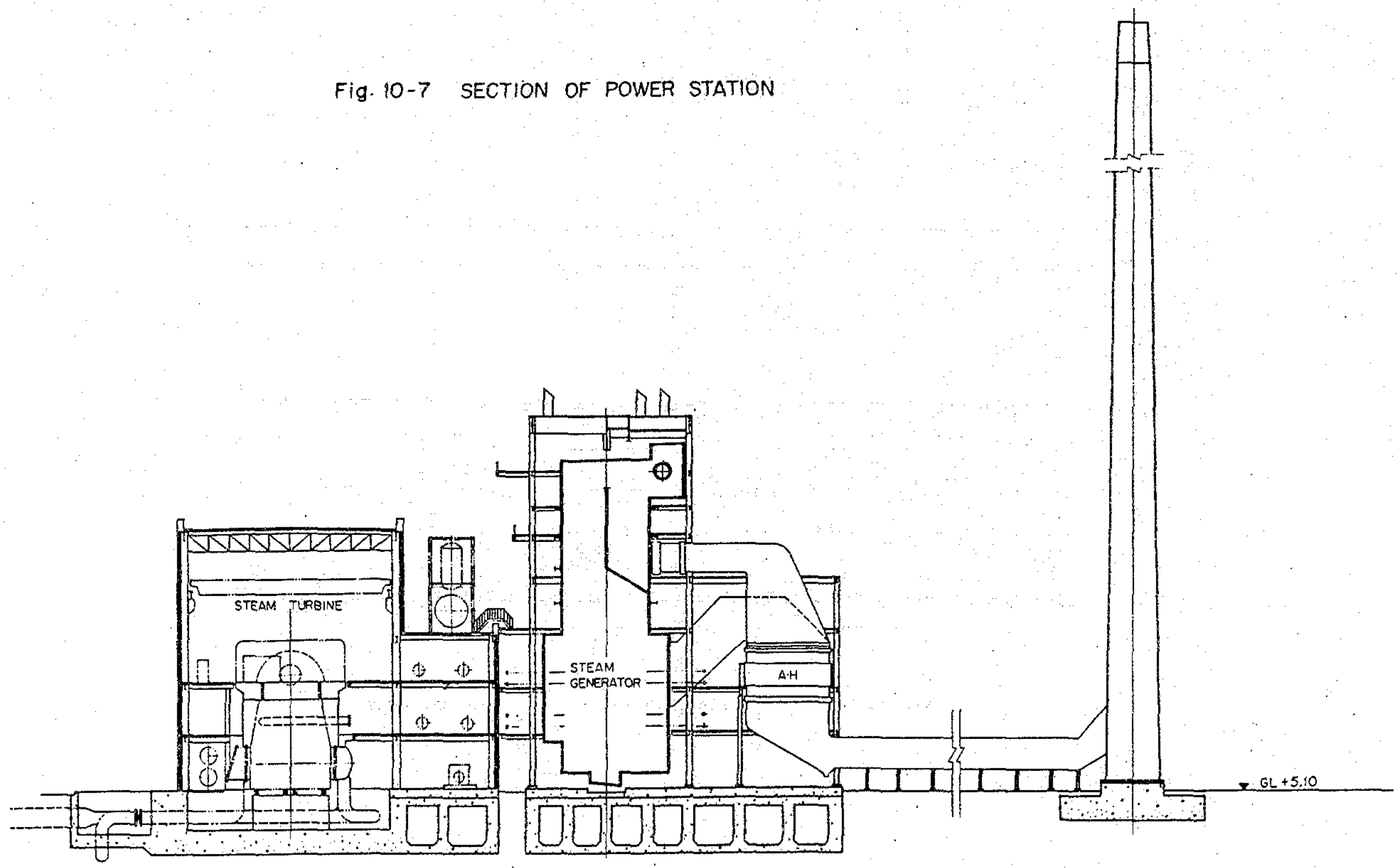


Fig. 10.8 POWER HOUSE (2nd FLOOR PLAN)

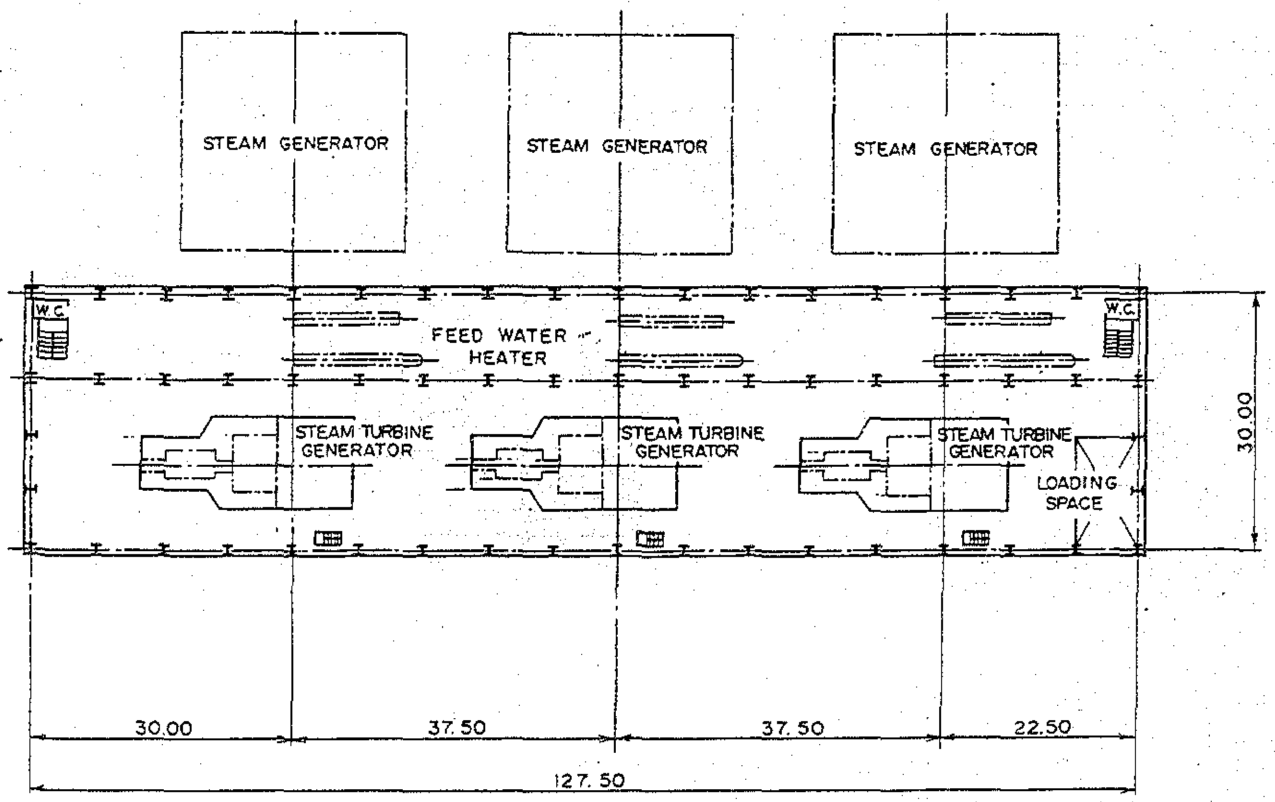


Fig. 10.9 ADMINISTRATION BUILDING PLAN

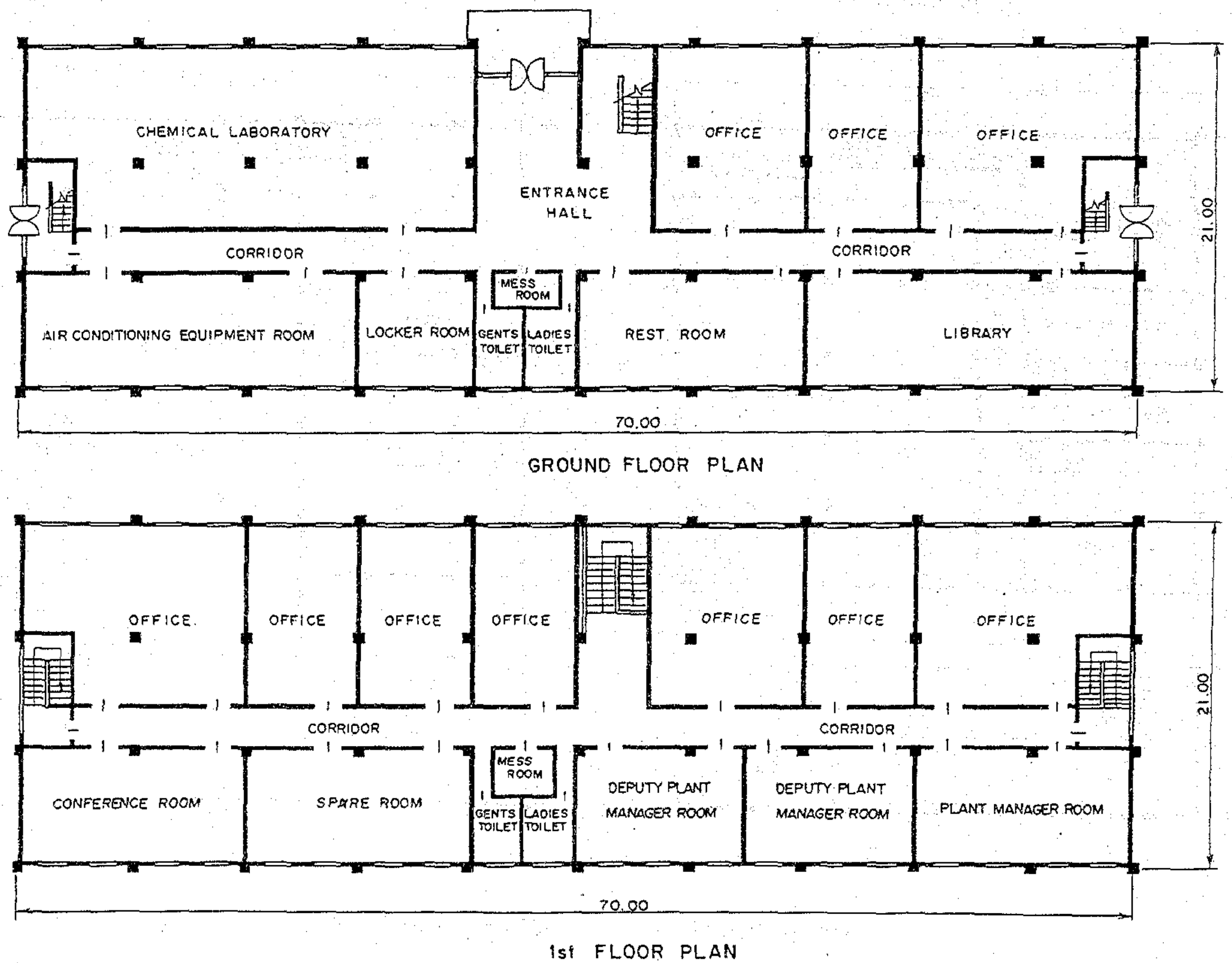
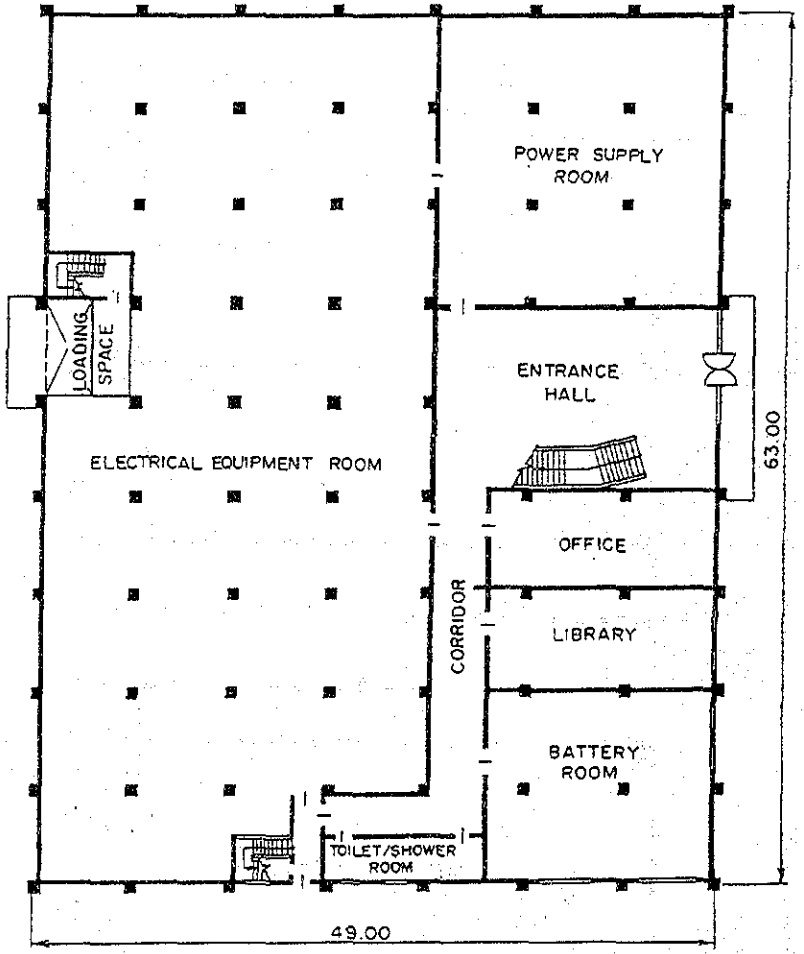
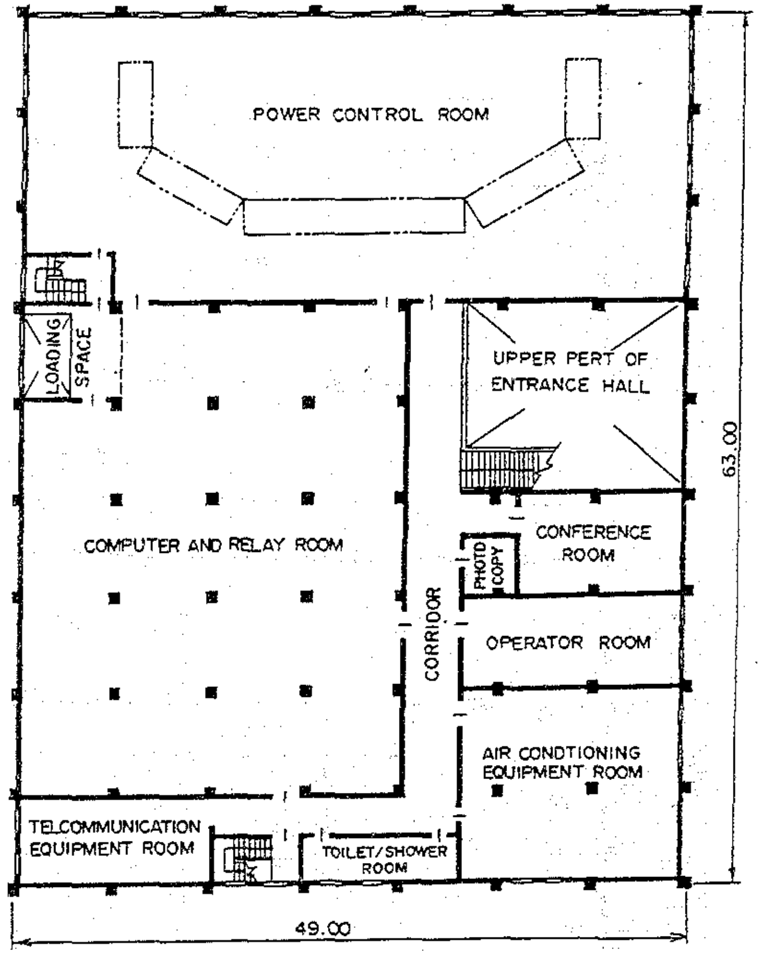


Fig.10.10 POWER CONTROL BUILDING PLAN



GROUND FLOOR PLAN



1st FLOOR PLAN

Fig.10.11 DESALINATION CONTROL BUILDING PLAN

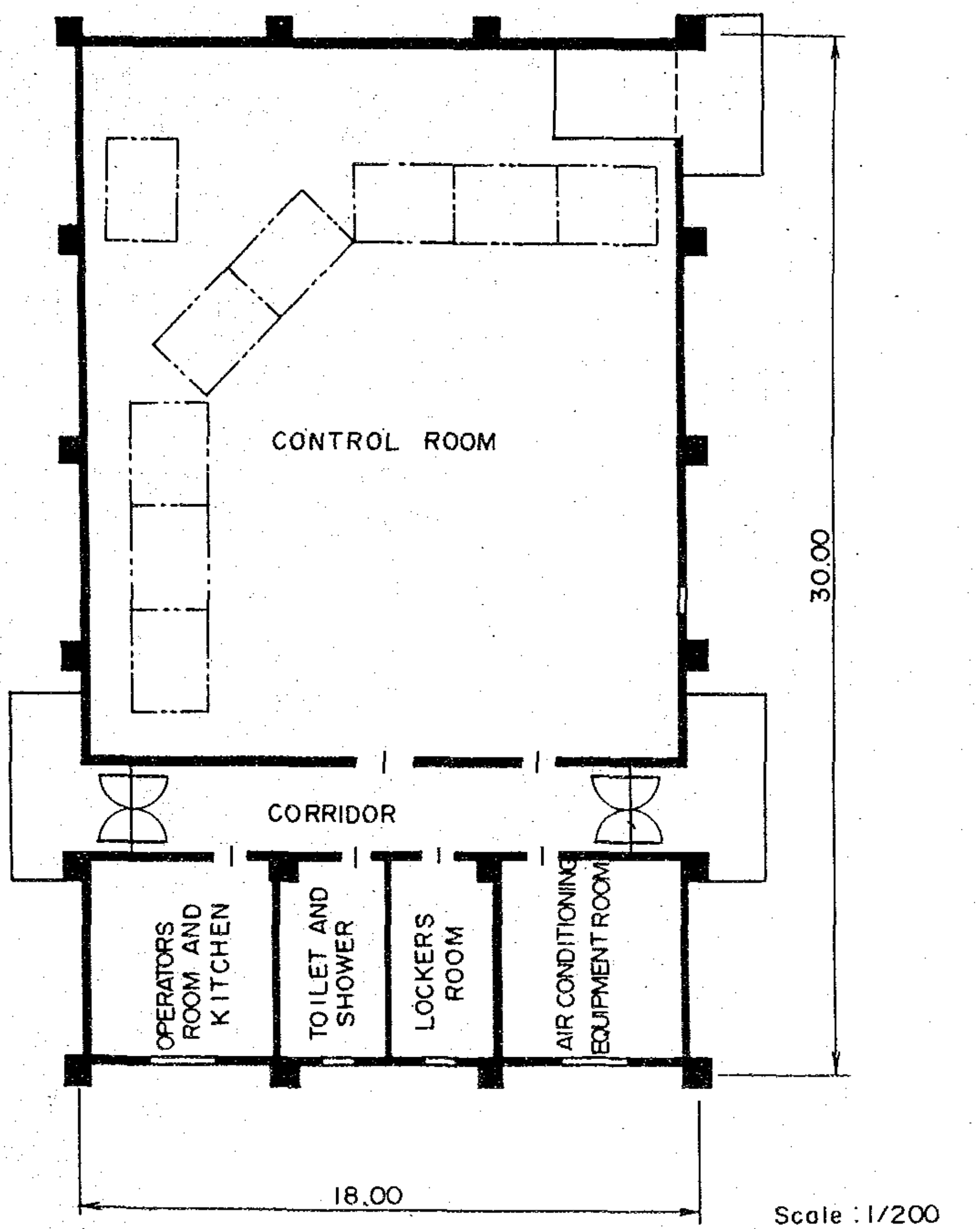
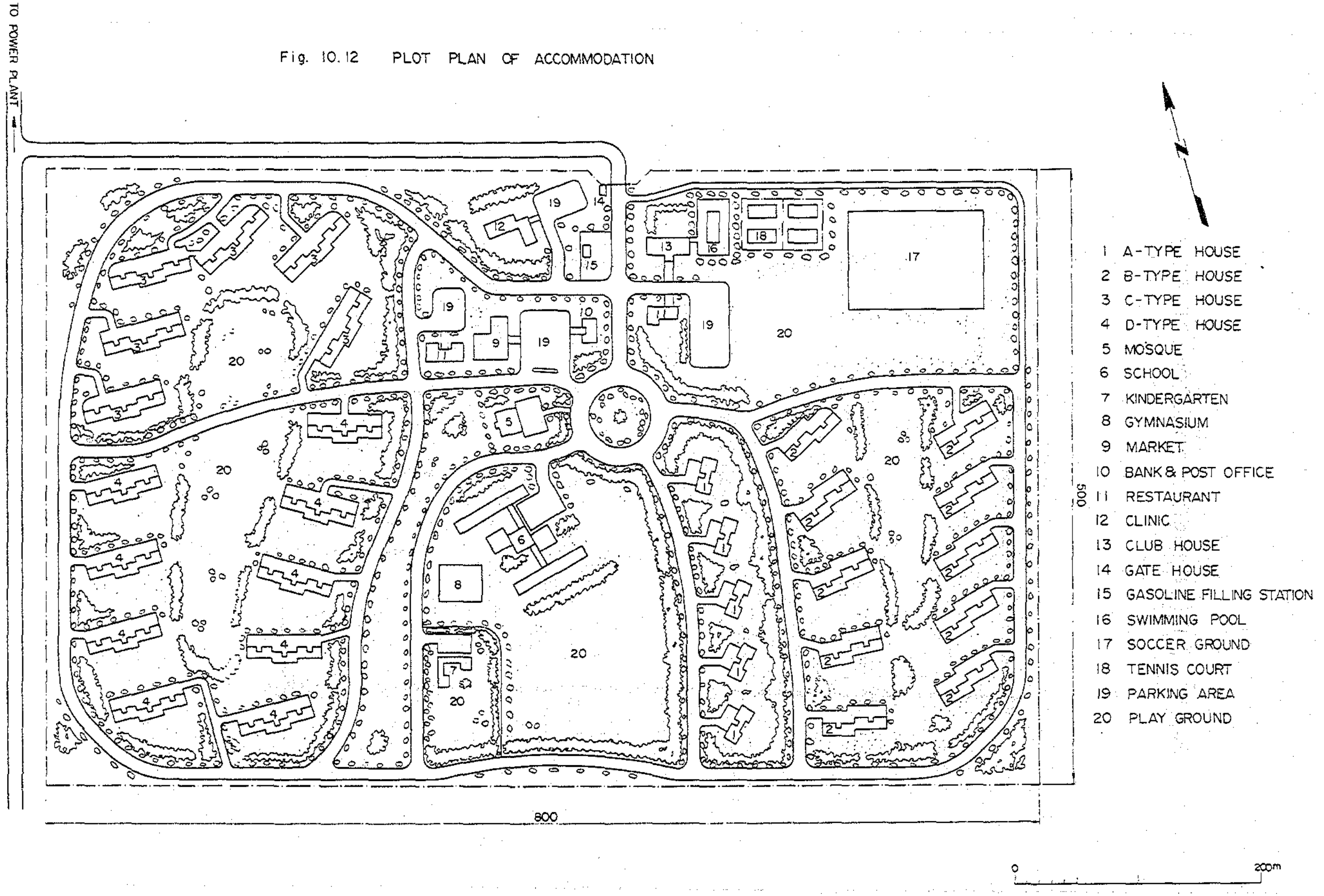


Fig. 10.12 PLOT PLAN OF ACCOMMODATION



CHAPTER 11

CONCEPTUAL DESIGN OF TRANSMISSION LINE

Chapter 11 CONCEPTUAL DESIGN OF TRANSMISSION LINE

11.1 POWER TRANSMISSION PLAN

The development scale of Barka Power Station is 740 MW in total as described in Chapter 4. The 740 MW power to be generated at Barka Station is successively put into service at stages, 160 MW in 1988 (the first year), 160 MW in 1989, 280 MW in 1990 and 140 MW in 1991 (the last year).

A portion of the generated power at Barka Station is expected to be consumed at the desalination plant which is to be constructed at the same site as the power station, and the most of electric power other than that for the desalination plant will be supplied to the Capital Area and towns and cities scattered along the Batinah coast.

Fig. 11.1 shows the salient features of the Barka Power Project and related transmission schemes in the Capital area and Batinah area.

11.1.1 Transmission lines for Capital area and Batinah coast

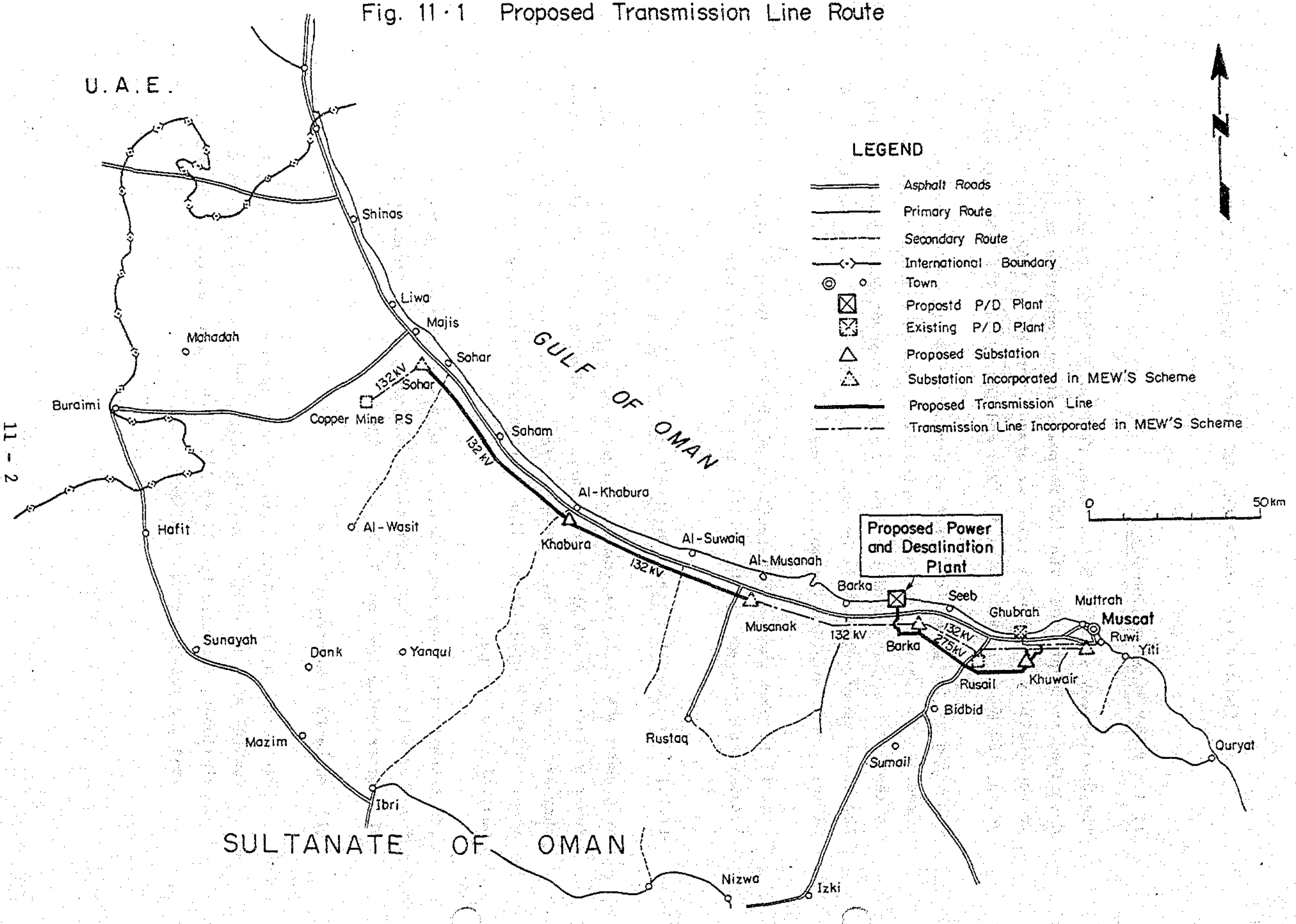
At present MEW is in the course of executing an expansion work of Rusail Power Station. A 249 MW of power will be added by 1987. At the same time they are accelerating the implementation of the power supply program by means of 132 kV transmission lines for the eastern Batinah area from the Capital Area system.

The transmission lines between Rusail to Barka and Barka to Musanna together with two (2) substations are currently under tender with the aim of commissioning them not later than 1986.

(1) Barka PS - Khuwair SS Line

According to the demand forecast in Chapter 4, the demand of the Capital area in 1988 - 1991, in which Barka station is to be commissioned, accounts for 91 to 83% of the total demand of the Capital area and Batinah area combined.

Fig. 11·1 Proposed Transmission Line Route



The transmission line from the Barka PS to the Capital area shall be designed so that it may have a capacity of transmitting whole power of Barka station to the Capital area.

The interconnection substation, where Barka power is connected to the Capital area system, will be located at a flat area at the foot of mountain, in Khuwair 3 km of south of Ghubrah Power Station. For selection of the site, the following points are taken into account - shortest line length to the load center as much as possible and easiest interconnection with the existing facilities, and besides, no problems will be encountered in power flow of this system (refered to the Khuwair interconnection substation).

As a transmission voltage for Barka PS - Khuwair SS line 275 kV was selected according to the comparison study in Chapter 13.

Barka Substation which is now under tender is located 10 km southeast of Barka Power Station. This location is very favorable for interconnection to the Batinah coast.

The 275 kV transmission line route is selected so that it should not hinder land development along the line as much as possible and so that the 275 kV line may always pass over the mountain side of 132 kV lines.

Starting from Barka switchyard, the line takes a course southward, across the highway 4 km ahead. Power for Batinah is stepped down to 132 kV at Barka Substation (expected commissioning in 1986) and connected to Batinah on going 132 kV system. Soon after π-branched at Barka Substation, the 275 kV line crosses over 132 kV Barka SS - Musanna SS line. Then it takes a course for Rusail and runs parallel to the 132 kV Barka SS - Rusail PS line on its mountain side.
At Rusail, the 275 kV line goes around the power staion compound on the south and then takes its course to the east and runs parallel to the 132 kV Rusail PS - Wadi Adai SS line on its mountain side, going around Seeb Airport Hights and Ghala Industrial Area, then reaches Khuwair Interconnection Substation. The 132 kV transmission line: Rusail PS - Wadi Adai SS and Ghubrah PS - Wadi Adai SS are going to be π-branched here and interconnected.

The timing of interconnection of 275 kV line will be, in accordance with the commissioning time of Barka power station and power flow situation in the system, February 1988 for Barka Substation and December 1988 for Khuwair Interconnection Substation, respectively.

(2) Musanna SS - Khaboura SS - Sohar SS Line

For rapidly ever increasing power demand in the northern Batinah coast (Sohar, Shinas and Saham etc.) and Inland area (Buraimi, Ibri and other towns and villages in those area), MEW has a program for supplying power to the said areas by means of reinforcing Copper Mine Power Station and newly development in Sohar. Copper Mine Power station having existing capacity 51 MW is due to increase its capacity to 54 MW in 1985 and 60 MW in 1986. In succession, two 30 MW units are due to commission at Sohar in 1987 and 1988, respectively. Total supply capacity in these area is planned to be 225 MW by 1988.

According to the demand - supply balance of Batinah and Inland interconnected system, it will keep equiliblium by 1988. However, a power shortage will take place in 1989.

On the other hand, the interconnection program of the Batinah and Capital areas are in the tendering stage, and 132 kV lines: Barka - Musanna - Khaboura are expected to be completed in 1986.

Since remarkable industrial development in northern Batinah is expected to be achieved in the near future, the line from Copper Mine to Sohar is considered to become an important trunk line in forming an interconnecting system between Batinah and Inland in the future, it is desirable for a 132 kV line to be constructed as soon as possible.

In accordance with the Barka Power Station's construction schedule and demand-supply balance of the area, the timing of interconnection of October 1988 for Musanna SS - Khaboura SS and April 1989 for Khaboura SS - Sohar SS are recommendable.

The transmission line route of Musanna SS - Sohar SS section was selected along the Batinah Highway on its mountain (western) side, the gas pipe line for Copper Mine is running there, where a cultivation is less advanced, so that the line may not hinder the cultivation as much as possible and also the line may not be influenced by saline wind from the Gulf.

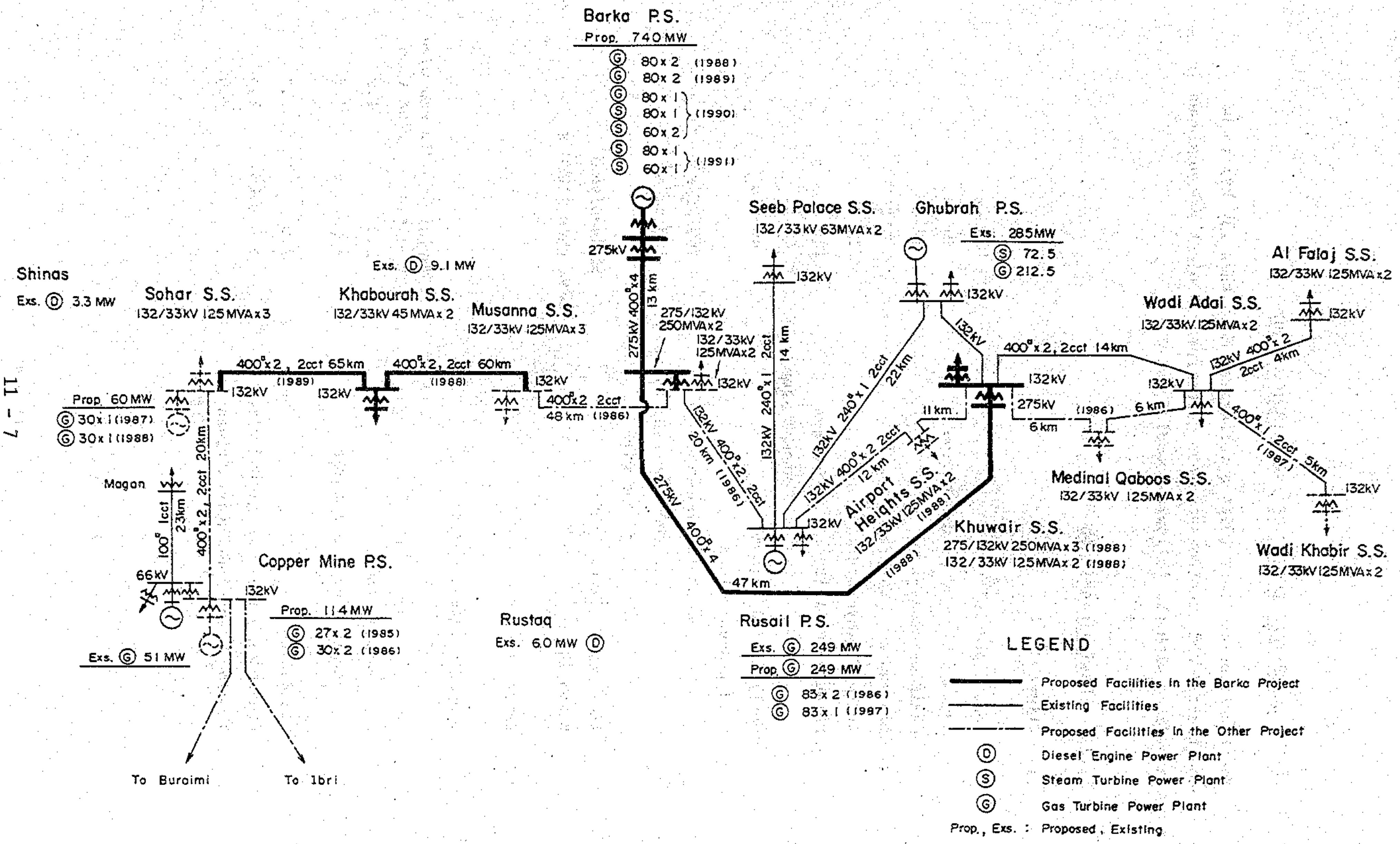
Although there is one 66 kV transmission line between Copper Mine and Sohar (33 kV from Magan), the line is already overloaded. Therefore, MEW needs to complete the another line with a voltage of 132 kV by the end of 1986.

The transmission line expansion program (more than 132 KV) required to be implemented by MEW by 1995, is summarized as shown in Table 11.1 and Fig. 11.2

Table 11.1 Capital and Batinah System Expansion Program

Section	Length (km)	Voltage (kV)	Number of Circuit	Conductor	Transmission Capacity (MW)	Year of Commissioning
(1) Transmission line to be constructed in the Barka Power Project						
Barka PS - Barka SS	13	275	2	AAAC 400 mm^2 x 4	770	1988
Barka SS - Khuwair SS	47	275	2	AAAC 400 mm^2 x 4	770	1988
Musanna SS - Khabourah SS	60	132	2	AAAC 400 mm^2 x 2	185	1988
Khabourah SS - Sohar SS	65	132	2	AAAC 400 mm^2 x 2	185	1989
(2) Transmission line to be constructed in the other NEW Projects						
Rusail PS - Wadi Adai SS	47	132	2	AAAC 400 mm^2 x 2		1986
Rusail PS - Barka SS	20	132	2	AAAC 400 mm^2 x 2		1986
Barka SS - Musanna SS	48	132	2	AAAC 400 mm^2 x 2		1986
Wadi Adai SS - Wadi Khabir SS	5	132	2	AAAC 400 mm^2 x 2		1987
Sohar SS - Copper Mine PS	20	132	2	AAAC 400 mm^2 x 2		1986

Fig. 11 · 2 ELECTRIC POWER SYSTEM
(Capital and Batinah Areas)



11.2 CONCEPTUAL DESIGN OF TRANSMISSION LINE

The transmission lines (with a voltage of more than 132 kV) to be constructed and incorporated into Barka Power Project are designed in accordance with the following conditions.

11.2.1 Design condition

(1) Climate

Annual precipitation		100 mm
Maximum 24 hour precipitation		80 mm
Maximum temperature		50°C
Minimum temperature		5°C
Average temperature		30°C
Relative humidity	Maximum	100 %
	Annual mean	40 %
Maximum wind velocity		40 m/s
Wind pressure load		
	for tower member	160 kg/m^2
	for conductor and overhead ground wire	100 kg/m^2
Isokeraunic level (IKL)		20 days/year
Elevation		less than 1,000 m

(2) Safety factor

Supports (steel tower)

	Normal condition	Broken wire condition
Tangent tower	2.0	1.2
Angle & dead end tower	2.5	1.2
Foundation	2.0	1.3
Conductor & overhead ground wire	5.0 (EDS)	2.5
Insulator and insulator strings		3.0

(3) Minimum ground clearance of conductor

132 kV lines	7.0 m
275 kV lines	8.32 m

(4) Standards and regulations

In the conceptual design of this Project, Japanese standards and MEW design criteria are adopted.

11.2.2 Transmission line voltage

(1) Barka PS - Khuwair SS line

The 132 kV is not suitable for transmitting bulk power of 740 MW Barka power for a distance of 60 km for technical and economic reasons. Introduction of higher voltage is absolutely required.

A voltage of 275 kV was finally selected among the prospective voltages: 220 kV, 275 kV and 330 kV based on economical comparison and consideration for adaptability for future system expansion. The detail of comparison is described in Paragraph 13.3.2 (2) in Chapter 13.

(2) Musanna SS - Khabourah SS - Sohar SS line

Since the power for Batinah coast is due to pass through Barka SS - Musanna line which is under construction by MEW, the proposed line voltage was selected at 132 kV which is adopted in the said line, to meet the line characteristics with that of the same.

11.2.3 Conductor

As for a conductor of transmission line in Barka Power Project, all aluminum conductor (AAAC) will be employed because of its advantage in respect of mechanical strength and anti-corrosive characteristics. For Barka PS -Khuwair SS line, 400 mm^2 quadruplex bundle conductor will be employed in terms of ampacity required and standardized size in the market.

In calculation of ampacity, MEW design criteria i.e. 50°C ambient temperature and 30°C allowable conductor temperature rise is adopted.

As for 132kV; Musanna SS - Khaboura SS - Sohar SS line, AAAC 400 mm^2, double bundle conductor is employed to meet the characteristics with that of Barka SS - Musanna SS line, preceeding project of MEW.

11.2.4 Insulation design

Dominant factors to be considered in insulation design are lightning phenomena (thunderbolts), internal lightning (abnormal voltage caused by switching action of circuit breaker, etc.) and besides contamination caused by salt and dust.

In the capital area and Batinah area it has 100 mm of annual precipitation which is deemed quite few quantity. It blows fairly strong monsoon and trades. It is hot and quite humid in summer.

These climate condition comes into serious disadvantage for insulator contamination by salt and dust.

Since a length of insulator string becomes a big factor in deciding tower size and eventually a construction cost, selection of insulator should be made carefully. In order to shorten the insulator length, applications of fog type insulator will be effective in some cases. However, there is no experience of having used fog type insulators in Oman.

For the contamination design for desert area of western Asia and Arab countries an aerodynamic insulator, superior in self-cleaning ability, has been extensively used in these years. Although there are long rod and disc types in the aerodynamic insulators, long rod type has some demerit of less flexibility for rational insulation design against various voltage classes and has a big risk of insulator breakage, which may cause a tower collapse, when it is vandalized or damaged during construction work. While the disc type is far advantageous in rational flexible design and avoiding risk of damage cited above. Accordingly an aerodynamic disc type insulater was selected for this Project.

Table 11.3 shows a calculation data for insulation design for each voltages and Fig. 11.4 shows a clearance diagram for the same.

11.2.5 Lightning protection design

IKL (isokeraunic level) 20 is specified for the Capital area and Batinah coast as MEW design criteria. This is judged reasonable from the indicated figures of count recorders attached to arresters at Al Falaj Substation which was investigated during the field survey.

In order to protect conductor from direct lightning, aluminum clad extra high strength steel cable (ACW), superior in anti-corrosive, 90 mm^2 one (1) line will be installed for 132 kV and two (2) lines of 90 mm^2 ACW for 275 kV will be installed. At the same time in order to reduce a tower grounding resistance, one earthing angle will be driven into each basement.

For insulator strings, arcing horn(s) will be installed to protect insulator from breakage by direct arc current of lightning flashover.

11.2.6 Measure for conductor vibration

In order to protect conductor (including overhead ground wire) from fatigue breakage to be caused by conductor vibration with breeze, effective dumpers will be installed on the wire when it is a single wire, and suitable distanced spacers will be installed in case of multiple bundle conductors.

11.2.7 Support

Vertical arrangement double circuit steel towers will be employed. For the convenience of maritime transportation and installation works, angle type towers will be selected.

11.2.8 Danger sign for aero-navigation

For the transmission towers applied to the Capital Area, MEW has special requirements for preventing air accidents. One method is to paint a tower with red and white paint, and the other is to install baloons with red and white color on the overhead ground wires.
Furthermore, during the night time, neon lamps (night warning device) should be mounted on the conductors to be located at highway crossings.

11.2.9 Summary of transmission design

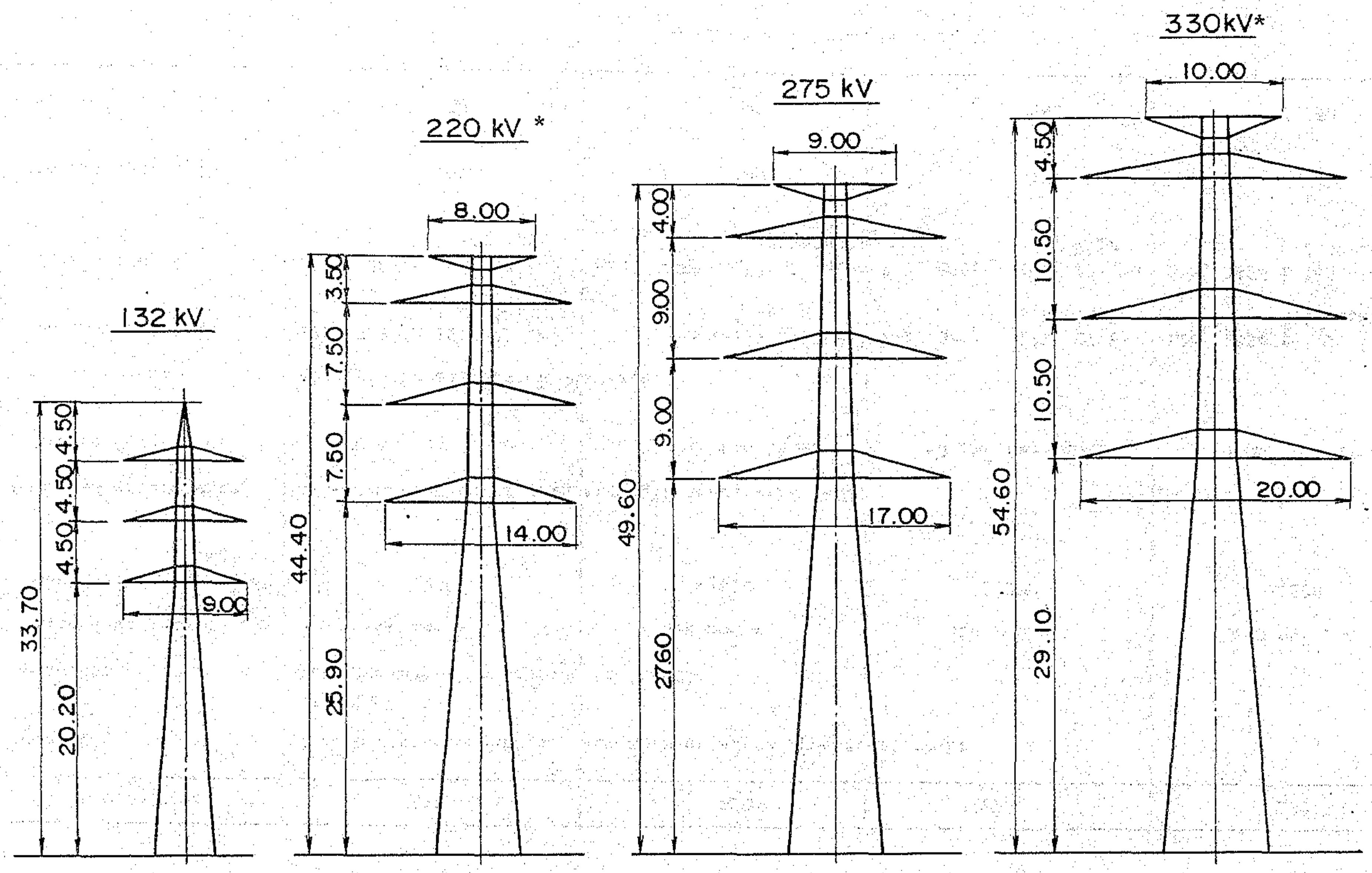
The outline of transmission line design, classified by voltages, taken into account the above-mentioned basic conditions are shown in Table 11.2. The dimension of typical suspension type towers for the respective voltages are as shown in Fig. 11.3.

Table 11.2 Outline of Transmission Line Design

Line Voltage	132	220 *	275	330 *
Support	Double circuits vertical arrangement angle type steel tower			
Conductor	All aluminum alloy conductor (AAAC)			
Size & No./phase	400 mm^2 x 2	690 mm^2 x 4	400 mm^2 x 4	400 mm^2 x 4
Max. working tension (kg)	3,200	4,600	3,200	3,200
Overhead ground wire	Aluminum clad extra high strength steel wire (ACW)			
Size & Q'ty	90 mm^2 one line	90 mm^2 two lines	90 mm^2 two lines	90 mm^2 two lines
Insulator string	Aerodynamic suspension insulator			
Suspension string	12t, 330ϕ x 127 21 pcs 1 string	12t, 380ϕ x 127 29 pcs 1 string	12t, 380ϕ x 127 37 pcs 1 string	12t, 380ϕ x 127 44 pcs 1 string
Strain string	21t, 380ϕ x 160 18 pcs 2 strings	21t, 380ϕ x 160 29 pcs 2 strings	21t, 380ϕ x 160 37 pcs 2 strings	21t, 380ϕ x 160 44 pcs 2 strings
Standard span (m)	300	350	350	350
Tower weight (t/km)	36	56	68	80

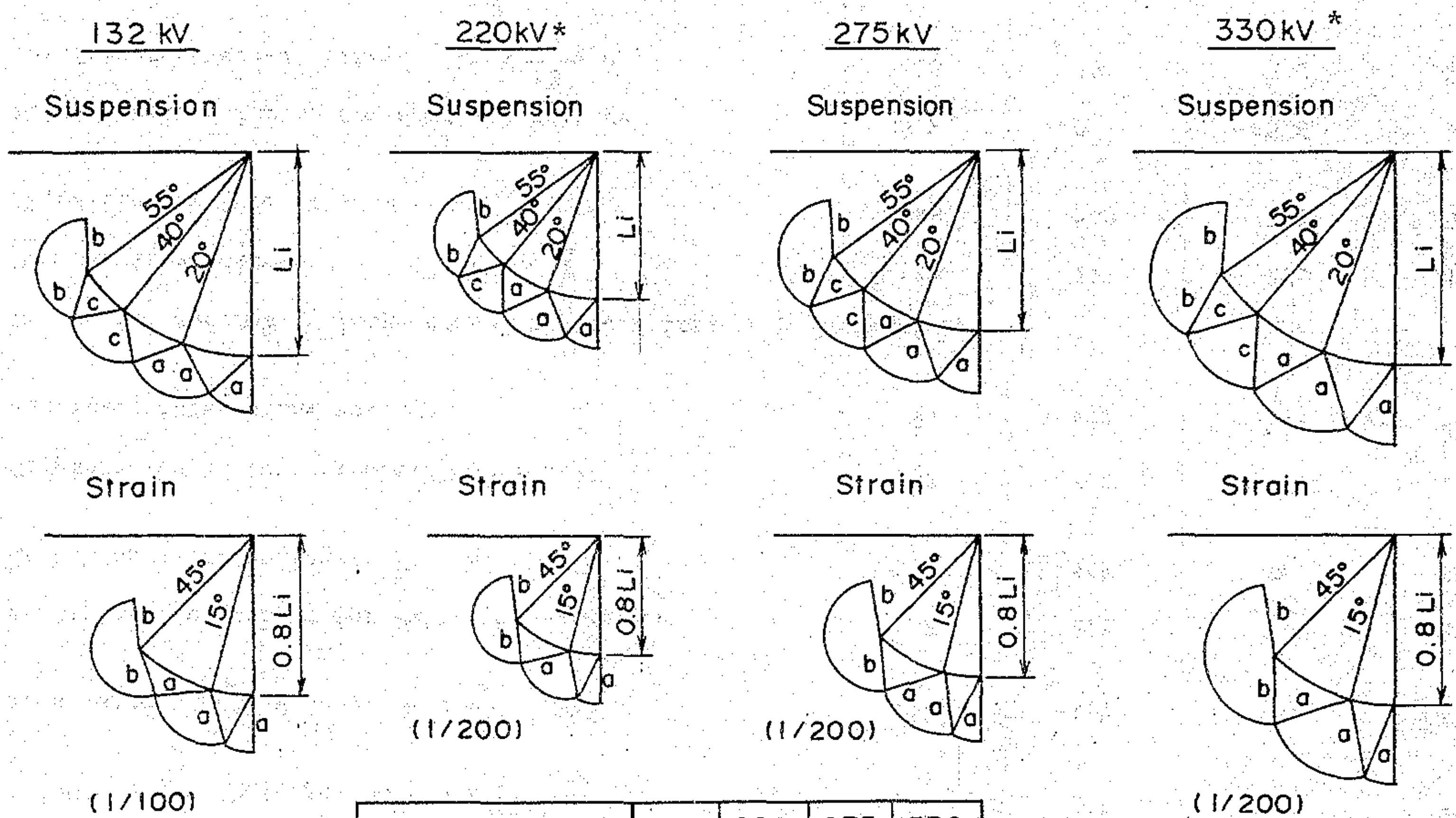
Note: * for comparison study

Fig. 11-3 Transmission Line Steel Tower Standard Suspension Type



Note: * for comparison study

Fig. 11 · 4 Clearance Diagram



Line Voltage (kV)	132	220	275	330
a (cm)	80	140	180	230
b (cm)	70	125	160	200
c=1/2(a+b) (cm)	75	133	170	215
Li (cm)	290	420	510	610
0.8 Li (cm)	230	340	410	490

Note: * for comparison study

Table 11.3 Insulation Design Calculation

(1) Design for abnormal voltage caused by switching surge

Nominal line voltage N (kV)	132	220*	275	330*
Allowable max. voltage: $Um = N \times \frac{12}{11}$ (kV)	144	240	300	360
Peak value to the ground: $Um \times \frac{\sqrt{2}}{\sqrt{3}}$ (kV)	118	196	245	294
Multiplication factor for switching surge: n	2.8	2.8	2.8	2.8
Switching surge voltage: $Um \times \frac{\sqrt{2}}{\sqrt{3}} \times n$ (kV)	331	549	686	824
Compensation factor for elevation etc.	1.2	1.2	1.2	1.2
Required withstanding voltage	398	659	824	989

(2) Design for abnormal voltage caused by power frequency fluctuation

Nominal line voltage N (kV)	132	220	275	330
Allowable max. voltage: $Um = N \times \frac{12}{11}$ (kV)	144	240	300	360
Multiplication factor for abnormal voltage	0.8	0.8	0.8	0.8
Persistent abnormal voltage: $Um \times \frac{12}{11} \times n$	116	192	240	288
Compensation factor for elevation etc.	1.2	1.2	1.2	1.2
Required withstanding voltage (kV)	140	231	288	346

Note: * for comparison study

(3) Design for Contamination

Nominal line voltage N (kV)	132	220	275	330
Required leakage distance 45 mm/line kV (mm)	5,940	9,900	12,375	14,850
No. of insulators required No. (Total leakage distance: mm)				
12t 330ϕ x 127 (295 mm/unit)	21 (6,195)			
380ϕ x 127 (340 mm/unit)		30 (10,200)	37 (12,580)	44 (14,960)
21t 380ϕ x 160 (335 mm/unit)	18 (6,030)	30 (10,050)	37 (12,395)	45 (15,075)

(4) Standard Insulation Gap

Nominal line voltage N (kV)	132	220	275	330
Required insulation level for switching surge from calculation (1) (kV)	398	659	824	989
Required air gap (cm)	77	136	177	223
Standard insulation gap (cm)	80	140	180	230

(5) Minimum Insulation Gap

Nominal line voltage N (kV)	132	220	275	330
Switching surge voltage from calculation (1) (kV)	331	549	686	824
Compensation factor for elevation: n'	1.1	1.1	1.1	1.1
Required withstanding voltage (kV)	364	604	755	907

Required air gap (cm)	70	123	160	198
Maximum insulation gap (cm)	70	125	160	200

(6) Minimum phase to phase clearance

Nominal line voltage N (kV)	132	220	275	330
Allowable max. voltage $Um = N \times \frac{12}{11}$ (kV)	144	240	300	360
Peak value to the ground: $Um \times \frac{\sqrt{2}}{\sqrt{3}}$ (kV)	118	196	245	294
Multiplication factor for switching surge (phase to phase): n	4.5	4.5	4.5	4.5
Max. surge voltage (phase to phase) (kV)	531	882	1,103	1,323
Required withstanding voltage (kV)	584	970	1,214	1,456
Required insulation gap (m)	120	215	300	415

(7) Data for clearance diagram

Nominal line voltage N (kV)	132	220	275	330
Standard insulation gap: a (cm)	80	140	180	230
Minimum insulation gap: b (cm)	70	125	160	200
$\frac{1}{2}(a + b) = c$ (cm)	75	133	170	215
Insulator strings length: Li (cm)	290	420	510	610
1.2 x a (cm)	96	168	216	276

CHAPTER 12

CONCEPTUAL DESIGN OF SUBSTATION FACILITIES

CHAPTER 12 CONCEPTUAL DESIGN OF SUBSTATION FACILITIES

12.1 PLANNING OF SUBSTATION FACILITIES

The power is supplied and distributed in the Capital area from power stations and substations linked with a 132kV trunk line system.

MEW plans construction of substations in Wadi Khabir, Barka, and Musanna in order to solve a supply shortage in some areas of the existing power systems and to link up with the Batinah coast area. Fig. 12.1 shows these power transmission systems.

On the power supply of Barka P.S., the optimum configuration of a power transmission system has been studied by employing a system analysis, taking into consideration the capacity of existing and planned substations to satisfy the demand forecasted in Chapter 4. A conceptual design has been made for each substation based on these results. Fig. 12.2 shows a proposed power system in the Capital area.

The power is supplied and distributed to Sohar and its neighboring towns and villages in the Batinah area from Copper Mine PS and Sohar PS.

On the interconnection of these individual systems of Batinah area and Capital area system, when the optimum operation of power systems and growth of the power demand in each area are taken into consideration, the linkage of the above Musanna S.S. and Sohar P.S. (Sohar S.S.) via the Kabourah S.S. is essential and the timing of linkage is set to 1989 in consideration of the supply-demand balance of supply area of Copper mine P.S. and Sohar P.S.

It is considered that, when this plan is implemented, the power supply from small-capacity diesel power stations installed in these districts would not be economically feasible in the neighboring districts of the transmission line that links the Capital area and Sohar P.S. The conceptual design of substations should be made along the MEW's principle, which intend to supply power by means of transmission and substation instead of diesel generators.

Fig. 12.3 shows the transmission system in the Batinah coast area.

The result of conceptual design can be summarized as shown in Table 12.1; the construction plan for a new transformer of substations and in Table 12.2; the major facilities of new substations.

12.1.1 Substation facilities reinforcement plan

(1) Load and substation capacity in the Capital area

The study on the substation facilities were made by dividing the area into the following four districts according to the current demand situation and topographic conditions.

The table below shows the load by districts according to the power flow record at the time of peak load during the summer of 1984, as shown in Fig. 12.4.

District	Town	Load (MW) (Sent-out)
Old town	Muscat, Mutrah, Ruwi Wattayah	151
New town	Qurum, Midinat Qaboos Al Khuwair, Al Ghubrah Al Azaiba, (Seeb Heights Town)	78
Rusail town	Airport, Seeb Rusail	51
Seeb town	Seeb Palace Barka Mabella	49
Total	-	329

Table 12.3 shows the results of rearranging the demand forecast shown in Table 4.10 classified into these four districts and Musanna district.

The table below shows the demand forecast of each four districts for 1995 excerpted from Table 12.3.

Fig. 12·1 TRANSMISSION LINE OF CAPITAL AREA AND MUSANNA AREA IN 1985

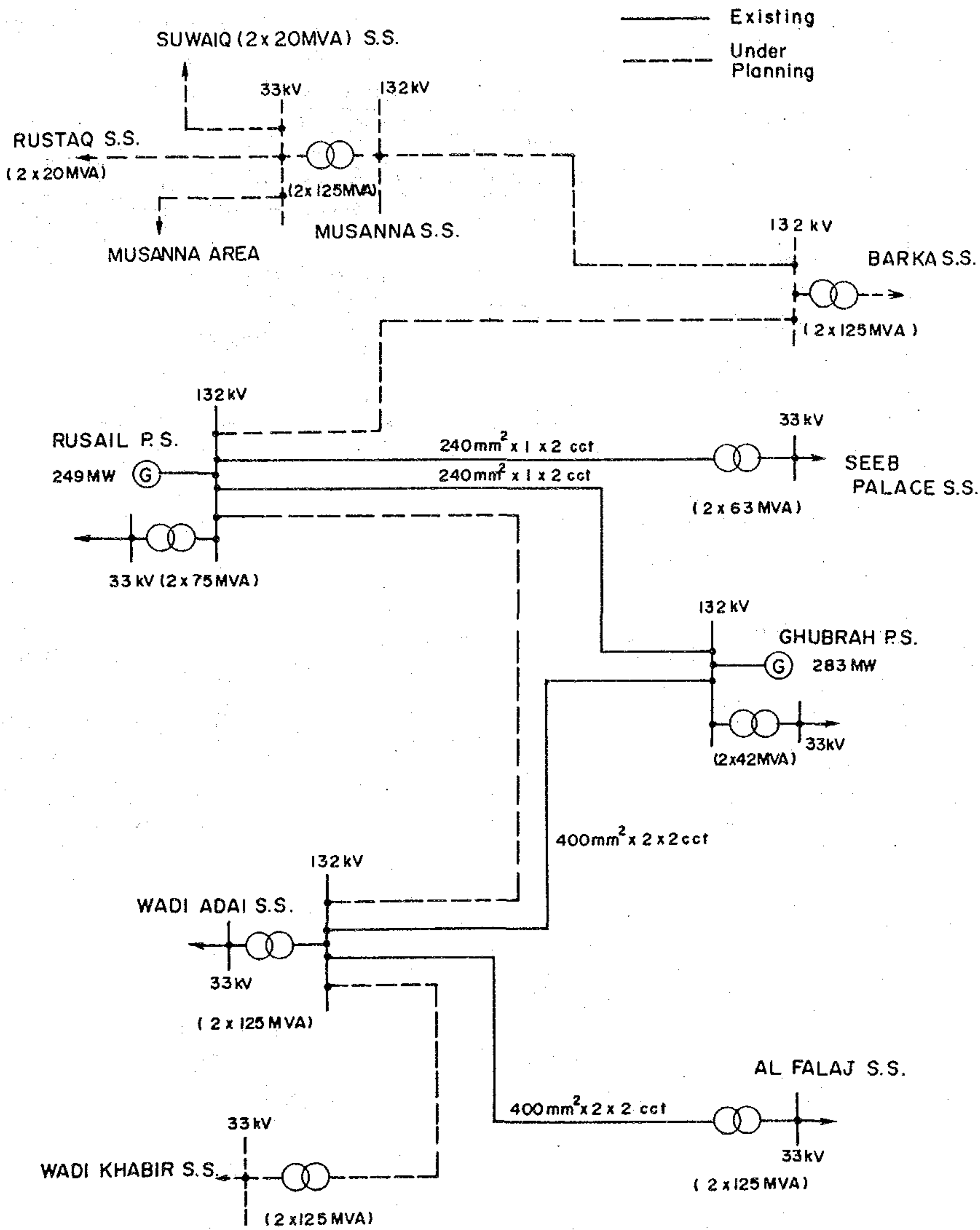


Fig. 12·2 TRANSMISSION LINE OF CAPITAL AREA IN 1995

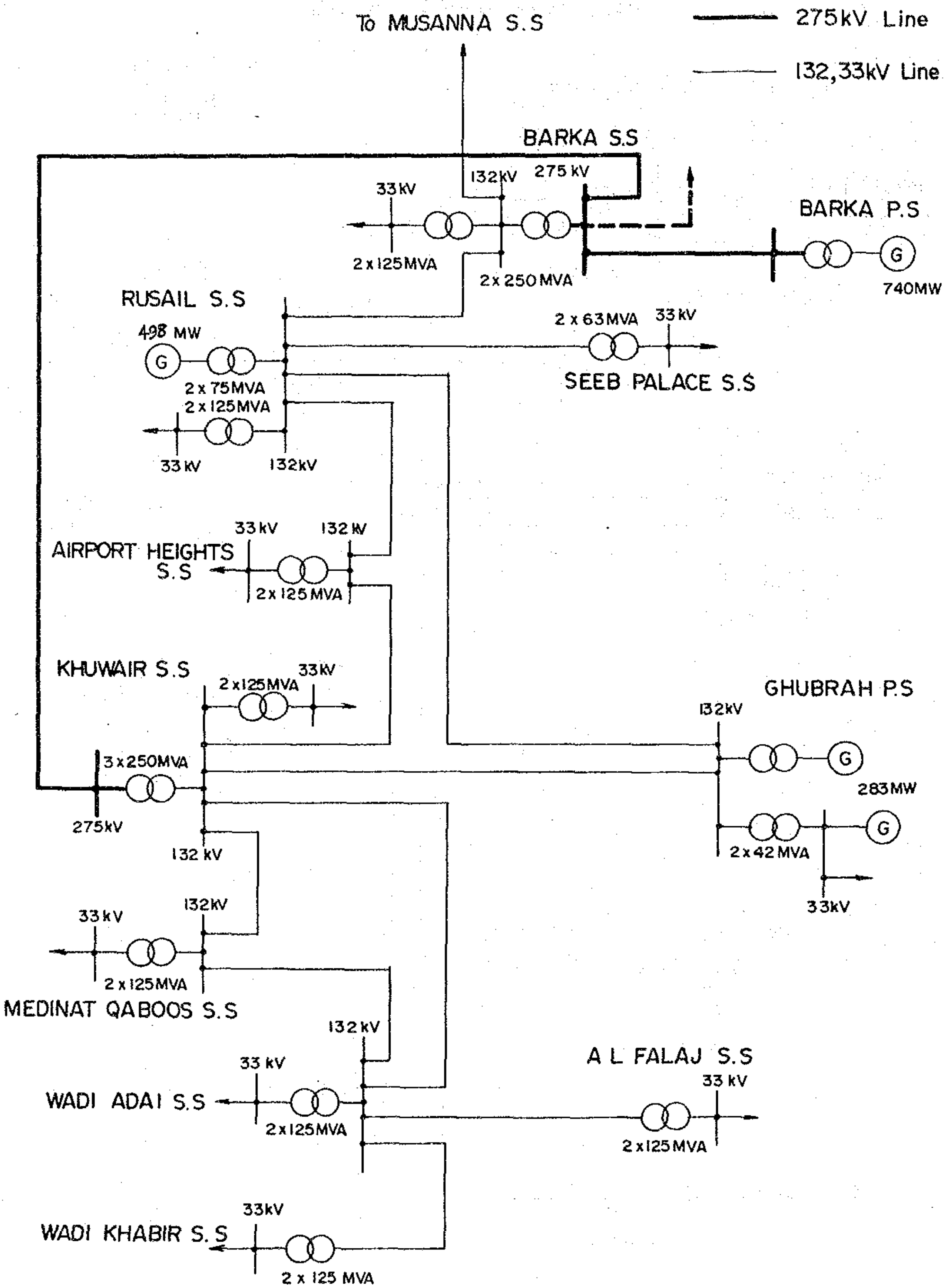


Fig. 12·3 TRANSMISSION LINE OF BATINAH COAST AREA IN 1995

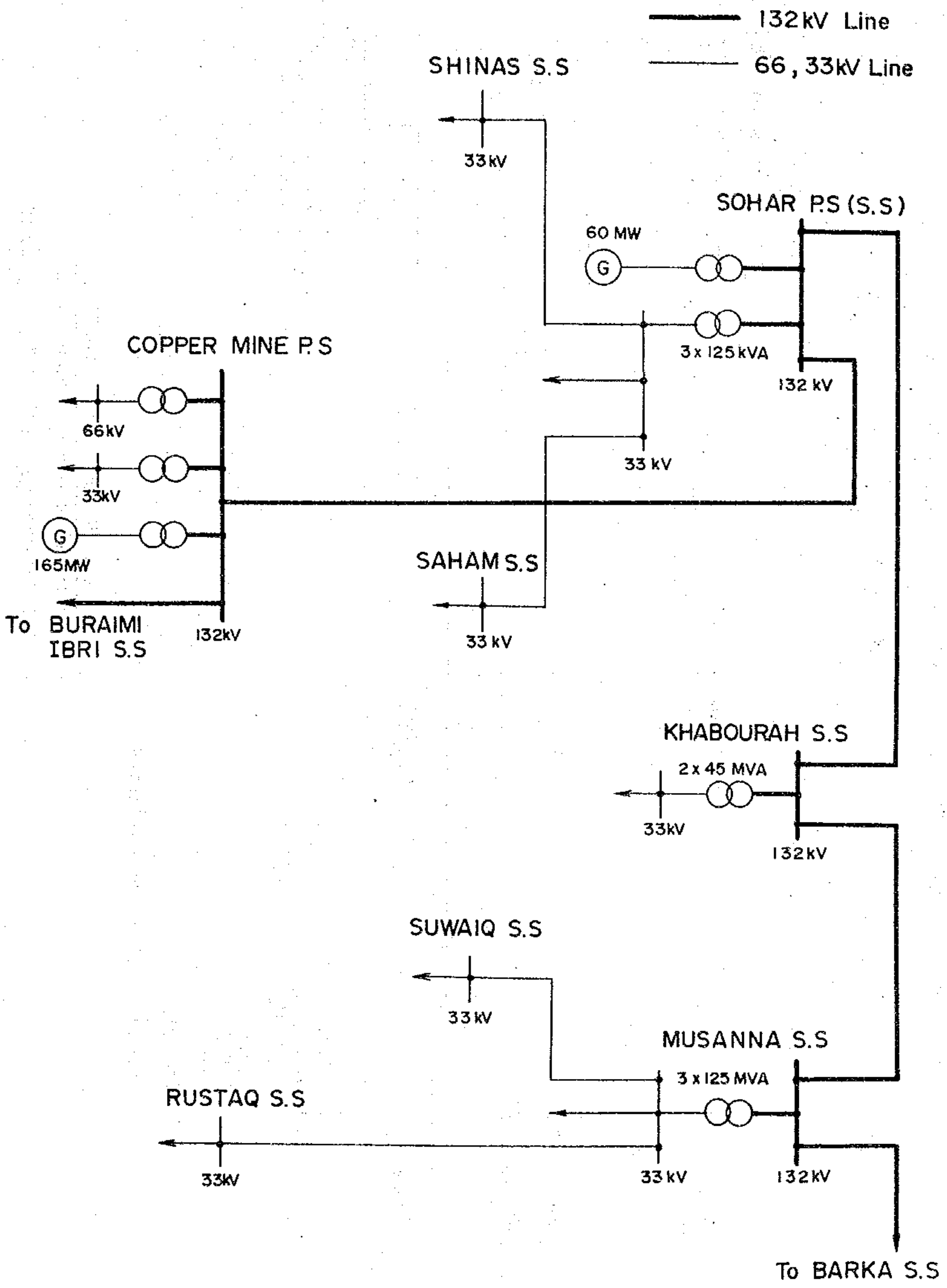


Fig. 12·4 POWER FLOW AT THE PEAK LOAD TIME IN 1984

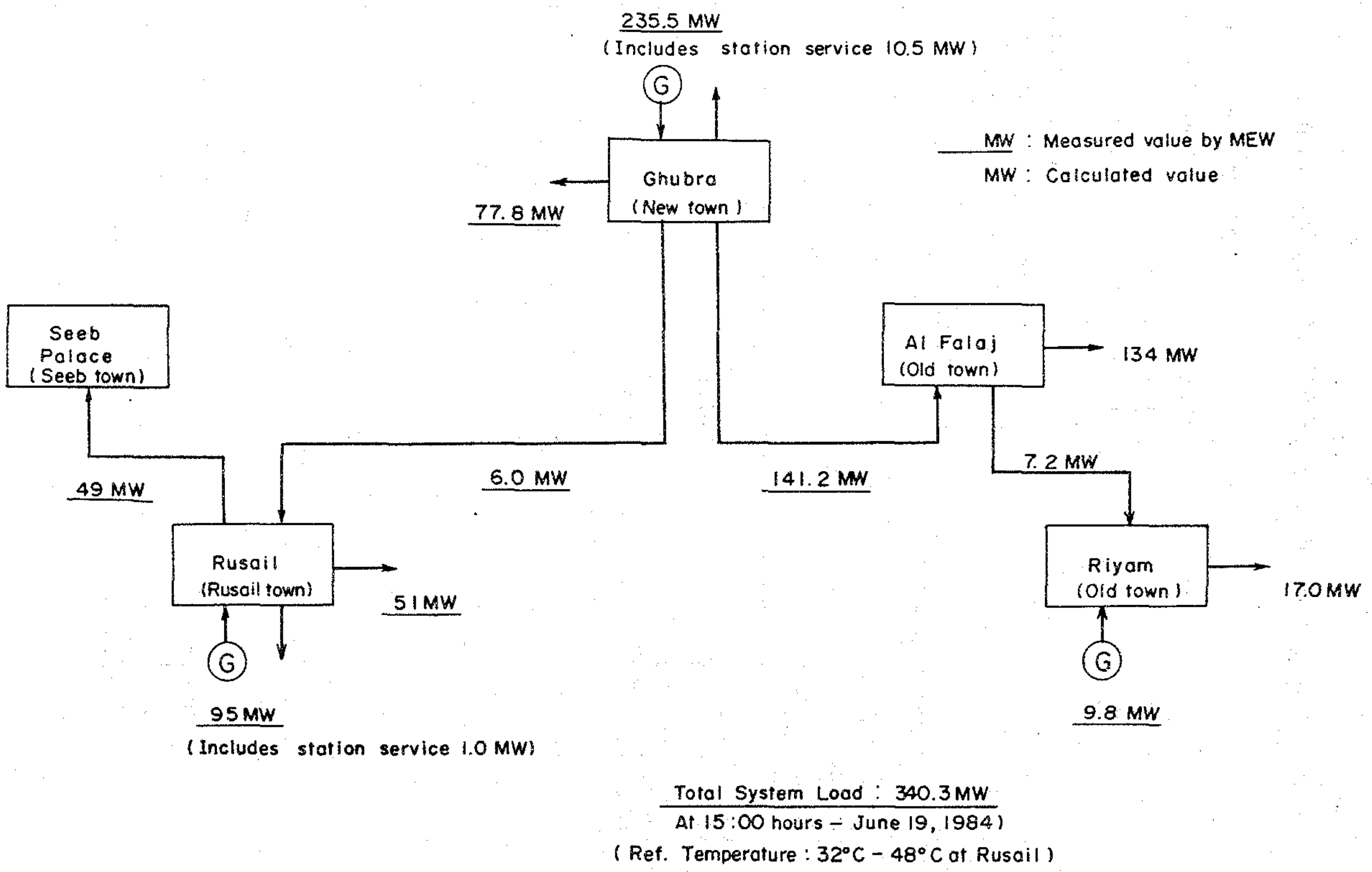


Table 12.1 Construction Plan for New Transformer of Substation

Substation	New or Extention	Voltage (kV)	Capacity (MVA)	Number of TR.	Completion Year
1) Substation undertaken by BARKA project					
KHUWAIR S.S.	New	275/132	250	3	1988
KHUWAIR S.S.	New	132/33	125	2	1988
BARKA S.S.	Extention	275/132	250	2	1988
KHABOURAH S.S.	New	132/33	45	2	1988
2) Substation undertaken by M.E.W.					
WADI KHARIR S.S.	New	132/33	125	2	1986
MEDINAT QABOOS S.S.	New	132/33	125	2	1987
AIRPORT HEIGHTS S.S.	New	132/33	125	2	1988
BARKA S.S.	New	132/33	125	2	1986
RUSAIL P.S.	Extention	132/33	125	2	1987
MUSANNA S.S.	New	132/33	125	2	1986
MUSANNA S.S.	Extention	132/33	125	1	1993
SOHAR P.S.	New	132/33	125	2	1986
SOHAR P.S.	Extention	132/33	125	1	1992
(AL FALAJ S.S.)	Extention	132/33	125	1	(1991)
(SEEB PALACE S.S.)	Extention	132/33	125	1	(1991)

Note: Substations in parentheses will be applied if a large amount of construction cost is involved in order to meet the condition of paragraph 12.1.2 e)

Table 12.2 Major Facilities of New Substation

Major Facilities		Substation							
		BARKA P.S.	BARKA S.S.		KHUWAIR S.S.			KHABOURAH S.S.	
Transformer	Capacity	Included in the power plant equipment	250 MVA		250 MVA	125 MVA		45 kVA	
	Number of phases		3 ϕ		3 ϕ	3 ϕ		3 ϕ	
	Frequency		50 Hz		50 Hz	50 Hz		50 Hz	
	Rated Voltage		275/132 kV		275/132 kV	132/33 kV		132/33 kV	
	Connections		Ya 0		Ya 0	Yd 5		Yd 5	
	Tap changing equipment		L.T.C.		L.T.C.	L.T.C.		L.T.C.	
	Number of units		2		3	2		2	
Circuit Breaker (G.I.S.)	Rated voltage	300 kV	300 kV		300 kV	300 kV	145 kV	145 kV	145 kV
	Rated current	2,000 A	2,000 A		2,000 A	1,200 A	4,000 A	2,000 A	1,200 A
	Rated interrupting current	31.5 kA	31.5 kA		31.5 kA	31.5 kA	31.5 kA	31.5 kA	31.5 kA
	Number of units	6	5		3	3	4	5	2
	Rated voltage	300 kV	300 kV		145 kV	36 kV	36 kV	36 kV	36 kV
	Rated current	1,200 A	1,200 A		1,200 A	3,000 A	600 A	1,200 A	600 A
	Rated interrupting current	31.5 kA	31.5 kA		31.5 kA	31.5 kA	31.5 kA	25 kA	25 kA
	Number of units	9	2		13	4	18	4	12
Disconnecting Switch (G.I.S.)	Rated voltage	300 kV	300 kV	300 kV	300 kV	300 kV	145 kV	145 kV	145 kV
	Rated current	2,000 A	2,000 A	1,200 A	2,000 A	1,200 A	4,000 A	2,000 A	1,200 A
	Number of units	14	14	6	8	9	8	14	6
	Rated voltage	300 kV	145 kV		145 kV				
	Rated current	1,200 A	2,000 A		1,200 A				
	Number of units	27	6		39				
Line Arrester	Rated voltage	266 kV	266 kV		266 kV	126 kV		126 kV	
	Rated discharge current	10 kA	10 kA		10 kA	10 kA		10 kA	
	Number of units	6	12		6	24		12	
Remarks		Going out only							

Table 12.3 Load Forecast for Capital Area

(MW)

Category	1984	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1. Lighting load											
old town (AL FALAJ, WADI ADAI S.S.)	151	183	199	211	222	234	247	261	275	289	306
new town (GHUBRAH P.S.)	78	107	116	123	130	136	144	152	160	169	179
Rusail town (RUSAIL P.S.)	51	63	68	72	76	81	85	90	95	100	106
Seeb town (SEEB S.S. BARKA S.S.)	49	60	65	68	72	76	80	84	89	94	99
Sub-total	329	413	448	474	500	527	556	587	619	652	690
2. New load											
old town	0	15	20	40	60	80	95	104	112	118	123
new town	0	35	52	132	192	242	291	320	346	360	374
Rusail town	0	65	115	115	115	115	118	121	125	128	131
Seeb town	0	0	0	0	0	0	0	0	0	0	0
Sub-total	0	115	187	287	367	437	504	545	583	606	628
3. New Interconnection											
Mabella (BARKA S.S. area)	(6.7)	15	18	20	24	27	31	36	41	47	54
Musanna	(5.45)	12	14	17	19	22	25	29	33	38	44
Suwaiq (Musanna area)	(6.9)	16	18	21	24	28	32	37	42	49	56
Rustaq (Musanna area)	(6.8)	15	18	21	24	27	32	36	42	48	55
Sub-total	0	58	68	79	91	104	120	138	158	182	209
4. Total											
old town	151	198	219	251	282	314	342	365	387	407	429
new town	78	142	168	255	322	378	435	472	506	529	553
Rusail town	51	128	183	187	191	196	203	211	220	228	237
Seeb town	49	75	83	88	96	103	111	120	130	141	153
Musanna town	—	43	50	59	67	77	89	102	117	135	155
Grand total	329	586	703	840	958	1068	1180	1270	1360	1440	1527

District	Demand forecast in 1995 (MW)	Demand forecast in 1995 (MVA) cos ϕ = 0.85
Old town	429	505
New town	553	651
Rusail town	237	279
Seeb town	153	180
Total	1,372	1,615

To this demand forecast, the following supply facilities exist at present (including the MEW projects which is under construction and planned to start shortly.)

District	Power Station, Substation	Facility	Capacity (MVA)	
Old town	AL FALAJ S.S. (Existing) WADI ADAI S.S.(") WADI KABIR S.S.	Transf. 132/33kV " " " "	250 " "	750
New "	GHUBRAH P.S. (Existing)	Transf. 132/33kV Generator 33kV side	84 95 (76MW)	179
Rusail "	RUSAIL P.S. (Existing)	Transf. 132/33kV	150	150
Seeb "	SEEB S.S. (Existing) BARKA S.S.	Transf. 132/33kV " "	126 250	376

As a result, power receiving facilities in Old Town and Seeb Town designed by MEW may have enough capacity under the present plan which is determined by "Method of Reinforcing Transformers in accordance with the paragraph 12.1.2", provided that the load distribution to three substations for old town and two substations for Seeb town be approximately equal in terms of transformer capacity and substation load be changed to sound 33 kV line at the time of failure in such a substation. If a large amount of construction cost is involved to meet the above requirements, additional 132/33 kV tansformers to handle the increasing loads should be planned at Al Falaj S.S., Seeb Palace S.S. or in another appropriate location, for instance.

For the New town and Rusail town, the substation capacities must be expanded as the present capacities will be insufficient in the near future.

When the demand growth rate, power consumption density and load distribution state are taken into consideration, the New town must have three more new substations and the preferable locations are in the neighborhood of Medinat Qaboos, Al Khuwair and Airport heights town. In the Rusail district, expansion of the Rusail P.S. is desirable.

To satisfy the demand in each district, installation or addition of 132/33 kV transformers in Medinat Qaboos S.S., Airport Heights S.S. and Rusail P.S. should be planned by M.E.W.

Table 12.4 shows the demand and supply capacity at substations for the capital area in 1995.

(2) Load and substation capacity in the Batinah coast area

The study of necessary substation capacities in the Batinah coast area was made in the respective three districts; Musanna, Khabourah and Sohar.

Table 12.5 shows the peak load in the summer of 1984 by districts and the demand forecast for 1985-1995 based on the Table 4-10 contents.

Each district depends on diesel generators (single unit capacity of 3MW) for power supply at present. Therefore, the supply capacity cannot catch up with the demand of the some area that increases every year and the load shedding is being applied at the peak time of summer.

MEW plans to complete the construction of Musanna S.S. by 1986 to supply the power to the Suwaiq and Rustaq towns, to expand the capacity of power station constructed in a Sohar copper mine near Sohar town to 165MW from current 51MW in 1986.

After then, a 60 MW power plant will be constructed near Sohar Town by 1988.

Accordingly, MEW must plan expanding the transmission and transforming facilities matching the expansion of power generation facilities in the Sohar S.S., in addition to Musanna S.S. where the construction plan is proceeding at present.

Table 12.4 Demand and Supply Capacity at Substations (Capital Area in 1995)

District	Substation	Demand forecast in 1995 (MW)		Capacity of S.S. and P.S. for 33 kV (MVA)			Remarks
Old town	AL FALAJ S.S.	143	429	125 x 2	250	750	Existing
	WADI ADAI S.S.	143		125 x 2	250		"
	WADI KHABIR S.S.	143		125 x 2	250		Under Planning
New "	GHUBRAH S.S.	130	553	179	179	929	Existing (Tr.+Gen.)
	QABOOS S.S.	141		125 x 2	250		Under Planning
	KHUWAIR S.S.	141		125 x 2	250		"
	AIRPORT HEIGHTS S.S.	141		125 x 2	250		"
Rusail "	RUSAIL P.S.	237	237	75 x 2	150	400	Existing
				125 x 2	250		Under Planning
Seeb "	SEEB S.S.	69	153	63 x 2	126	376	Existing
	BARKA S.S.	84		125 x 2	250		Under Planning
	Total	-	1,372	-	-	2,455	-

Table 12.5 Load Forecast for Batinah Coast Area

District	Town	Load Forecast (MW)											
		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Musanna	Musanna	5.45	-	12	14	17	19	22	25	29	33	38	44
	Suwaiq	6.9	-	16	18	21	24	28	32	37	42	49	56
	Rustaq	6.8	-	15	18	21	24	27	32	36	42	48	55
	Sub total	19.15	-	43	50	59	67	77	89	102	117	135	155
Khabourah	Khabourah	7.67	9	10	12	13	16	18	20	24	27	31	36
Sohar	Saham	7.9	10	16	19	23	27	32	37	43	49	56	65
	Sohar	10.6	13	21	25	30	37	44	50	57	66	76	87
	Shinas	2.8	4	5	7	8	10	11	13	15	17	20	23
	Sub total	21.3	27	42	51	61	74	87	100	115	132	152	175
	Others	-	45	85	100	117	136	153	168	190	210	229	257
Total		48.12	81	180	213	250	293	335	377	431	486	547	623

12.1.2 Method of substation reinforcement

New or additional installation of substations should be conducted based on the following criteria:

a) An expansion of existing facilities should be made when the actual load reaches a level of forecasted demand with 20 - 30% allowances.

b) The capacity is determined in consideration of a failure of one largest transformer capacity in the pertinent district.

c) Each sustation is equipped with at least two transformers.

d) The transformer capacity is selected out of the standard capacities based on the results of power flow by the system analysis and economic calculations.

e) It should be arranged that customers living in places between the power plants and their adjacent substations can be supplied with power from either stations.

(1) Locations and capacities of substations to be reinforced in the Capital area

Based on the demand-supply state on substation facilities reviewed in the preceding clause, the supply capacity shortage up to 1995 is about 470MVA in the New town and about 130MVA in the Rusail town.

A 250 MVA substation will be constructed in Medinat Qaboos S.S. by 1987 to meet the highly increasing demand, a 250 MVA substation will be constructed in Khuwair S.S. by 1988, and a 250 MVA substation will be constructed in Airport Heights S.S. by 1988 when the housing complex is completed. The proposed substation in Medinat Qaboos is also under consideration by M.E.W.

The new substation will be constructed near Airport Heights Town in consideration of heavy load requirements anticipated, although the Khuwair S.S. is capable of supplying power to the town.

Secondly, distribution of loads among the substations in 1995 is considered. Although the Ghubrah P.S. has the capacity of 179 MVA, its maximum load should be limited to 130 MW to maintain the sufficient capacity even if the largest transformer (42 MVA) fails. The load exceeding 130 MW will better be supplied from Medinat Qaboos S.S. and Khuwair S.S. as far as possible.

The power sent from the Barka P.S. is to be led to the Barka S.S. and received by the Khuwair S.S. as described in Chapter 13. The reason for leading the power to the Barka S.S. is that the transmission power through the 132kV transmission line between the Rusail P.S. and Barka S.S. exceeds the capacity when one line only is used.

As to the substation location, the Al Khuwair district is selected for the reason of -takeout from the Ghubrah P.S. - Wadi Adai S.S. line would be advantageous for the system operation, since the transmission capaicty between the Rusail P.S. and Ghuburah P.S. is small. The Khuwair S.S. is located in the center of the following new consumption districts and the location seems to be the optimum for a transmission line lead and for securing the land space.

Khuwair South town	30MW (1990)
Ghubrah South town	30MW (")
Azaiba town	30MW (")
Total	90MW (")

For the Medinat Qaboos S.S. and the Airport Height S.S., lead-in from power transmission lines between Rusail P.S. and Wadi Adai S.S. is considered suitable.

(2) Locations and capacities of substations to be reinforced in the Batinah coast area

The three sites of Musanna, Khabourah and Sohar are selected as the substation sites to take in the 132kV transmission line in the Batinah coast area. The installation of the Musanna S.S. and Sohar S.S. will be undertaken in accordance with the MEW plan, but the Musanna S.S. is to be interconnected with the Capital area in 1986, with the Khabourah S.S. in 1988, and eventually with the Sohar S.S. in 1989 when the 225MW supply available from the Copper Mine P.S. and Sohar P.S. will not be sufficient enough to meet the demand of the area.

The capacity of each substation is determined as follows:

a) Musanna S.S.

Three 132/33 kV transformers (125 MVA) will be installed by 1995, from which power will be supplied to Suwaiq and Rustaq Town at 33 KV.

b) Khabourah S.S.

Two 132/33 kV transformers (45 MVA) will be installed by 1988.

c) Sohar S.S.

The Copper Mine P.S. will be interconnected at 132 kV, and three 132/33 kV transformers (125 MVA) will be installed by 1995, from which power will be supplied to Saham and Shinas at 33 kV.

The construction plan for the above facilities is shown in Table 12.1.

Those substation sites should be selected at suitable places between centers of demand and the transmission lines which are to be installed along the highway on the southern (mountain) side as shown in Fig. 11.1.

Fig. 12.5, Fig. 12.6 shows the Power system in 1995 in the Capital area and Batinah coast area.

12.1.3 Determination of transformer capacity

The capacities of transformers were determined based on the demand forecast in the supply area and on careful studies of the economy including the power flow state, voltage fluctuation rates and measures to be taken in case of failures by employing a system analysis.

(1) The standard capacities of the transformers were determined as follows, according to JEC standards:

3-phase, 30, 45, 100, (125), 150, 200 and 250 MVA
125MVA written in parentheses is the MEW standard.

(2) The transformer capacity for each substation was selected considering the above standard values, the system analysis and economic calculation:

Fig. 12·5 PROPOSED POWER SYSTEM IN 1995
(CAPITAL AREA)

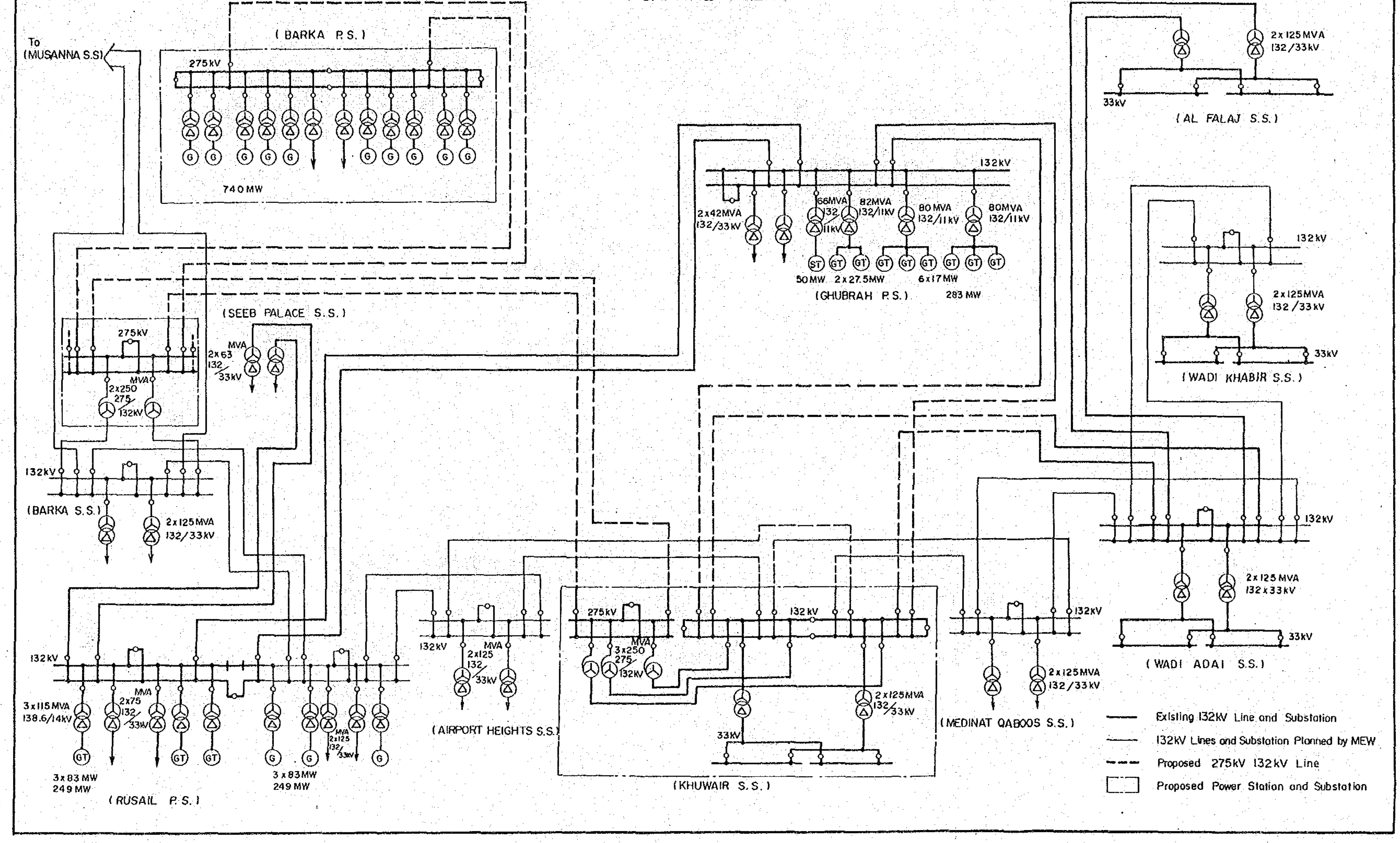


Fig. 12·6 PROPOSED POWER SYSTEM IN 1995 (BATINAH COAST AREA)